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From Young Children's Ideas about Germs to Ideas Shaping a Learning Environment

Marida Ergazaki · Konstantina Saltapida · Vassiliki Zogza

Abstract This paper is concerned with highlighting young children's ideas about the nature, location and appearance of germs, as well as their reasoning strands about germs' ontological category and biological functions. Moreover, it is concerned with exploring how all these could be taken into account for shaping a potentially fruitful learning environment. Conducting individual, semi-structured interviews with 35 preschoolers (age 4.5–5.5) of public kindergartens in the broader area of Patras, we attempted to trace their ideas about what germs are, where they may be found, whether they are good or bad and living or non-living and how they might look like in a drawing. Moreover, children were required to attribute a series of biological functions to dogs, chairs and germs, and finally to create a story with germs holding a key-role. The analysis of our qualitative data within the "NVivo" software showed that the informants make a strong association of germs with health and hygiene issues, locate germs mostly in our body and the external environment, are not familiar with the 'good germs'-idea, and draw germs as 'human-like', 'animal-like' or 'abstract' entities. Moreover, they have significant difficulties not only in employing biological functions as criteria for classifying germs in the category of 'living', but also in just attributing such functions to germs using a warrant. Finally, the shift from our findings to a 3-part learning environment aiming at supporting preschoolers in refining their initial conceptualization of germs is thoroughly discussed in the paper.

Keywords Early year education · Ideas about germs · Learning environment about germs · 'Living/non-living' · Reasoning about germs

Introduction to the Study

A growing body of research in early year education is concerned with how young children construct their knowledge about the living world (Wellman and Gelman 1992; Keil 1994;

M. Ergazaki (✉) · K. Saltapida · V. Zogza
Department of Educational Sciences & Early Childhood Education, University of Patras, 26500 Rio-Patras, Greece
e-mail: ergazaki@upatras.gr

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Carey 1995; Hatano and Inagaki 2006), as well as with how they may be supported in this process within appropriately designed learning environments (Zogza and Papamichael 2000; Solomon and Johnson 2000; Williams and Binnie 2002; Zogza 2007).

Inagaki and Hatano (2006) suggest that what has to be ascertained in order to claim that young children do hold a naïve theory of biology, is whether they have the ability to make the crucial distinctions between 'living' and 'non-living' and between 'mind' and 'body', as well as to mobilize 'causal devices' when attempting to articulate their own explanations about phenomena of the living world. According to Wellman and Gelman (1992) and to Keil (1994), there are three distinct biological sub-domains within which children of preschool age appear to be able to draw upon 'causal devices'. More specifically, it has been suggested that preschoolers can be engaged in shaping causal relationships, when reasoning particularly about growth, inheritance and illness.

Nevertheless, this suggestion has been challenged quite strongly as well. According to Carey (1995), the so-thought 'causal devices' of young children may finally turn not to be actually 'causal'. In other words, it has been suggested that–when reasoning about biological phenomena in the three aforementioned contexts–preschoolers may be capable of shaping relationships rather on an 'input–output' level, than on a 'cause–effect' one.

Regarding illness in particular, this actually means that although young children may easily make the 'illness–germs' connection, they cannot really create a reasoning loop in order to explain it. In other words, 'input'–which is germs–and 'output'–which is 'illness'–are not put together by young children on the basis of an explanatory device that consider germs as invading and using the body to cover their own needs (Carey 1995).

Solomon and Cassimatis (1999) enhanced this claim with three studies where children of preschool age were told stories with a person having symptoms like stomachache because of (a) germs, (b) poisons or (c) overeating and were required to judge whether another person could catch such symptoms from the one that already has them. Since very few children were actually able to use the origin of the symptom (germs, poison, overeating) as a criterion for judging the possibility of its transmission to another person, there is no evidence of a naïve biological theory of illness that considers germs as the key-part of an underlying causal process.

This seems to be also confirmed by Nagy (1953), who having worked with 370 children age 5–10, suggested the 'principle of automatic infection and healing' as central in their conceptualization of illness. In other words, according to her findings, children seem to think of germs as causing an 'automatic' shift to illness no matter what the status of the germs or the condition of the body is, and of medicines as causing an 'automatic' shift back to health.

