Acknowledging drawing as a mediating system for young children's ideas concerning change of state of matter

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Abstract

In this paper, we focus on young children's drawing activity in the context of science education research adopting a sociocultural perspective which emphasises that thinking can be transformed through cultural tools. Children's 'voice' is not limited to written and oral communication, so drawing can provide opportunities for children to actively participate to knowledge construction and research. A qualitative research methodology was adopted, and two sets of drawings collected from different classes in Greece and Singapore during a common teaching intervention designed to foster children's understanding of change of state were analysed. Findings presented in this paper concern children's visual representations of melted objects and the process of melting. Six categories describe the ways that a melted object can be presented (e.g. drops, lines, flow, puddle) and four categories describe changes during melting (e.g. increased number of drops, decrease in size). Educational implications for teachers are thoroughly discussed.

KEY WORDS

Early childhood science, drawing, young children's ideas, change of state

Résumé

Dans cet article, nous nous concentrons sur l'activité de dessin de jeunes enfants dans le contexte de la recherche sur l'enseignement des sciences en adoptant une perspective socioculturelle qui souligne que la pensée peut être transformée par des outils culturels. La 'voix' des enfants ne se limite pas à la communication écrite et orale, et en ce sens, le dessin peut offrir aux enfants la possibilité de participer activement à la construction de leurs connaissances et à la recherche. Une méthodologie de recherche qualitative a été adoptée, et deux séries de dessins ont été analysées. Ces dessins ont été recueillis dans différentes classes en Grèce et à Singapour au cours d'une intervention didactique commune destinée à favoriser la compréhension des enfants sur le changement d'état. Les résultats présentés dans ce document concernent les représentations visuelles des enfants d'objets fondus et du processus de fusion. Six catégories décrivent la manière dont un objet fondu peut être représenté (par exemple, gouttes, lignes, écoulements, flaques) et quatre catégories décrivent les changements au cours de la fusion (par exemple, augmentation du nombre de gouttes, diminution de la taille). Les implications pédagogiques pour les enseignants sont discutées en détail.

Mots-Clés

Sciences de la petite enfance, dessin, idées des jeunes enfants, changement d'état

Introduction

Researchers working with young children are generally concerned with the implementation of practices which should enhance rather than overshadow young children's ability to contribute meaningfully to their own learning and development. Within a sociocultural framework learning is seen as occurring through children's participation in various activities and practices of their family, school and community, integrated with social relationships and cultural tools which serve as mediating components that transform knowledge and create meanings, rather than transmit knowledge (Robbins, 2005; Rogoff, 2003). This perspective emphasizes that it is through contexts, actions, meanings and involvement in activities with others that development occurs (Fleer & Robbins, 2003; Robbins, 2005). Participatory learning promotes a view of children as active participants as well as "experts in their own lives" (Clark, 2005, 2010), and gives value and status to children's everyday experiences. This means that educators and researchers have to employ learning processes that enable children to participate, stimulating their way of thinking, talking, interacting and making decisions on subjects that affect their everyday practices.

The importance of science at an early age has been advocated by many researchers (see for example Eshach & Fried, 2013; Kloos et al., 2012). In encouraging early childhood science learning, children are prompted to think scientifically by observing and reflecting on concepts and phenomena in an appropriate environment which fosters individual and collaborative explorations and provides meaningful ways for children to make sense of the world. However, the place of science in early childhood education, takes many different forms as kindergarten teachers may not systematically stimulate children's science learning. Attempting to include and teach science in their classrooms, they are facing challenges such as feelings of uncertainty or lack of content knowledge and pedagogical strategies (Kallery, Psillos, & Tselfes, 2009). When teachers include science activities in their curriculum, they usually plan science teaching "around 'what to do' rather than around how children can make meaning of what is done" (Areljung, 2019, p. 239). Moreover, they promote children's own exploration which usually lacks the necessary teacher mediation and fails to maintain the children's focus on the scientific meaning of their observations (Fleer, 2009). Considering the conclusion of these previous studies, we advocate that more child-centered and child-friendly procedures, with an emphasis on meaning-making, should be adopted.

