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ORIGINAL PAPER

Cultural semiotic resources in young children's science drawings

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Abstract

This study aims to explore the meanings communicated by young children with visual cultural semiotic resources available in the science classroom. It is a case study in an Early Childhood Education classroom of 23 children (3–4 years old) and their teacher, all engaged in a long-term science project about snails. We focus on the analysis of two series of drawings of snails made by children a month apart, examined through two complementary lenses: comparative content and social semiotics. The findings show that, during their first year of formal schooling, children acquired a range of semiotic resources to communicate to others, which are part of their classroom culture, rather than explicitly taught. Children used these resources to construct sophisticated meanings through their science drawings, highlighting what they considered important and accounting for different modalities and categories. These results point to the importance of supporting drawing tasks in early years, as well as providing opportunities for discussing and interpreting representations. A methodological contribution of this research regards the combination of two complementary foci in the analysis of children's drawings that allows for a nuanced examination of their learning and abilities for meaning making.

Keywords Early childhood · Social semiotics · Drawings · Communication

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Why this research?

We position young children as capable science learners. Learning science can be considered as the active appropriation of culturally mediated semiotic resources (Jewitt, Kress, Ogborn and Tsatsarelis 2001). Young children engage in this process using multiple modes of communication; thus, they become active producers of meaning in multimodal ways, for instance, through drawings. At the early childhood (EC) level, drawing is a common practice as well as a mean and a tool for meaning making (e.g., Brooks 2009), and research has pointed to the influence of the context in children's decisions about how and what to draw (e.g., Danish and Phelps 2010). We have only identified one publication (Areljung, Skoog and Sundberg 2022) addressing children's learning and use of cultural semiotic resources in drawings at such an early stage of formal schooling. Yet, relevant implications for practice and research can be derived. We aim to contribute to the literature with an examination of initial steps in 3–4-year-olds' learning and use of visual semiotic resources. We examine the *visual grammar* (Kress and Van Leeuwen 1996) of their science of drawings, that is, how elements are combined to create meaning. We identify and describe semiotic resources of visual communication that have a *meaning potential* regarding the relative importance of the different contents depicted, or the modality of the drawings (Jewitt and Oyama 2001). They are part of the class culture, rather than explicitly taught, as children engage in interpreting images and drawing tasks. Additionally, from a methodological perspective, we seek to explore the potential of combining *comparative content analysis* and *social semiotics* approaches in accounting for children's learning through the interpretation of their drawings.

These objectives are pursued through the following research question: *Which meanings do young children communicate with visual cultural semiotic resources available in the science classroom?*

Next, we introduce the theoretical fields on which we build for this study.

Cultural historical approaches to science education in early childhood

In this section, we address: the theoretical lenses that frame this research and justify why these are appropriate to examine young children's science; the teacher's role, with a focus on multimodal communication in the classroom; and conclude with a brief overview of research on children's science drawings.

Cultural historical approaches to learning consider that cognitive development occurs through social interactions. Thus, learning is explored as a dynamic construct that takes place when children interact with their environment (Fleer and Veresov 2018a, 2018b). Over several decades, a body of research about children's ideas has documented that they already hold their own concepts about the natural world before schooling (e.g., Inagaki and Hatano 2006) and has identified paths of development over time once children enter formal education (e.g., Barr and Galili 1994). Naïve ideas are often different from (Western) scientific ones, and Fleer and Robbins (2003) argued that a focus on their categorization had limitations for providing educational solutions at the EC level and could lead to a deficit view. These authors pointed to the need for expanding the borders of the object of research and examining the full social situation where learning takes place, considering the specific culture as well as the dynamics of children's thinking (Fleer and Robbins 2003).

Positioning interactions as the source of development, a growing body of research in young children's science learning, has unpacked social processes in the context of EC science, pointing to play-based settings as rich learning contexts and deriving implications for teacher practice and education (e.g., Roth, Goulart and Plakitsi 2013; Fleer and Pramling 2015). As illustrated by Andersson and Gullberg's (2012) study in the context of a floating-sinking experiment in an EC classroom, an analytical lens focusing solely on the use of scientific concepts did not capture the affordances of children's engagement in the activity, neither the teacher's active support, whereas sociocultural lenses allowed for doing so. This paradigm is fruitful for highlighting the resources children bring with them as science learners and knowledge producers, as well as for identifying pedagogical practices that can empower them (Siry 2014).

Early childhood teachers can foster children's engagement with science, for instance, by setting up open-ended and participatory classroom structures that enable children's agency (Siry, Wilmes and Haus 2016). Science teaching practices are influenced by teachers' perceptions. EC pre-service teachers in Sundberg and Ottander's (2013) study consider science as being excessively academic for preschool, which implies tensions in order to meet the preschool science curricula. A later study by Areljung, Ottander and Due (2017) showed that EC teachers found ways of handling both cultures, science and preschool, in their practice. Sundberg, Areljung, Due, Ekström, Ottander and Tellgren (2015) identified teachers' strategies used to overcome the challenges implicit in making the EC curricular content visible while pursuing children's interests, conciliating learning and care. Emotions are relevant dimensions involved in young children's science, and research has documented that EC teachers' scaffolding in science can pursue affective goals (Eshach, Dor-Ziderman and Arbel 2011; Monteira, Jiménez-Aleixandre and Siry 2022).