The lack of an explanatory device in the specific context might be related with young children's poor conceptualization of germs as living entities. Studying germs' graphic representation, definition and activity inside the human body, Nagy (1953) reported that her 5–10 year old informants identified germs (a) as what 'makes us ill', (b) as certain animals, particularly insects like flies for instance, and (c) as bad things like dust or poison. Most of the younger children (age 5–7) did not identify germs as certain animals and thus represented them with abstract figures like dots or round and angular shapes. Nevertheless, almost half of the children of this age group could not come up with any representation of germs at all. Finally, in regard to germs' activity inside the human body, things like 'illness causing', 'damage causing' and 'living' were mentioned by several children of all age groups, while 'living' appeared to be understood as 'walking around', 'eating' and 'breeding' at least for the age group 8–10.

Moreover, Solomon and Cassimatis (1999) argued that preschoolers do not understand germs as uniquely biological agents; namely, as agents that are ontologically distinct from

non-biological ones such as poison. More specifically, according to their findings children did not make different attributions of properties such as moving, eating, having babies, thinking and feeling sad to germs and poisons, while they did make different attributions of these properties to germs and animate beings such as people, ants and trees. Exploring further preschoolers' conceptualization of germs as living entities in another study, Solomon and Cassimatis (1999) found that only 17% of their informants made the attribution of 'eating' to germs, 0% made the attribution of 'growing' and 33% made the attribution of 'dying'. Considering these properties as central to reasoning about the 'living–nonliving' distinction, the findings of Solomon and Cassimatis (1999) indicate that most preschoolers did not think of germs as living entities. In fact, they did not show for germs the pattern of inductive inference they showed for plants and animals.

Children of older ages appear to have a poor conceptualization of germs as well (Simmoneaux 2000; Hilge and Kattmann 2003; Hőrsch and Kattmann 2004; Bandiera 2007). Working with 416 children of 7, 11 and 14 years, Byrne et al. (2008), have traced 'anthropomorphic and anthropocentric' ideas about several germ features such as their 'living state'. Most of the children in each of their 3 age groups appeared to consider micro-organisms as living things, with this proportion being lower in the younger group as one might expect. Nevertheless, the right identification of germs' living state was not carried out through biological ideas, but through ideas such as germs' inability 'to talk to each other' ('non-living') or germs' ability 'to move and kill people' ('living').

Taking into account the plausibility of the idea that a better conceptualization of germs as distinct living entities may be a missing element of key importance for the development of explanatory devices in the context of illness, the present study is concerned with tracing 35 preschoolers' ideas and reasoning strands about germs, exploring the ways in which these could shape a possibly fruitful learning environment, implementing the latter with small groups of preschoolers, and finally exploring the learning impact on them. It is noted that the implementation phase of the study is reported elsewhere (Ergazaki et al. 2008), while in this paper we are particularly concerned with the tracing phase and its implications for the development of the learning environment.

The study theoretically draws on 'constructivist theory', which views learning as an active process of knowledge construction on behalf of the learners, rather than as a passive process of knowledge transmission on behalf of the teachers (Bruner 1966; Piaget 1970; Vygotsy 1978). The construction of new knowledge by the learners is considered to be closely related to the knowledge they already have. According to Piaget and his well-known notions of 'assimilation' and 'accommodation', in order to make meaning of a new experience, individuals incorporate it into an already existing framework of mental representations, which may or may not change in order to fit the new experience (Piaget 1970). New experiences are organized and understood by the learners on the basis of their current cognitive structure (Bruner 1966).

This process has also a significant inter-personal aspect which has been emphasized by the Vygotskian model of 'social constructivism' (Vygotsy 1978) and the associated theoretical construct of the 'zone of proximal development' (Moll 1990). Being conceptualized as the distance between the level of reasoning strands that learners can develop by themselves and the level of those that they could develop if they were appropriately supported by their teachers or collaborated with more capable peers, this 'zone' can only be defined on the basis of a good understanding of the initial state of the learners (Zogza 2007).

Taking into account the key role that learners' prior knowledge may hold in the process of learning, a significant part of Science Education research has been concerned for quite a long time with children's 'preconceptions' about entities and phenomena of the natural and

biological world (Pfundt and Duit 2002; Duit 2009). The elicitation of the 'ideas' that even very young children bring with them into the classroom, may provide a solid ground for developing constructivist learning environments (Driver and Oldham 1986; Hedegaard 1990; Ravanis and Bagakis 1998). Customized to children's current understandings, such environments tend to promote the active participation of children in their own learning, engaging them in inquiry-based activities and meaningful exploration of concepts (Zogza 2007).