Children use drawings as a tool for understanding and representing important aspects of their knowledge and experiences. Van Oers (1997) used the term semiotic activity in order to describe the process of meaning making that is conducted through symbolic systems highlighting the interrelationship between iconic and symbolic thinking. He underscored that "schematic representations (like drawings, for instance) are often used as a starting point for semiotic activity of young children, as they can be used as meaningful objects of conversation" (van Oers, 1997, p. 239). When drawing is placed in a central position in the curriculum, children may build upon their competence as "multimodal text makers" (Kress, 2005) and come to understand the formal symbolic systems of school-based literacy and numeracy. Moreover, drawing is particularly helpful for young children, who may not be completely fluent and often struggle to communicate efficiently as it offers a feasible tool to overcome such restrictions and facilitate communication, meaning-making and problem-solving (Brooks, 2005). Children usually combine their own symbols with these they obtain from their everyday environment, and/or conventional graphic symbols (e.g., letters, numerals, signboards), which they may use in their own ways in order to communicate their ideas (Papandreou, 2014). Hence, introducing children to drawing activities is important for the development of their symbolic competences, and engages them in recognising the power of symbols (linguistic and non-linguistic ones) (Lange-Küttner & Thomas, 1995). By slowly allowing children to perform a wider range of operations within a system of symbols, drawing activities "lead to the further development of abstract thinking, imagination and logic reasoning" (ibid., p. 151).

Drawing as a participatory method

In many research studies children are seen as agents in their own learning and development and participation is a key factor in children's learning. Attention has been given to the inclusion of children's voices in research using participatory methods to support children as competent meaning-makers and communicators of their thinking and experiences (Clark, 2005; Flewitt, 2005). Using participatory methodologies has been foregrounded as a way to unfold young children's potential to contribute rich and useful perspectives, and to inform research about their lives as well as teaching. During the last decades there has been a shift towards increased interest in children's drawings. Considering drawing as a process and as a purposeful way of creating marks on a sheet of paper which have a certain meaning allows children express their ideas and feelings and enables adults to focus on them. As Hopperstad (2008, p. 134) pointed out drawing is "a meaning-making process in which children draw signs to express their understanding and ideas in a visual-graphic form […] it is always meaningful for the child that makes it (a drawing), reflecting the child's interests and intentions and conveying meaning in a form the child finds suitable". Wood and Hall (2011, p. 270) confirm the above stating that children's drawings "are a form of cultural transmission of their everyday knowledge, their imaginative capabilities and their invented meanings". The use of drawing has become a more common strategy in research with younger children because through drawing, young children can be understood by researchers on their own terms (Tay-Lim & Lim, 2013). Brooks (2019b) proposes that drawing can be a visual representation of thoughts, distinct from speech (oral or text), because drawing can be seen as a simultaneous whole that parallels Vygotsky's description of thought, while speech implies a linearity in the way something is recalled. "As a deliberate, symbol-mediated activity, drawing might be considered a cultural tool that facilitates the acquisition of higher mental functions" (ibid., p. 5).

Drawing is included in many of the learning activities young schoolchildren participate in and is considered a usual kindergarten activity. Most of the children enjoy drawing and they use it widely to serve different purposes in various everyday activities at home and at school (Hall, 2009). However, for many parents and educators the drawing activity is mostly considered as a prewriting activity, that reinforces the development of fine motor skills, "a low status, time-filling occupation" which fills gaps in the everyday schedule, offers a way to decorate the classroom, illustrates children's versions of stories, or is just a way to relax and have a good time (Anning & Ring, 2004; Papandreou, 2014). Wood and Hall (2011, p. 270) propose that "drawing is much more than a pre-writing skill, or a developmental transition from 'drawing things to drawing speech'. The focus is on understanding the more complex purposes that drawing fulfils for young children, as an intrinsically valuable form of abstraction

and communication, as a social practice, and as a symbolic means of bridging home and school contexts".

Drawings are seen as a primary symbolic activity that reveals the child's own forms of expression, including thoughts, feelings and interpretations of experiences relating to his/her life. In order to understand children's drawing, it should be regarded as a cultural activity which takes place in a certain context. This context is defined by the available tools and materials, and by peers and adults who participate or interact with the child. The most known educational approaches that consider drawing as one of the "hundred languages" children use to express themselves and communicate with others about the way they perceive the world around them, is the Reggio Emilia approach (Edwards, Gandini, & Forman, 1993) and the project and inquiry-based approach (Helm & Katz, 2001). As Cox (2005, p. 124) argues, considering drawing "as an aspect of the interactive, communicative context in which children's thinking develops clearly places the study of children's drawing in a Vygotskyan perspective". When drawing is acknowledged as a language (meaning, a communication and thinking tool) it becomes a fundamental mediating system for knowledge construction. However, children's drawings can easily be misunderstood by adults therefore, rather than assuming their meaning it is important to "tune into" (Anning & Ring, 2004, p. 118) children's perspectives and listen to the meanings of their drawings. When adults engage young children in conversations about their drawings, they imply that their drawings are valued and are interested in fully understanding children's intentions as well.