The EC teacher plays a central role in shaping children's communication in the culture of science, acknowledging and modeling valid ways of communication in the classroom. Dialogic teaching is an approach that fosters children's participation in conversation, supports listening to each other in order to expand meaning making, and is responsive to the situation (Kim and Wilkinson 2019). EC teachers can enact responsive dialogue in their science instruction (e.g., Gustavsson, Jonsson, Ljung-Djärf and Thulin 2016), fostering children's epistemic talk (e.g., Monteira and Jiménez-Aleixandre 2016). Several studies have addressed multimodal communication through the examination of teacher's practices, as well as the resources used in the science classroom (Jaipal 2010), highlighting diverse modes of meaning making such as children's embodiment (Siry and Gorges 2020); and showing that certain resources, such as open-ended science notebooks, provide a space for multiple modes of interaction and representation, as well as for deepening understandings (Wilmes and Siry 2020). Teachers are capable of scaffolding multimodal interactions in the EC class, such as gestures and visual representations with physical tools, among others, for science meaning making (Samuelsson 2019). Drawing is a common semiotic mode in EC, and research shows that it supports conceptual development (e.g., Fiorella and Zang 2018) and scientific observation (e.g., Cappelle, Franco and Munford 2023). Regarding children's biological knowledge, Bartoszeck and Tunnicliffe (2017) documented that their drawings of living organisms were detailed, including parts of plants and animals. Rybska, Tunnicliffe and Chyleńska (2014) examined children's drawings of snails, finding significant differences in the representations of organs by children of different ages. These two studies examined drawings as mirrors of children's ideas about the world. While this perspective can bring a valuable lens on children's ideas, we agree with other authors (e.g., Fleer and Pramling 2015) in considering drawing a social process in which the decisions about what and how to include are culturally mediated. As such, drawings are not merely an expression of ideas, but a cultural product. In that sense, Fragkiadaki, Fleer and Ravanis (2021) advocate for the possibilities brought by combining the strengths of conceptual and cultural analysis in exploring young children's science drawings. Several studies have examined drawings together with the context in which they were produced. In a study with 5- and 6-year-olds, Danish and Enyedi (2007) identified a range of factors that influence children's decisions about what to represent, including interactions with peers, instructions for the task, and what in class culture is considered to do the task "well." Similarly, Lundin and Jakobson (2014) found that the factors that determined the features included in 8-year-olds drawings of the human body included their ability to draw, what fit the paper, their own experiences or what was considered appropriate to depict. Danish and Phelps (2010) reported that both the production and revision of drawings by kindergartners were influenced by their teacher, their peers, as well as the classroom norms. Research has also addressed classroom conversation about drawings. In Danish and Saleh's (2014) study, the teacher prompted children to discuss and revise their drawings, making explicit their criteria about what is a good scientific representation, promoting changes in their criteria, including aspects such as accuracy. In a study with 5-year-olds, Monteira and Jiménez-Aleixandre (2016) found that, in the course of a science project, children were able to reflect upon their own drawings representing the topic of investigation. Children referred to the new findings they constructed over the inquiry project, pointing to the aspects the drawings did not account for. That is, dialogue about drawings fostered epistemic talk. In a later study, Monteira, Jiménez-Aleixandre and Siry (2022) found that consistent verbal and structural scaffolding over 3 years of EC education promoted children's autonomy in producing drawings of increasing complexity in the course of science projects and that they constructed meanings about the features of scientific drawings. Areljung, Skoog and Sundberg (2022) pointed as well to children's emergent disciplinary drawing in science. Nevertheless, Areljung, Due, Ottander, Skoog and Sundberg (2021) also reported that teachers rarely supported drawing, nor considered it as a means for building and communicating science understandings.

In sum, drawing is a common practice in EC classrooms that is socially mediated. Children are able to build and communicate science meanings with drawings as active participants in the culture of the EC classroom, and their teachers have the potential to set up the structures that facilitate these processes. The process of representing involves the choice of semiotic resources, often introduced by the teacher (Areljung, Skoog and Sundberg 2022). Semiotic resources have a cultural history and create meanings in a specific context for which this representation is adequate: the science classroom. This stance directs us to the social semiotics theoretical framework that serves as foundation for our work.