Considering the above, the question addressed here is 'how do young children reason about germs and their ontological status'. In particular, (1) 'what do they think about the nature, location and appearance of germs', (2) 'do they attribute any biological functions to them', and (3) 'do they appeal to such biological functions when classifying germs within the ontological categories of living or non-living'. Moreover, we address the question of 'how young children's traced ideas and reasoning strands may shape a new learning environment that could possibly support them in reaching a better conceptualization of germs'.

Thus, the objectives of this paper are to explore:

1. Young children's ideas about the nature, location and appearance of germs, as well as their reasoning strands about germs' ontological category and biological functions.
2. The ways in which these ideas and reasoning strands could be taken into account for shaping a learning environment within young children's potential.

Methods

The Overview of the Study

Thirty-five preschoolers (age 4.5–5.5,) who were attending three public kindergartens in the broader area of Patras during 2008, contributed to the study as our informants. All of them were quite familiar with educational interactions since they had already completed several months as kindergarten pupils. Moreover, they had never taken part in formal learning activities about germs up to that point.

Tracing children's ideas and reasoning strands about germs and their ontological status was carried out through 20–30 min, individual, semi-structured interviews. These were conducted by one of the researchers in quiet places of the children's schools and they were also tape-recorded. The interviewer had previously become familiar with the informants, and their own assent for participating had been asked along with their parents' informed consent.

The Interview Protocol

The interview protocol was organized in three parts. In the first one, after exploring what the word 'germs' may bring to children's mind, drawing upon the work of Nagy (1953) we traced their ideas about what germs are, where they may be found, whether they are good or bad and living or non-living and how they may look like if drawn on a piece of paper.

In the second part, we engaged children in a modified version of Solomon and Cassimatis' (1999) 'attribution task'. Narrowing our scope to biological functions only, we asked children to attribute eating, breathing, moving, reproducing and dying to an entity easily perceived by them as living (a dog), an entity easily perceived by them as non-living (a chair) and to the entity in question (germs). Children were required to state reasons for

attributing or not these functions to the given entities with the question 'how do you know that … this … does or doesn't do … that'.

Nevertheless, it should be noted that the questions concerning dogs and chairs aimed merely at contributing in tracing the 'target reasoning', namely the one through which our informants attribute or not a series of biological functions to the entity of interest, germs. In other words, we are not actually interested in these responses *per se*, but in using them towards creating a rather demanding 'dilemma' for children: That of attributing or not biological functions to germs by categorizing them either along with a living entity (dog), or along with a non-living entity (chair).

Finally, children were asked to create a story with germs holding a key-role, in order to express themselves more freely and probably shed more light for us on their own conceptualization of germs.

The Overview of the Analytic Procedure

The 35 tape-recorded interviews were transcribed and prepared for coding within the qualitative analysis software 'NVivo'. Coding the prepared interviews resulted in a series of 'categories' which were organized to the 'coding scheme' presented in Fig. 1a and b.

Moreover, several 'attributes' with respective 'values' were assigned to each interview, most of the times on the basis of the coding itself. For instance, the 'attribute' 'Germs breathing: Why' with possible 'values' a series of different types of reasoning which are shown as siblings of the 'category' 'Reasoning about bio functions' in Fig. 1b; or more interestingly, the 'attribute' 'Models: Why', which was created in order to help us describe the possible patterns in children's reasoning about the attribution of biological functions to germs.

More specifically, the three criteria chosen to shape children's models have to do with:

(a) The number of biological functions attributed to germs: A model is considered to be 'full' with 4–5 of the biological functions in question attributed to germs, 'partial with 3–4, and finally 'one-instance' with only 1.
(b) The consistency with regard to the type of reasoning activated for the different biological functions in question: A model is considered to be 'consistent' when showing the same type of reasoning (i.e. human-based reasoning) for a number of biological functions which may vary according to the model's fullness: 3–5 biological functions for a 'full' model, 2–3 biological functions for a 'partial' model, and of course 1 biological function for a 'one-instance' one.
(c) The frequency of the desired type of reasoning ('biological') for the different biological functions in question: When the biological reasoning is absolutely absent from a model, this is characterized (a) as 'bio free' if it is either a 'one-instance' model or a 'partial_inconsistent' one, and (b) as 'non bio' if it is either a 'partial_consistent' model or a 'full_consistent' one. Moreover, a model is characterized as 'bio trace' or as 'bio focus' when the biological reasoning appears for a number of functions which may vary according to the fullness of the model.

Findings

The analysis of our data in regard to our 1st research question, namely children's ideas about the nature, location and appearance of germs, showed the following.