Drawing and science learning

Acknowledging that children often have ideas and unspoken knowledge, therefore they know more than they say, research suggests that drawing is an effective strategy for eliciting children's thinking about concepts and phenomena from the natural world, and get them involved in scientific thinking (Delserieys, Impedovo, Fragkiadaki & Kampeza, 2017; Ehrlén, 2009; Kampeza & Ravanis, 2012; Papandreou & Terzi, 2011). During classroom inquiries, children may draw to display previous or new understandings, and to record their observations, measurements, plus other kinds of data collected during learning experiences (Chang, 2012; Kampeza & Delserieys, 2019). In addition, using drawings made during different phases of an inquiry can help children "revisit their learning and rethink what has been addressed" (Chang, 2005, p. 104).

In a similar way to what can be encountered with oral language, when young children start to draw, their drawings often contain graphic symbols which are not always self-explanatory. Children enter schooling with a range of mark making strategies which is usually inspired by modes of communication in home or other settings. "Learning to

draw and learning to speak both depend on acquiring increasingly complex effective rules" (Willats, 2005, p. 13). This places the adult, trying to read the drawing, in a position where the "rules" used by the child have to be inferred from the context, from the child's explanations of the drawing, and from the child's own knowledge of the situation. When young children make and use marks in their drawings, they are using these means to achieve their representational purpose (Cox, 2005) stressing the close relationship of drawing with the thinking process. Drawing tasks "prevent children from feeling constrained by the need to match their responses to conventional answers […] In connection with this, it is considered that, when drawing, children are reconstructing their thinking and representing their own mental images" (Villarroel & Infante, 2014, p. 120). Children's concepts and experiences are central, and they are not handled as "getting in the way" of scientific learning, but rather they provide a rich variety of understandings from which scientific learning can take place. Therefore, teaching can be concerned with how to enable the everyday concepts (presented in the drawings) that children develop through their experience with the world and the scientific concepts to come together in meaningful ways.

Apart from the focus on the potential for increasing children's engagement in a learning community, Prain and Tytler (2012) propose three dimensions so as to consider how visual representation construction supports students' science learning. Their work is embedded in a sociocultural perspective and considers the process of meaning-making for students with 1) a semiotic perspective, focusing on students' capacity to recognise and use material and symbolic tools, 2) an epistemic perspective, that relates to the use of these tools for scientific inquiry in the classroom, and 3) an epistemological perspective, considering how students engage in the process of constructing and interpreting the representations they produce. These dimensions attribute an important role to drawing, as children use them to focus on key aspects of a problem, select appropriate symbols and signs, and apply relevant background knowledge to a problem. Moreover, drawing can be "understood as enacting science learning and reasoning because this kind of activity is consistent with how knowledge is developed and communicated in the science community" (Prain & Tytler, 2012, p. 2757).

Children's ideas considering change of state of matter

Understanding basic scientific concepts at a fundamental level is crucial, as they form the foundation for science learning at higher levels. Although changes of the state of matter are associated with everyday life, and usually curricula incorporate learning contents that refer to phase changes of matter, there have been few studies on this issue especially in early years' education. Young children often focus on the appearance of an

object rather than its material composition, so in order to develop a concept of material that is independent from the object Rahayu & Tytler (1999) propose that teaching of materials in early primary school should focus on physical change and particularly, on changes of state (melting and solidification).