Social semiotics of visual communication

Learning can be considered as a process of sign-making, through which children "remake" what the teacher communicates (Jewitt and Oyama 2001), for instance, through drawings. A social semiotic approach views the choices involved in the process of sign-making as determined by cultural aspects (Kress and Van Leeuwen 1996). As expressed by Jewitt and Oyama (2001): "Social semiotics of visual communication involves the description of semiotic resources, what can be said and done with images (and other visual means of communication) and how the things people say and do with images can be interpreted" (p. 134). Similarly to linguistic structures, visual structures suggest particular interpretations of the meaning conveyed by the image. For instance, the layout of the elements of an image and the divisions and connections among them are semiotic resources because they are means for meaning making. The interpretations of these resources by the producer and the receiver of the message are based on cultural assumptions, that determine the potential of a semiotic resource to become a signifier in a given culture. According to Kress and Van Leeuwen, when producing their drawings young children "are unaware of established conventions and relatively unconstrained in the making of signs; […] they do not have such rich cultural semiotic resources available as do adults" (1996 p. 7). In other words, on the one hand, children might lack semiotic resources, and, on the other hand, they are "free" to create their own ones. While they become enculturated they are acquiring resources from the culture they grow in. Such assumptions are instrumental for the discussion of the principles of analysis of visual productions that draw upon the Social Semiotics approach.

Kress and Van Leeuwen (1996) sort meaning potentials of semiotic resources into three categories: *representational*, *interactive* and *compositional*, and each category includes several types of resources.

The *representational meaning* of resources refers to the identity, the essence of what is represented: an image can have either a narrative or a conceptual structure. A *narrative structure* is identified by the presence of a vector, a line that connects actors and elements, and these drawings express an action or event that is happening. A drawing with a *conceptual structure* may define (*symbolic*), classify (*classification*) or analyze (*analytical structure*) the entities represented.

The *interactive meaning* of resources relies on the interaction suggested between image and viewer. According to the type of interaction, images can be classified into: (1) *contact*, when explicitly addressing the viewer; (2) *distance*, when suggesting different degrees of familiarity with the elements depicted, depending on the distance from which they are represented; (3) *point of view*, if they are represented as seen from different perspectives; and (4) *modality*, which has to do with degree of certainty, it can be scientific, such as in diagrams, or artistic, such as in drawings in a graphic novel.

The *compositional meaning* of resources refers to the layout and to the relationships between its elements. *Information value* is given by the placing of the elements. For instance, in Western culture, the nucleus of the information is usually in the center of the picture space, whereas known information often is placed on the left-hand side and unknown information in the right-hand side. *Framing* refers to the connection and disconnection among the entities depicted: for instance, separation between the drawing of the snail (that refers to the object of the task itself) and the child's name (that refers to classroom pedagogic rules, in this case, the practice of labeling one's work). *Salience* has to do with the balance (bigger in size, misplacing) between entities, which can account for their relative importance and plays an aesthetic role.

In this study, the sign-makers are the children in the classroom and the representations examined are those of the snail as made out of several body parts; thus, the focus is on the analytical structures and part-whole relationships they represent.

Methods

This section describes the design of the study, the context and the principles and tools for analysis.

Research design

We take a qualitative perspective (Merriam 2009) with a case study design (Yin 2003), accompanying an urban middle-class group of 23 children (10 girls/13 boys) and their teacher for 3 years of EC education (3–6 years old), in selected sessions, while they engage in school science projects. The teacher is part of a professional community of six experienced EC teachers who carry out a science project in their classrooms every year. Three children come from families of immigrant origin—two from North Africa and one from Eastern Europe. All of them were born in Spain and are fluent in both Galician and Spanish, the co-official languages used in the classroom. Two children have special educational needs. Children's anonymity is guaranteed by using pseudonyms and avoiding information that could lead to their identification.

Informed consent to accompany and record selected sessions (52 sessions; 48.5 h of video-recordings) and gather children's productions, such as drawings, was given by the families and head of school. This paper focuses on data from the first year of study (3–4-year-olds), when the group was engaged in a project about snails. Two series of 18 drawings of a snail made a month apart are analyzed.

Context: the Snails project and the teacher's focus on producing and interpreting drawings.

In order to account for the factors that mediated the production of drawings we are guided by the theoretical framework. Hence, together with the conditions for the production of the drawings analyzed, we address the teacher's pedagogical practices and her focus on drawings.

The teacher views children as capable science learners and considers that engaging in science poses benefits for their integral development. Because she emphasizes children's active role in learning, the design of the project about snails was open and depended on children's interests. Along the project, drawings were used to learn and to share what was learnt. Consistently, the teacher prompted whole class discussions for interpreting the meanings conveyed by children's drawings, as well as by images brought by herself. Semiotic resources were not explicitly taught, but were implicit in the drawings used and produced in the classroom, as explained next. Regarding their representational meaning, the teacher decided the focus of the drawing tasks, either processes (e.g., the course of an experiment) or concepts (e.g., a snail, such as the drawings analyzed here). For the interactive meaning, the teacher chose different drawing tools and instructions for the drawing tasks, depending on the modality, either scientific or artistic. Scientific modality was embedded in the images that contained information about the snails' features, for instance, their anatomy. One child brought an image of the snail body parts depicted in a perspective that allowed for observing them in great detail and that did not have a background. This image was discussed and children pointed to where these parts were located on snail's body. The teacher also brought images of cartoon snails, showing a background and human-like expressions, which was discussed in terms of joy, a different approach to that used for discussing the image of a "real" snail. The compositional meaning was embedded in features such as separation between elements—labels and drawings—or framing. For instance, the teacher provided children with templates that contained a space for drawing the experiments they carried out and a separate space to paste in the correct order the words that made up the conclusion.