Our informants associated the word 'germs' mainly with health and hygiene issues. In fact, 28 of the 35 children referred exclusively to 'illness', 'illness contagion' or 'hygiene

a

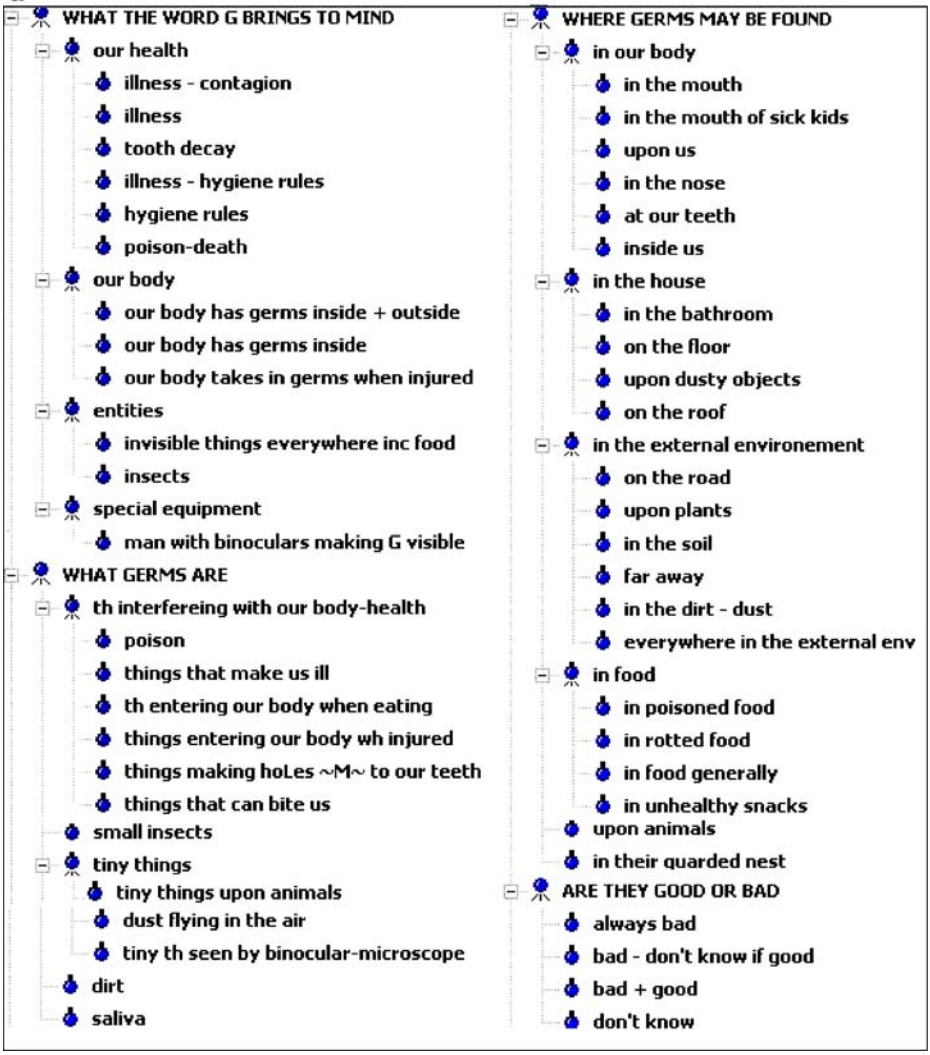

Fig. 1 **a** The coding scheme (1st part). **b** The coding scheme (2nd part)

rules' (washing hands or brushing teeth), when they were required to state what the word 'germs' brought to their mind. Moreover, two children made double references, combining health or hygiene issues either with 'entities' they considered as germs ('insects'), or with 'our body' ('our body has germs inside and outside'). Exclusive references to 'our body' were made only by two of the 35 children ('our body has germs inside', 'our body takes in germs when injured'), while two others referred also to 'entities' such as 'insects' or 'invisible things everywhere including food'. Finally, one child associated the word 'germs' with the 'special equipment' (binoculars) that makes them visible to the scientists (Table 1).