McKeon (2004) suggests that children may be familiar with some changes of state such as melting, but although they might be able to identify melting in ice and understand the change from solid to liquid, it is difficult for them to generalize from this change so as to include other substances. She also points out that teachers should have in mind that some children "consider that melting always involves water and that melting materials such as wax or butter produce water" and that evaporation is a complex idea as it involves the "apparent disappearance of a liquid and it occurs in quite different situations" where the liquid may be more or less obvious (McKeon 2004, p. 99). Young children do not make connections between the state of the materials and their temperature and "the primary difficulty concerning the change in the state of matter is the issue of the thermal balance restoration mechanism between two bodies, namely the heat transfer from the warm body to the cold body" (Ravanis, 2013, p. 135). In addition, children usually confuse the concept of heat and that of temperature and may use them inconsistently. Children also may not realize the importance of the surroundings; therefore, children do not always consider that objects in the same thermal environment will have the same temperature (Arnold & Millar, 1996). In another study (Paik, Kim, Cho, & Park, 2004, p. 222) the researchers inferred that young children "generally perceive the phenomena related to state change based on their sensory experience of the change without seeming to have any clear understanding of conditions under which the change of state occurs". They suggest that learning first about the invisible states involved in boiling and condensation may be more difficult for students to understand, than if they begin by learning about visible states such as melting.

Research question

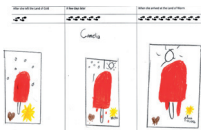
Within a sociocultural framework that underpins our pedagogical approach, this paper focuses on how the visual language of drawing provides children with the opportunity to engage in science activities and explores the specificities of drawings used in a science context with young children. More specifically we sought to contribute to this field by exploring children's drawing as a meaning-making process that supports children's perspectives as well as thinking and learning. For the purpose of this paper the research questions are a) what are the different ways that children use in order to display in their drawings complex ideas or explanations in science and b) how the integration of drawings in different phases of a teaching intervention can play a supportive role for teachers.

Methodology

A qualitative research approach was adopted, and categories derived from empirical data. Two sets of data were collected: drawings from a group of 28 children, 4-5 years old, who attended two kindergarten classes in Greece in a public school in Patras, and drawings from 18 children, 6-7 years old, who attended Grade 1 of a primary French school in Singapore. All drawings were produced following relatively open instructions given by teachers in classroom settings. The context in which the drawings were realized was part of a larger project concerning children's understanding of the change of state of matter, mainly melting and solidification (Kampeza & Delserieys, 2019). A story was developed by the authors for the purpose of the study and narrated to the children by their teachers with no visual support. The objective was to develop a meaningful context where young children would be concerned with materials and the role of temperature in the state of materials, the role of heat in melting and that each of the materials retains its essential identity, even though its properties may change (Table 1). The second, third and fourth drawing focused on melting, using the same materials at different situations, before and after observation. The drawings highlighted the different ways that the children used in order to represent melted objects and the melting process.

Table 1

Succession of the drawings and experiments as they were triggered by the context of the story "Land of Warm and Land of Cold"

Drawing 1	Drawing 2	Experiment 1 (solidification)	Drawing 3	Experiment 2 (melting) and Drawing 4
				 

The classes in both countries were selected through purposeful sampling since the criterion was to gather information so as to obtain an in-depth understanding of the phenomenon at issue (Creswell, 2012). This study does not claim to propose a com-

parative approach involving two different educational contexts. Rather, the intention is for a cumulative approach in which the variety of data enriches the proposed analysis. Children in both schools were encouraged to build their understanding in ways that were personally meaningful to them. Drawings from 1st graders were included given their potential to complement the findings from the preschoolers' case through the examination of drawings which combined written words or sentences in the drawing, but this perspective is beyond this paper's scope.

Results

The analysis of the drawings' content showed six categories that describe the way that young children represent a melted object. The following table (Table 2) presents these categories, a short description of the drawings' elements in each category, and some indicative examples.

Table 2

Categories which define children's visual representation of a melted object (an ice-lolly, a butter star and a heart-shaped chocolate)
[Greek Child (GC), French Child (FC) _ drawing number]

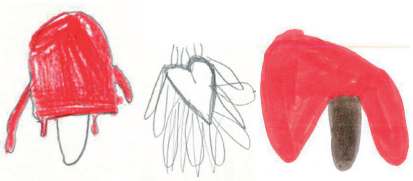
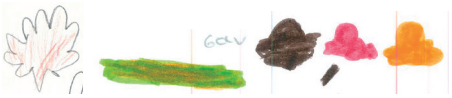
	Categories	Indicators	Examples
Representation of melted object	Drops / Rain	Around or below the object, drops or rain are usually in the same colour as the object	 FC10_d4 GC17_d3 GC25_d3
	Flowing	Material flowing from the object (often involves that the shape of the object is distorted)	 FC14_d2 FC22_d2 GC2_d2