For carrying out the drawing tasks, children were distributed in four tables. As shown by the drawings collected and class observations, children's drawing abilities, fine motor skills and attitudes toward drawings differed. The teacher planned enough time for the tasks to ensure that every child was able to practice drawing and to accomplish them the best way each one was able to. When doing the drawings, the teacher's instructions were the same for all. She emphasized:

- Accuracy: before drawing, children were asked to discuss the contents they were going to represent and, on most occasions, to label them.
- Clarity and aesthetics: while the children were drawing, the teacher moved around the tables acknowledging careful sketching, asking them to be neat or to use all space available in their sheets of paper. Nevertheless, she did not stop them from drawing what they considered appropriate.
- Authorship: the teacher asked the children to label the productions with their names.

Children drew the first series of snails when they had only been with the snails for two weeks. The teacher asked the pupils to draw a snail, sketching it first with a pencil. Afterward, she gave them a pen to draw over the pencil and label it "snail." Then, the teacher cut out the snails and the label and pasted them on a colored card decorated by the children.

The second series was made a month later. The children spent about ten minutes purposefully observing and holding the snails, while discussing what they were seeing. In the course of the observations, children pointed to the "poo" and the "slime." The children named these body parts: shell, foot, mouth and radula; one child said snails had two tentacles while another one disagreed and said they had four; the teacher then asked them about the tentacles' functions and several children said they were for senses, to which the same child that said it had four tentacles pointed out that snails do not have nose; and all children but one agreed that snails do not have hair. The teacher posed questions that were responsive to children's talk, such as: "where the slime comes from?", "what are tentacles for?". The children drew the snails in 10 min. They were given a blank white sheet of paper and a black pen. The teacher asked the children not to "paint" (meaning not to fill the drawing with colors), just "draw" one snail with all its parts.

The science project began with the teacher bringing a box with snails into the classroom. When children drew the first snail, they had been looking after the snails for two weeks. In order to learn how to do so, every day they opened the box, cleaned it and checked what they had eaten. When children drew the second snail, they had already been pursuing answers to many of their own questions about the animals that arouse, while they were looking after them. They did so through experiments designed by themselves, information search and purposeful observation. We characterize it as a type of observation has a clear focus, is prolonged in time and strongly scaffolded by the teacher, prompting children to discuss and make sense of what they see. Over the session when the second snail was drawn, the teacher used the presence of the researcher as a stimulus to review previous learning constructed through the experiences that took place during the month.

Principles and tools for analysis

The analysis was emergent and developed in interaction of data with literature. The large dataset was employed to contrast information when needed.

In a first step, and due to the relevance of these type of tasks in the classroom (364 drawings collected in the context of snails' project), children's drawings were examined.

Second, because the snail was the central content of the science project, the second series of drawings of a snail were selected for analysis, as they were the only ones not altered by the teacher—for instance, she cut and pasted some of their drawings into a new card decorated by children, and others were made on a template. Social semiotic analysis (Kress and Van Leeuwen 1996) was used to identify the semiotic resources used by children in these drawings. In interaction with the literature, a rubric of five types of semiotic resources was elaborated. Table 1 summarizes the coding categories for the analysis: modality, point of view (interactive meaning), salience, information value and framing (compositional meaning. The category *Resource expression* corresponds to how each type of semiotic resource was used in these drawings. In order to properly "read" the images, it was necessary to determine the orientation of the sheet of paper according to the combination of the information provided by the position of the tentacles (pointing up) and the slime (at the bottom), and the orientation of the letters in the children's name.

For *modality*, images were coded into scientific, when they correspond to a prototypical snail and are not portrayed against a decorated background, or non-scientific, when they represent one particular snail and include ornaments and decorations in the background. For the *point of view*, we took into account the axis in which the tentacles are positioned with respect to the shell: vertical for the front view and horizontal for the side view. *Salience of elements* refers to oversizing, misplacing, or saturating a given element by using several layers of pen. *Information value* characterizes the positioning of the elements on the sheet (center, sides). *Framing of the image* refers to the positioning of the depicted elements relative to each other and to their separation. Results from these analyses revealed the semiotic resources used by children to represent the snails' body, that is, *how* this content is represented and *what* these choices mean. Additionally, the transcript of the session when the drawing was made was subjected to discourse analysis (Gee 2005) to characterize: (a) the course of the session; (b) the instructions for the drawing task; and (c) the development of the drawing task.

Third, in order to complement these results, a second series of drawings of a snail made at the beginning of the project (one month before) was selected for further analysis, as it allowed for analyzing changes along time in the two series of drawings of a snail for each child. The teacher had modified this series of drawings, so a social semiotic analysis as described above was discarded. Instead, comparative content analysis (Bell 2001) was chosen as an analytical method. This analysis serves to the purpose of examining comparable samples of observable content by identifying and comparing visual, verbal, oral and graphic products using explicitly defined categories (Bell 2001). In order to quantify categories of content, it is necessary to define variables and values. A content *variable* consists of any dimension or range of options. A variable can have different *values*, which are elements that belong to the same class. Variables in this study correspond to a snail's body parts, such as the tentacles, or processes, such as slime production; and the different choices of representation account for the values. For example, for the variable *tentacles* there are three possible values: *zero*, *one* or *two* pairs. Additionally, in order to understand the context of creation of these drawings, the teacher was interviewed, as the session was not recorded.