The strong association of germs with health and hygiene issues held by our informants also emerged through their most frequent way of defining germs. Twenty-eight of the 35 children defined germs as 'things interfering with our body & health'. More specifically: as

b

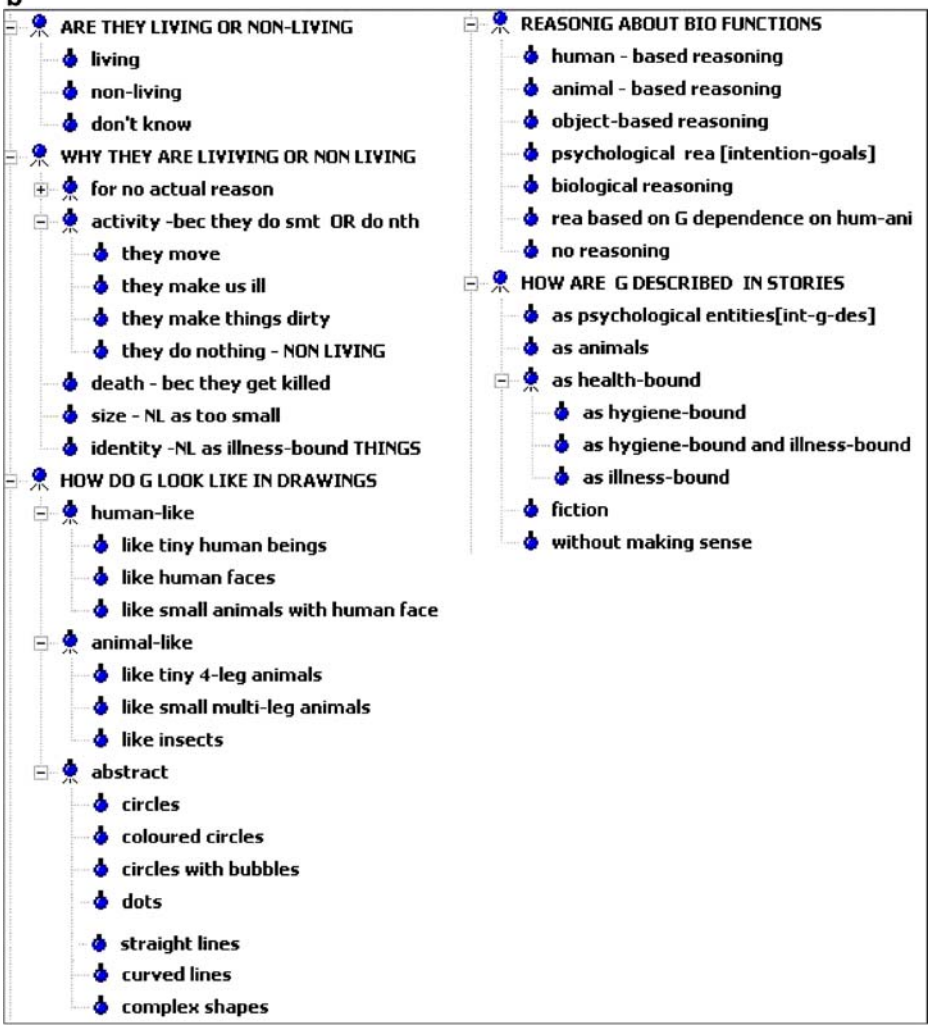

Fig. 1 (continued)

'things that make us ill', 'things making holes-homes to our teeth', 'things entering our body when injured' or 'when eating', 'poison', 'things that can bite us'. As shown in Table 2, 23 of these 28 children expressed this notion exclusively, while the remaining five combined it with other notions according to which germs may be 'dirt', 'small insects', 'tiny things' (such as 'dust flying in the air') or 'saliva'. Finally, much fewer children defined germs exclusively as (a) 'small insects' (4/35), (b) 'tiny things' found either 'upon animals' or within the visual field of a 'man with special equipment' (2/35), and (c) 'dirt' (1/35).

The most frequent ideas about germs' location were (a) 'our body' ('mouth', 'mouth of a sick kid', 'nose', 'teeth', 'inside us' or 'upon us') (18/35), and (b) the 'external environment' ('road', 'plants', 'soil', 'far away', 'dirt-dust', 'everywhere in the external

Table 1 The word 'germs'

'What does the word germs bring to children's mind'	Number of children
Our health	28
Our health & entities	1
Our health & our body	1
Our body	2
Our body & entities	2
Special equipment	1

environment') (17/35). As shown in Table 3, most of the 21 children who gave only one location for germs, referred to 'our body' (9 children) and to the 'external environment' (8 children), while only two referred to the 'house' ('floor' & 'dusty objects', or 'floor' & 'toilet'), one to 'food' and one to 'animals'. Moreover, a rather significant number of children (the remaining 14) appeared to be familiar with the idea that germs may be found in different places. This is shown by their multiple references such as for example the one to 'our body & external environment & house' or the one to 'external environment & upon animals & food' (Table 3).