TABLE 2

	Categories	Indicators	Examples
Representation of melted object	Radiation	Wavy lines like radiation emanating from the object	 FC2_d2 FC17_d2
	Structures	Structures inside the shape of the object	 FC15_d2 FC18_d2
	Object and puddle	The object and a puddle below, surrounding or covering the object	 FC3_d4 GC3_d2 GC17_d2
	Puddle or line	Unrecognisable shape (puddle-like shape), or a line (like a liquid surface)	 FC1_d2 GC27_d4 GC27_d3

The first category presents the melted objects as having drops, or lines, or rain, mostly below or around the object. The drops or lines are usually in the same colour as the object. This visual representation could be an influence deriving from the everyday experience of dripping. The "flowing" category represents the melted material connected to the object, and in some cases this melting involves a change in the original shape of the object. Another category is "radiation" where the melted object is presented with wavy lines, emitted circumferentially from the object. This category was found only in older children and was associated to the visual representation of the object being hot. Older children's drawings were also included in the "structures" category,

where uneven shapes or lines form a kind of inner structure inside the shape of the object. The drawings that were included in the "object and puddle" category displayed a visual representation of the object which was not clearly discerned and a puddle of the melted material below, surrounding or covering the object. The "puddle or line" category contains drawings which presented the melted material in an irregular shape that could be a puddle-like shape or a line representing a liquid surface.

In some of the drawings, children had the chance to represent the same objects at different temperature conditions. The following table (Table 3) presents some of the ways the children used in order to express their ideas concerning the underlying changes of objects when the process of melting is taking place.

TABLE 3

Categories which define children's visual representation of the process of change during melting

	Categories	Indicators	Examples
Representation of change	More drops / rain	Increase in the number of drops, without clear difference in the object's size or shape	 GC23_d3
	Object size decreases	Decrease in the object's size with no clear indication of where the matter goes	 FC23_d2
	Object size decreases with drops, rain, puddle	Decrease in the object's size and an increase in drops numbers or liquid material	 FC10_d4  FC14_d4

TABLE 3

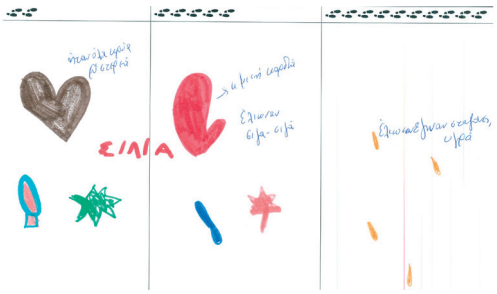
	Categories	Indicators	Examples
Representation of change	Object becomes an unrecognisable shape	Distortion of the object's shape until it is no longer recognisable (becomes a puddle, a line)	 GC6_d2 FC17_d3

The first category contains drawings that include subsequent signs and symbols of the melting object, which are expressed with an increase in the number of drops or lines, but at the same time there is no clear difference in the object's size or shape. The second category is comprised of drawings that include subsequent visual representations of the melting object, which show a decrease in the object's size, but there is no clear indication of where the "missing" matter goes. The next category combines elements from the previous categories, that is the drawings present subsequent visual representations of the melting object showing a decrease in its size and at the same time an increase in the number of drops. Drawings that were included in the last category displayed subsequent visual representations of the melting object in which there is a distortion of the shape until it is no longer recognisable (becomes a puddle, a line).

The fact that children had the opportunity to draw what would happen to the materials in different conditions, highlighted ideas concerning more in-depth explanations of the process. For example, in Figure 1 two children drew the melted objects describing the process in terms of producing "more" melted material meaning that there may be an "equal" amount of solid and liquid substances and in terms of "missing" melted material. Furthermore, in the second drawing it is interesting to note that the objects are presented in different melted phases according to the material they are made from (the chocolate heart is almost half, the butter star has a liquid line, and the ice-lolly has already melted).

FIGURE 1

FC3_d3: Solid objects are melting and as the process evolves the liquid material increases in drops.



GC14_d3: The change in the state of matter doesn't happen simultaneously for all the materials (intermediary drawing: the chocolate heart is almost half, the butter star has a liquid line, the ice lolly has melted).