Table 1 Types of semiotic resources

Type	Resource expression		Definition
Modality	Scientific		Representation of a model of a snail – not a portrait of one of the snails from the box, but a prototype of a snail. Drawing not decorated
	Non-Scientific		Representation of a particular snail. Drawing is decorated
Point of view	Predominantly Front		Snail is heading toward the viewer: the snail's tentacles are placed on a vertical axis (mostly on the upper part) with respect to the shell
	Predominantly Side		Snail is heading toward one side: the snail's tentacles are placed on a horizontal axis with respect to the shell
Salience	Relative importance of elements	Oversized element	Element salient in size, not proportional to the rest of elements
		Misplaced element	Element that cannot be seen the way it is represented from the chosen perspective
		Saturation	Successive layers of black pen applied to one or several elements of the drawing
Information Value	Position of the image is centered or uses predominantly one of the sides		How the elements are placed on the sheet: left, right, up
Framing	Separation of elements		There are elements of the image that are disconnected, for instance, name and drawing
	Relative positions among related elements		Relative positions between slime and body, for instance, and orientation on the sheet

Results: children's appropriation and use of cultural resources to express science meanings

In this section, we present first the overall results of the analyses, and second, these results are elaborated in order to answer the research question**:** *Which meanings do young children communicate with visual cultural semiotic resources available in the science classroom?*

Overview of results of the analyses

The results for the semiotic analysis are shown in Table 2. The drawings show that children were appropriating an array of semiotic resources they used to express modality and relationships between elements when building representations.

The results for the comparative content analysis of the two series of drawings are summarized in Table 3, according to the three coding dimensions: (a) representation of the whole body; (b) body parts represented (further divided into tentacles, eyes, mouthparts and helix) and; (c) production of slime.

There was an evolution from anthropomorphic models of snails, some of which have human-like mouths and limbs, to less anthropomorphic ones. Drawings in the second series incorporated observed parts, such as tentacles and eyes, and processes, such as the production of slime. Parts such as the snail's shell were represented more accurately. Next, we discuss these results grouped in four categories: resources used to (a) express modality; (b) highlight content; (c) establishing elements as belonging to different categories; and (d) appropriation of written communication. In order to protect children's anonymity, while keeping the information given by the presence and position of the label, children's names were covered by an oval shape.

Resources used to express modality

All but one of the 18 drawings from the second series depicted a scientific-like modality. Drawings in scientific modality correspond to the criteria of: (a) being a model or prototype of any snail, as opposed to being the representation of a particular snail and; (b) lacking a background. One drawing (Fig. 1, Alberto) was coded as non-scientific. Kress and Van Leeuwen (1996) point out that the way settings are represented is important to identify the modality, and Alberto seems to have depicted a given snail within a specific environment or setting, as it includes a background. In other drawing tasks during the project, children did draw backgrounds, mainly in producing artistic drawings. One of such drawings was actually used by the teacher as the background on which the first drawings of a snail were pasted (e.g., Figs. 2 and 4). In this case, Alberto's choice for paying attention to the background was interpreted as his aim of decorating the drawing, whereas the other children's choice of not drawing a background is interpreted as their aim to emphasize relevant aspects of the snail itself.

The results of the content analysis also point to children's aim to depict snail's anatomy—parts of *any* snail, not one in particular. Although the first series of drawings were produced after observing the snails for two weeks, 12 out of 18 drawings still included anthropomorphic features, such as human-like faces and head separated from the body. In contrast, only three of the second series of drawings were anthropomorphic. Sebastian's (Figs. 2 and 3) and Ali's (Figs. 4 and 5) first and second drawings illustrate these changes. Six of the drawings in the first series represented legs or arms (see Fig. 4), but none in

Table 2 Semiotic resources mobilized by the children in the second drawing. $N=18$

Type	Resource expression		No. drawings
Modality	Scientific		17
	Non-scientific		1
Point of view	Predominantly front (tentacles top/tentacles bottom)		8/1
	Predominantly side (snail looking to the right/left)		4/3
	Not clear		2
Salience: Relative importance	Strategies for making something salient	Oversized element	14
		-Tentacles	4
		-Eyes	3
		-Slime, radula (each in 2 drawings)	4
		-Body, shell, mouth, nose (each in 1 drawing)	3
		Saturation	12
		-Slime	6
		-Helix, unknown elements (each in 2 drawings)	4
		-Body, shell, tentacles (each in 1 drawing)	2
		Displaced element	3
		- Slime	2
		- Radula	1
Information Value	Drawing occupies the center of the sheet		15
	Drawing occupies mainly one area of the sheet (right/top)		2/1
Framing	Separation between some elements		17
	-Child's name and snail (front/back)		14/2
	-Several snails (horizontal/vertical disposition)		4/2
	-Child's name and radula		1
	Relative positions among elements and/or on the sheet	Child's name on the top/bottom	11/4
		Tentacles directed toward the top of the sheet	14
		Slime underneath the body	8