Going back to children's ideas about germs' nature and particularly upon whether germs are considered by them as 'bad' or 'good', we note that the idea of germs being 'always bad' was the most frequent (20/35). Moreover, eight children stated that there are definitely 'bad' germs but they weren't able to reject or accept the possibility of the existence of 'good' germs as well, and five children appeared to accept this possibility but without being able to state something specific about them. Finally, two children didn't give a response to this question (Table 4).

Although most of the children (20/35) explicitly recognized that germs are invisible to the bare eye, they came up with several representations of germs in their drawings. As shown in Table 5, nine children created 'human-like' representations where germs were depicted as 'tiny human beings' (5 children), 'human faces' (2) or 'small animals with (emphasized) human faces') (2) (Fig. 2). Moreover, seven children created 'animal-like' representations of germs: They drew germs as 'tiny 4-legged animals' (3 children), 'tiny multi-leg animals' (2 children) or 'insects' (2 children) (Fig. 3). But more interestingly, the most frequent representation type appeared to be the 'abstract' one (19/35). In particular,

Table 2 What germs are

'What germs are'	Number of children
Things interfering with our body–health	23
Things interfering with our body–health & dirt	1
Things interfering with our body–health & small insects	1
Things interfering with our body–health & small insects & dirt	1
Things interfering with our body–health & tiny things	1
Things interfering with our body–health & saliva	1
Small insects	4
Tiny things	2
Dirt	1

Table 3 Where germs may be found

'Where germs may be found'	Number of children
Our body	9
Our body & external environment	2
Our body & house	2
Our body & external environment & house	2
Our body & food	1
Our body & food & external environment	1
Our body & nest	1
External environment	8
External environment & house	2
External environment & upon animals	1
External environment & upon animals & food	1
House	2
Food	1
Food & upon animals	1
Upon animals	1

germs were represented as 'circles' in several versions (12), 'dots' (2), straight or curved 'lines' (2) and 'complex shapes' that combined some of the former (3) (Fig. 4).

According to Table 6, the germ-stories of our informants had mainly to do with health or hygiene issues (26/35). For example, 'germs in food–either dirty or just unhealthy–make kids ill and a doctor is needed to save them', 'germs just move from food to a kid's teeth', 'germs move from the soil to kids' feet which need to be washed' or they 'move from the soil to kids' hands and from the unwashed hands to their mouth, which makes them finally ill'.

More interestingly, in some stories (5/35) germs were presented as 'psychological entities'; in other words, as entities having intentions, goals or preferences. For example, germs were presented as creatures that 'being bothered by the noise of people in the house, they get out and climb up to a tree to spend some time together and even get a snack from the tree roots if hungry'. Finally, germs were presented as small animals 'which run to their nest and eat tiny bits of bread' (1/35), while one child set a totally fictional context where 'a donkey gets irritated and kicks the annoying germs in order to leave him alone'. Two children did not manage to create a story with any sense at all.

But what did the informants of the study think when it came to germs and biological functions? The findings in regard to our 2nd research question are the following.

According to Table 7, 10/35 children showed a completely problematic view on the performance of biological functions by germs, since they did not attribute to germs any of

Table 4 Are germs good or bad

'Are germs good or bad'	Number of children
Always bad	20
Bad–don't know if good	8
Bad & good	5
Don't know	2

Table 5 Germs in children's drawings

'How do germs look like in children's drawings'	Number of children
Human-like	9
Animal-like	7
Abstract	19

the biological functions in question. Nevertheless, 10/35 children appeared to be at a slightly better point by attributing 'a few' biological functions to germs (1–2/5). Finally, the remaining 15 children did not show significant problems: eight of them attributed to germs the most biological functions in question (3–4/5) and seven attributed all five of them.

The attribution of 'eating' and 'reproducing' to germs appeared to be harder for our informants, since those who did not make it were much more than those who did. For example, in regard to germs' 'eating', 11 children gave 'yes', while 22 (the double) gave 'no'. On the contrary, things appeared to be less difficult for 'breathing', 'dying' and of course 'moving'. For example, regarding germs' 'breathing', 17 children gave 'yes' and 16 (namely almost the same number) gave 'no'.

The analysis of our data showed six types of reasoning employed at different frequencies when the informants were engaged in attributing biological functions to germs (Table 8). These were defined by us as follows.