Examples of presenting the melting process in different temperature conditions Amelie's dice game

DISCUSSION

According to a sociocultural perspective, learning can be defined "as a change in the child's relation to another person and activities in specific settings" (Fleer & Pramling, 2015, p. 203) and teaching in early science can be described as a collective process where the participants share individual meanings and construct common new meanings and relevant concepts. Drawing is an open-ended approach to learning which has been receiving increased attention in recent years. It is placed among the visual languages which children have at their disposal in order to express ideas, elaborate experiences, and therefore participate in their own learning. It can play a crucial part featuring children's perspectives and ensuring their participation and activation of multimodal expression and communication. Young children's drawings make possible to adults to get an opening into their ideas and how they shape these and can be used as a bridge between the child's inner world and the world of communication and sharing of ideas (Brooks, 2009a). Drawing, and mark making, is also among the child's first efforts at abstraction. Using drawings, children do not just represent objects; rather they also

represent actions, movement, feelings (Brooks, 2009a; Papandreou & Birbili, 2017). Through drawings children recall ideas, knowledge and experiences and they use them to organise information and knowledge or explore concepts and phenomena. In other words, drawing can enhance children's learning when it is valued by educators in early childhood settings given that it provides insights into young children's thinking.

Usually when early childhood educators decide to teach science to young children they concentrate on setting up learning environments which provide various resources where discovery learning is promoted without their crucial guidance, or they attempt to employ inquiry-based approaches where they usually have difficulties, because the children do not readily ask scientific questions that can be used as the starting point for the inquiry (Fleer, 2009). In this paper we sought to highlight the use of drawings in early science contexts. Integrating drawing in different phases of a teaching intervention encouraged children to express a broad range of ideas concerning the change of state of matter and the melting process.

Displaying ideas concerning the change of state of matter

Drawing involves simultaneously memory, imagination and observation as well as interpretations of experiences and everyday practices. When children draw, they usually become fully engaged with the subject being drawn (Brooks, 2009b). Moreover, children come up with many different symbols which at times share common meanings and at times they stand for things in their own. Drawing can be seen as a learning strategy which mediates science learning, in the sense that the combination of imagination and creativity that can be expressed by children in their drawings serve as an asset to overcome limitations, organise their knowledge more effectively and integrate new and existing understanding. "Constructing a representation is constrained productively by its purpose, context and the various physical and conventional resources available for any representation (Prain & Tytler, 2012, p. 2758). Therefore, it leads the way to further development of children's abstract thinking and reasoning.

In the present study children's drawing is not used for classifying children into fixed developmental stages or as a step toward the development of writing; rather it may serve as a means to recognize the ways in which children use drawing to express scientific ideas and the potential drawing has to function as a learning and teaching tool. The different categories that were formed stress the diversity of solutions found by children to invent a visual representation as well as the importance of freedom from the side of children to express rich ideas through drawing and communicate their thinking in their own ways. Children used a variety of signs and symbols to represent both the melted material as well as the process of melting (drops, lines, shapes, puddles). The diversity of these ideas probably wouldn't be expressed orally in the framework of a semi-structured interview or by providing children with predetermined pictures. It was

interesting to notice that some drawings were closer to everyday observations (such as drops of flowing) while others presented more abstract models (such as radiation or different shapes inside solids which could resemble a representation of particles). Children's drawings uncovered different ways that children use to represent complex ideas or explanations in science so it appears that drawing can enhance science understanding and supports understanding as the move from informal and intuitive signs to formal symbols and abstraction. In helping children to shift from basic recitation to higher levels of thinking, the ability to visualize ideas, concepts and problems is essential (Brooks, 2009a). In addition, reasoning based on representational construction supports quality learning in science because it enables children focus on key aspects of a phenomenon, specific details, the clarity of the meaning (Prain & Tytler, 2012).

Integration of drawing in different phases of teaching intervention

Seeking children's perspective, drawing was integrated in different phases of the teaching intervention. The role of drawing activity appears crucial as it optimises the opportunities for:

a) Children's participation for planning teaching in class (capitalizing on ideas displayed at the beginning, during or at the end of a teaching sequence)

Children's thinking in general and in science specifically, is not static. Teachers had the opportunity to embrace children's dynamic thinking, at different phases of the teaching intervention, that is before posing the basic problem in the story, while considering specific temperature conditions (land of cold and land of warm), after an experimentation. In that way teachers could be more informed and address children's learning needs or certain interests. "When drawing is viewed as a tool that is part of a meaning-making repertoire this should help teachers see drawing as part of a learning process rather than as a product that is indicative of a more rigid stage of development" (Brooks, 2009a, p. 339).