the second series did. Figure 2 is a smiley snail with a human-like face, which shows the influence of Sebastian's previous ideas, cultural and representational repertoires. Mediated by the experiences provided by the project, he developed a representation that included features that are more typically associated with scientific ones, for instance, he chose a profile view that makes it possible to represent all body parts studied (Fig. 3). Ali's drawings (Figs. 4 and 5) reveal a similar trend. His first drawing (Fig. 4) shows an anthropomorphic snail with two pairs of limbs whose face, with two tentacles on top, occupies the proportions and the place in the snail's body later occupied by its shell (Fig. 5). His second drawing is a closer representation of the actual shape of a snail: proportions of shell and body, number of tentacles, and one pair of them with bulging eyes.

Resources used for highlighting

Most children chose to highlight some elements in their drawings by using different strategies as seen in the table: oversizing (14 drawings), saturation (12 drawings) or by displacement (3 drawings). One child highlighted several parts we could not identify. Nevertheless, his choice of differentiating several important elements indicates that he saw the snail's body as made up of different parts.

A nose was represented and highlighted by oversizing it in the second series in one case. We interpreted that it was drawn in reference to an experiment carried out in the class, in which they learnt that snails had the sense of smell, as reported during the session. While discussing snails' parts before producing the drawing, one boy said that snails did not have a nose. The teacher acknowledged his claim and pointed out that drawing a nose would not be correct. Nevertheless, while children were engaged in producing representations, she did not stop them from drawing parts she considered inaccurate, as in this case. When turning to the comparative content analysis, we observe that another child, Sebastian, did not represent a nose in the second drawing, as he did in the first, but, instead, the pair of tentacles responsible for the smell function (Figs. 2 and 3).

Snails' mouthparts, highlighted in the three drawings in which they were represented, were studied in-depth along the project. At the beginning, children noticed the holes left in the food by the snails and discussed their ideas about snails' mouth and teeth and began an investigation to find out more about the snail mouthparts. They found out that, to eat, snails pull out their *radula*, which is a thin, long and rough part with pointed denticles that allow them to scrape off food and take it to their intestine, and that snails have neither teeth nor tongue. In the session, children explained to the researcher what a radula looked like and how it worked. As it is inside the body, the radula cannot be seen in its entirety so, displacing this piece outside, like one child did, indicates, from a semiotic perspective, the child's aim to include it in the drawing and to highlight it as an important part of a snail's body. In Sebastian's second drawing, all the elements but the radula are scaled in size: he highlighted this piece by oversizing it. The content analysis confirms the importance this body part took for children: nine of the drawings in the first series represented an anthropomorphic mouth, in five cases with teeth (see Fig. 2), while in the second series only one human-like mouth was represented (see Table 3).

Similarly, in the second series, slime was highlighted in 10 cases, which indicates that children considered it an important feature of snails or of what they do. Children chose to highlight it through oversizing (2 drawings), saturating (6 drawings) or displacing it (2 drawings) in the picture (Table 2). The teacher reported that at the beginning of the project some children said that slime was "disgusting", while, when the second drawings were

Table 3 Comparative content analysis of the evolution of dimensions represented in snail's first and second drawing. $N = 18$

Dimensions			1st drawing	2nd drawing
Representation of whole body	Anthropomorphic body		12	3
	Body with legs or arms		6	0
Body parts	(a) Tentacles	0 tentacles	4	2
		1 pair	11	7
		2 pairs	3	9
	(b) Thicker end of tentacles (eyes)		1	12
	(c) Mouthparts	Anthropomorphic mouth with teeth	5	0
		Anthropomorphic mouth without teeth	4	1
		Radula	0	3
	(d) Helix		3	9
Production of slime			1	11

made, all of them liked to touch the snails and let them walk over their arms, talking about the slime they left behind while doing so. In eight cases, the slime was placed underneath the snail's body from which it is segregated. Ali's second drawing represents a snail with slime underneath its body saturated so heavily that the sheet of paper was torn (Fig. 5, *Hole* indicated with a label and an arrow). When contrasting with the results from the comparative content analysis, it is found that there was a shift from 1 to 11 drawings representing the production of slime.

This finding shows that children were acquiring a range of resources to communicate what they considered important.

Resources used to establishing elements as belonging to different categories

This finding has to do with emerging knowledge about rules for the representation tasks in the context of the classroom. 17 of the 18 children used different resources related to composition, such as separation among elements, and this resource is used mainly to separate the child's name and the snail (16 cases), even by writing their name on the back of the drawing in 2 cases. Only one drawing, namely Alberto's (Fig. 1), the child whose drawing did not have a strong scientific modality, did not separate any elements. Name and drawing were separated as if they belong to different ontological categories: the task itself and the

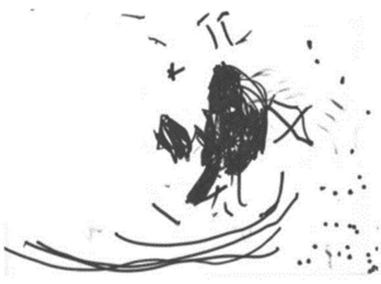


Fig. 1 Alberto's second drawing

Figs. 2 and 3 Sebastian's first and second drawings

Figs. 4 and 5 Ali's first and second drawing

class protocol of identifying the authorship. The two children who wrote their name on the back made this distinction clear. Another child, Alma, who was not yet able to write, drew letter-like symbols (see Fig. 6), separated from the drawing of the snail. One child drew the radula as a separate element, although it cannot be seen from the outside. When interpreting this finding together with the content analysis of *mouthparts*, this decision seems to signify the importance of this body part to the child.