– 'Human-based', 'animal-based' or 'object-based' reasoning when children attributed or not biological functions to germs, based on an analogy of germs with (a) human beings ('germs do not breath because they don't have a nose like we do', 'germs move

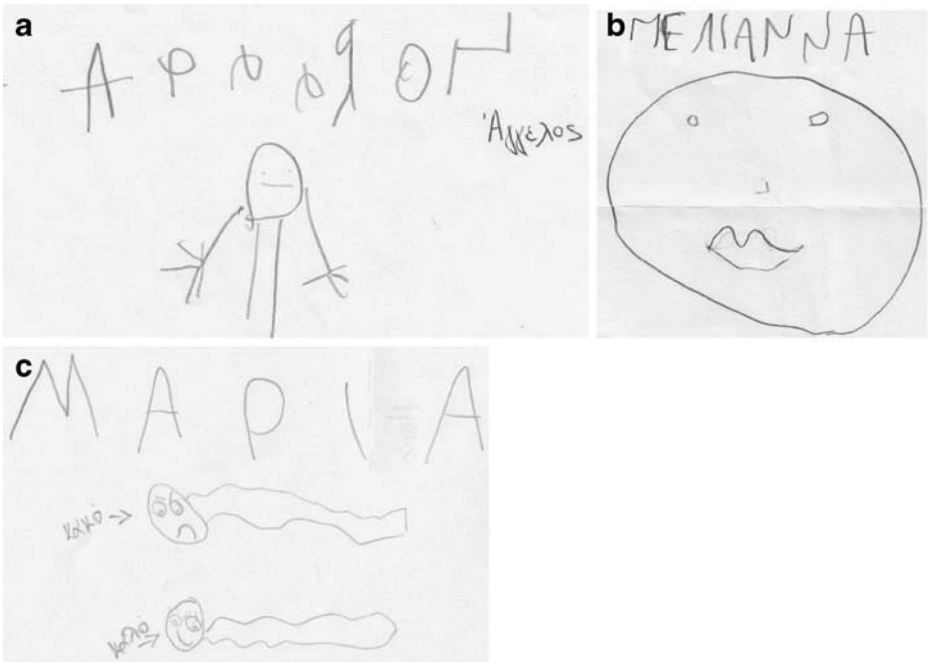

Fig. 2 Examples of drawings with 'human-like' representations of germs

Fig. 3 Examples of drawings with 'animal-like' representations of germs

because they play inside our body after eating their lunch') (b) familiar animals ('germs move because they have wings'), and (c) non-living objects ('germs do not eat because they are like the ball'). These types of reasoning were activated by our preschoolers 37, 3 and 8 times correspondingly.

– 'Psychological' or 'biological' reasoning when the attribution or not of the biological functions to germs was carried out on the basis of germs' conceptualization (a) as psychological entities, namely as entities having intentions, goals or preferences ('germs breath because they want to live', 'they move in our body in order to catch the food that drops down to our belly', 'they make babies in order to become many), and

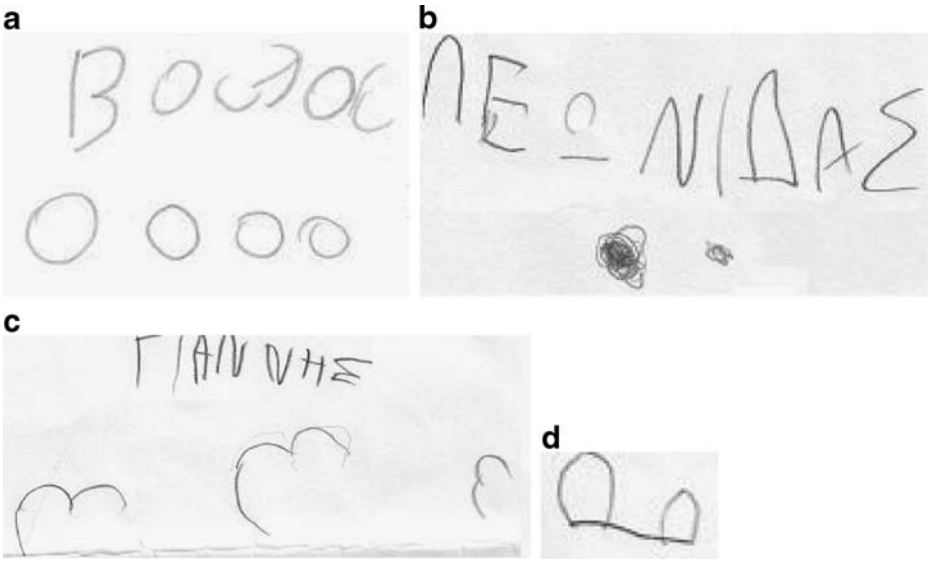

Fig. 4 Examples of drawings with 'abstract' representations of germs

Table 6 Germs in children's stories

'How are germs described in children's stories'	Number of children
As health-bound	26
As psychological entities	5
As animals	1
Fiction	1
With no sense	2