b) Elaborating on science concepts (after narration, or experimentation)

Participating in drawing activity provides a base for the child's learning but discussion and a focus on specific concepts deepen understanding. Explaining is a basic element in learning, therefore giving systematic attention to the children's visual representations and extending children's initial responses is important to introduce young children into the act of explaining. Children can refer to their drawing to share information with others that would be difficult to explain otherwise, so drawing enables their ideas to become visible and accessible. The accompanying talk should not be seen as overriding the meaning of the drawing, but as an interplay of the different ways of making meaning. "It is important for the teaching of science that the pedagogy celebrates the subjective

sense of science that children bring with them to the social and material preschool environment (as a resource). It is the teacher who creates the dynamic conditions, and it is s/he who acknowledges the thinking flux and subjectivity of both children and self" (Fleer & Pramling, 2015, p. 205).

c) Focusing on concepts and processes

As it is already pointed out, the use of drawings focuses the attention on some elements that might otherwise be ignored. The close relationship between a sign and its meaning implies a mental activity. Drawing allowing a different form of organization of ideas, highlights the important role that signs can perform in meaning making, directing attention, shaping experience and gradually establish higher forms of mental functioning. Children in our study used lines, irregular shapes to show change, or to show "flowing" indicating correlations and explanations. Development of meaning suggests a degree of increased generalization and abstraction so when children are encoding and decoding their intentions in their drawings, they focus their attention to the building of concepts and the connections between concepts (Brooks, 2009a).

d) Realising different levels of children's understanding (readiness)

Drawing activity can encourage the child's expression of ideas offering the opportunity to create simple or more complex visual representations and enable educators to recognize different levels of understanding among children. Today's classrooms are characterised by widespread diversity and teachers need to adjust their instructional methods as students differ in terms of experience, culture, language, interests, readiness to learn, modes of learning, pace of learning, etc. (Tomlinson, 1999). The notion of homogeneity in early years' classrooms is progressively challenged. A fundamental characteristic of differentiation is the acknowledgement of its dynamic nature; the differences among children are not static. "In a differentiated classroom, assessment is ongoing and diagnostic. Its goal is to provide teachers day-to-day data on students' readiness for particular ideas and skills, their interests, and their learning profiles" (Tomlinson, 1999, p. 10). Drawings can support teachers to have more explicit understanding of children's readiness where readiness can be defined as a "student's current proximity to specified knowledge, understanding, and skills" (Tomlinson & Imbeau, 2010, p. 16). In our study, some children drew melted objects while others drew the object without modifications, some children made connections to temperature conditions and provided explanations while for others the experimentation seemed necessary in order to make more focused observations. As readiness suggests a temporary condition that depends on specific understanding, integrating drawing activity in various aspects of everyday practice can help teachers sharply focus on children's needs and provoke learning.

Conclusion

The child's experiences, motives and interests are key to any pedagogical situation. From a sociocultural perspective, teaching is concerned with how scientific ideas are internalised by children not by simply replacing everyday by academic concepts but considering how everyday and scientific concepts encountered in school can come together in meaningful ways. This means acknowledgement of richness and complexity in children's thinking and provision of appropriate tools.

Participation has to do with the idea of making meaningful choices and suggests that educators should take the perspective and "voice" of children into account when planning everyday learning activities, routines and support interactions. Accepting that participatory learning is an active process where educators scaffold and enhance children's understanding through children's experiences and ideas, which act as a resource during the learning of scientific concepts, requires that both verbal and non-verbal expression of children should be considered.

It is crucial that teachers recognize and develop children's own visual representations displayed in drawings, because in doing so they will help children make connections between their informal marks and later abstract symbolism. In the present research, we highlighted that children are capable of producing drawings which are meaningful and can be related to scientific ideas. However, the focus on drawing raises significant demands on teachers apart from considering children's control over visual resources and children's feeling of confidence in the situation. Most teachers may not recognise and therefore may not support children's scientific mark-making or feel stressed to respond to assessment standards and manage classroom time. Providing support, time, and appropriate circumstances for children to pursue complexity in their drawing also must be part of the teaching and learning environment. It is important that teachers value children's drawing for the information and ideas they contain, utilize drawing in almost every aspect of the curriculum, and think of it not just as a record of children's thinking but as part of a learning process.

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