Appropriation of written communication

Children who took part in this study were learning to read and write and every day at school they were in touch with texts and labels, although by their first year of schooling most of them were able to write only a few letters. The analysis of compositional

Fig. 6 Alma's second snail

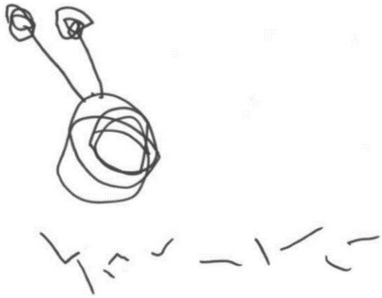
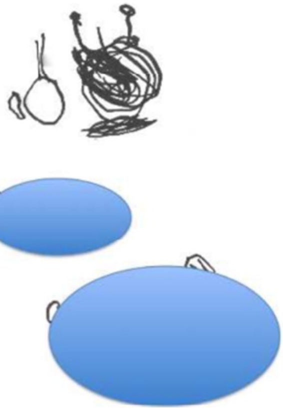


Fig. 7 Alejo's second drawing



resources indicates that children were appropriating written communication, as many children began their drawings from left to right and from top to bottom, as discussed below, a pattern that is consistent within Western culture.

The teacher's demands for the tasks required the use of all space available in the sheet for the drawing, which involved placing the drawing in the center of the sheet and distributing elements, such as drawing and label, harmonically. This requirement was reflected in the data submitted to semiotic analysis: 15 drawings are placed in the center of the page. Some children did not calculate accurately how much space they were occupying with their drawings and, as they were drawing directly with the black pen, they did not have the chance to erase. Eleven of the children who wrote their name centered on the front of the sheet did so at the top, while 4 wrote it at the bottom. Two of the remaining three children, like Ali (Fig. 5), wrote it on the left, which is where they start writing.

When drawing more than one snail, children separated them horizontally (four cases) or vertically (two cases). In two of these six drawings that showed more than one snail, assuming that the most accurate ones were the latest being produced, the direction in which they were drawn was from left to right, as in Western writing (see Fig. 7).

From the remaining four drawings: Raissa's was drawn from right to left, that is, the direction in which her family language is written, as she is of Arab origin; Ariadna's went from bottom to top, like consecutive lines on a written page; Igor's showed three figures: the two at the sides are saturated, which might suggest that he started the drawing in the center or nucleus of the information.

In summary, an array of semiotic resources were learnt and used by children to express meanings about snails that could be shared with their peers and teacher. Thus, examining children's representations from this perspective is relevant to account for children's science and cultural gains, as well as for valuing the teacher's practices, as discussed next.

Discussion

We interpret the appropriation of visual resources for conveying meanings about snails, through a sociocultural approach. Scientific drawing is a social practice, which, as other social practices, is "constructed over time by members of a sustaining social group. Such classroom cultures are formed through locally interpreted and recognized ways of talking, being, and knowing." (Kelly and Green 2019, p. 1). As discussed above, the use of semiotic resources was not explicitly taught, but rather appropriated over time by the children in a supportive environment.

Results from the analyses indicate that there were five dimensions of scientific and cultural gains shown by children through their drawings:

- First, as evidenced through the comparison of the first and second series of drawings, it may be said that children appropriated the tools to recognize anatomical features in the snail's body and to visually represent them in a scientific way, rather than in an anthropomorphic one. In children's cultural environment there are numerous images, drawings, films or cartoons in which animals, and in particular invertebrates, are represented with anthropomorphic features. Children became part of a classroom culture in which visual representations are valid means to learn and share scientific knowledge. As illustrated earlier, science representations and cartoons were addressed in different terms in the classroom talk and children were aware of their different purposes. Consequently, children represented the second snail in such a way that their drawings belong to the category of science representations. This finding is aligned with other studies in EC that report children's increasing awareness of what constitutes a science representation (Monteira, Jiménez-Aleixandre and Siry 2022).
- Second, children used visual semiotic resources in order to highlight which parts of a snail they considered important to describe. Children highlighted body parts that, following their own interests, had been specifically addressed during the project. In doing so, they mobilized different resources, for instance, oversizing elements or displacing them. They also represented processes they observed and researched, such as the production of slime, and for addressing this process it was necessary for them to overcome prejudices about slime, which in public representations is considered "disgusting." This points to the relevance of emotions in science learning, in particular in EC classrooms (e.g., Fleer 2013).
- Third, children were able to develop multimodal communication competences. The semiotic resources identified in the analysis were children's own creation, as they were not reproducing others' resources. Each child brought his or her particular interpretations and approaches, and created resources in order to communicate specific meanings in great detail. They appropriated and used *visual grammar* (Kress and van Leeuwen 1996) as a result of their enculturation in the continuous use and

interpretation of visual representations fostered by their teacher. This point is of great importance, as language is central to learning and the view that language/s is/are a resource (Halliday 1992) allows for considering its generative role beyond a traditionally normative evaluative standard. Adopting such a stance is quite important in the case of young children who are appropriating both linguistic and semiotic resources, which will be instrumental in and for their learning process.

- Fourth, children were able to mobilize resources in order to meet the tasks' objectives. For instance, all children but one, chose a scientific modality for the drawing resources related. They followed class protocols such as labeling the task. When doing so, they used to composition, such as framing the snail and appending their names as separate elements, differentiating two different ontological categories: drawing and labels conforming to class rules, and placing the information in the center. This finding suggests that children were acquiring the tools to recognize and represent the same content and modify its meaning depending on their interests and what seemed to be more appropriate within a given context.
- Fifth, the use of framing also indicates a growing awareness and understanding of written communication, even before children were able to write proficiently. For instance, Ali's drawing is positioned toward the left-hand side. Even though Ali's family is of Arab origin, and they do not start writing on the left-hand side, his drawing reflects the school enculturation, as writing is a skill that children were learning in this first year of schooling.

The findings point to two main recommendations for practice that are fostering children's agency and supporting their engagement with representations. Children are capable science learners, as shown by this study, and to fully develop their capacities there is a need for participatory classroom structures that foster their agency (Siry, Wilmes and Haus 2016). In this classroom, children's interests and contributions were taken into account and the science project is devoted to answering their questions. The teacher valued science learning and her practice was responsive, promoting purposeful dialogue in the classroom (e.g., Kim and Wilkinson 2019). She was responsive to children's talk about observations, experiments, evidence, description of events… and intervened with tailored prompts, fostering reflection and meaning making. Her practice is aligned with the four competences that Anderson and Gullberg (2014) denote as relevant for EC teachers: "(1) paying attention to and using children's previous experiences; (2) capturing unexpected things that happen at the moment they occur; (3) asking questions that challenge the children and that stimulate further investigation; and (4) situated presence, that is, ''remaining'' in the situation and listening to the children and their explanations." Within this safe environment children felt valued and were able to bring their own resources for learning. Moreover, research has documented that, often, young children's teachers do not feel comfortable when teaching science because they feel they lack content-specific knowledge (e.g., Gerde, Pierce, Lee and Van Egeren 2018). Whereas following children's interests may pose difficulties in order to meet the curricula (e.g., Lewis et al. 2019), we find this is a fruitful approach in early years science that can help in overcoming difficulties related to teacher's self-perception regarding low content knowledge. In our study, due to the open-design, both the teacher and the children in this study were learning together. We agree with Zembal-Saul, Siry, Monteira and Bose (2022) in that teacher education for EC science can play an important role to embrace "a pedagogy of listening and responsiveness, an inquiry stance toward teaching and learning" (p. 78).

Despite being one of the most common pedagogical practices in EC classrooms, teachers do not always consider drawing as a resource for learning science and these tasks are less supported than other tasks, such as writing (Areljung, Due, Ottander, Skoog and Sundberg 2021). Nevertheless, our study points to the importance of supporting drawing tasks since early years, as well as providing children with opportunities to discuss and interpret visual representations. In other words, creating a classroom culture where these social practices are jointly constructed and valued, as suggested by Kelly and Green (2019). Representations are mediating tools in science and providing opportunities to engage in representational practices since EC is important to foster "emergent disciplinary drawing in science" (Areljung, Skoog and Sundberg 2022), and it can lead to cognitive and metacognitive gains (Monteira, Jiménez-Aleixandre and Siry 2022).

Regarding implications for research, the innovation of this study relates to the use of social semiotic analysis and the combination of two foci, *how* (social semiotics) and *what* (content), in our analysis, to examine socially constructed meanings, appropriate for the purpose of sharing science knowledge. The large data set allows for a nuanced understanding of the context, and the sociocultural perspective is key for interpreting the results of the analyses in order to unpack and contextualize children's complex learning gains. As children engaged in learning science, they decided how and what to draw in order to meet their teacher's assignment by combining the elements in her or his drawing using semiotic resources that emerged from and could be understood within the culture of their classroom (Kress and Van Leeuwen 1996). These children were in school for the first time and, by combining both perspectives, we can have a broad perspective of their learning gains, not only in the field of science, in such a little period of time.

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Author contributions S.F.M generated the data examined in this manuscript as part of her PhD dissertation—which was directed by M.P.J., and wrote the main manuscript text. All authors collaborated in the analysis and revised the manuscript.

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Data availability The datasets generated and analyzed during the current study are not publicly available as they contain sensible information and are subjected to personal data protection.

Declarations

Conflict of interest The authors declare no competing interests.

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