(b) as biological entities, namely as entities in the 'living' category ('they breath because they need air to stay alive', 'they make baby germs because they are living … like dogs', 'they don't breath because they are not animals'). 'Psychological' reasoning was activated by our preschoolers five times, while 'biological' reasoning was activated seven times, the four of which concerned the biological function of 'breathing'.

– 'Reasoning based on germs' showing dependence upon humans or animals when the biological functions of germs were closely related with humans or animals ('germs breath in our body because they take our air', 'germs move because they are upon a dog which moves all the time', 'germs die because we kill them'). This type of reasoning was activated 14 times.

Finally, it should be noted that the lack of reasoning in regard to the attribution or not of the biological functions in question to germs was much more frequent even compared to the type of reasoning with the highest frequency; namely, the 'human-based reasoning' which was activated 37 times. Among the 101 times of 'no reasoning', 26 had to do with 'reproducing', 20 with 'breathing', 19 with 'eating', 19 with 'moving' and 17 with 'dying'.

The models we located regarding the reasoning that underlied the attribution or not of biological functions to germs are summarized in Table 9 along with their frequencies. Children's models were rather poor in: (a) their content (the number of the 'full' models was no more than 11), (b) their consistency (the number of the 'consistent' models was no more than 8), and (c) their biological orientation (the best model was the 'partial_consistent_bio' which was reported just once).

More specifically, among the nine children with 'partial' models, only three showed consistency in their type of reasoning for attributing biological functions to germs, while just one of these three activated consistently the biological reasoning in particular. Moreover, among the 11 children with 'full' models (namely, among those who responded for each of the five biological functions in question), five did show consistency in their type of reasoning. Nevertheless, this consistency had never to do with the 'biological' reasoning: apparently, no child gave a 'full_consistent_bio' model.

Table 7 Attribution of bio functions to germs

'Do they attribute the biological functions in question to germs'	Number of children
All (4–5)	7
Several (3–4)	8
A few (1–2)	10
None (0)	10

Table 8 Types of reasoning about germs & bio functions

'Reasoning about bio functions: types of reasoning'	Times of appearance
Human-based	37
Animal-based	3
Object-based	8
Psychological	5
Biological	7
Reasoning based on germs' dependence upon humans or animals	14
No reasoning	101

In relation to the findings that concern children's conceptualization of germs' ontological status, we note the following. Twenty-four out of the 35 informants of the study classified germs as 'living', while 9 classified them as 'non-living' and two did not make any classification at all (Table 10).

Nevertheless, most of the children were not actually able to come up with justifications for classifying germs either as 'living' or as 'non-living': 14 out of the 24 children that classified germs as 'living, as well as three out the nine children who classified them as 'non-living', did not give any reason at all. On the other hand, the ten children that warranted their classification of germs as 'living', did it by appealing: (a) to germs' 'activity' (7) and specifically to 'movement' (5/7), to 'making us ill' (1/7), to 'making us dirty' (1/7), and (b) to germs' 'death' (3/10). Moreover, the 6 children that warranted their classification of germs as non-'living', they did it based: (a) on the notion of germs as 'things' causing illness (4/6), (b) on the lack of 'activity' by germs (1/6), and (c) on their microscopic size (too small to be living) (1/6).

Discussion

In this section, we summarize the conceptualization of germs that our informants appeared to have, in order to finally deal with our last question; that is, to explore the implications

Table 9 Models of reasoning about germs & bio functions

'Reasoning about bio functions: models'	Number of children
No model	8
One instance_Bio free	6
One instance_Bio trace	1
Partial_Inconsistent_Bio free	4
Partial_Inconsistent_Bio trace	2
Partial_Consistent_Non bio	2
Partial_Consistent_Bio	1
Full_Inconsistent_Bio free	4
Full_Inconsistent_Bio trace	2
Full_Consistent_Non bio	5

Table 10 The ontological status of germs

'Are germs living or non-living'	Number of children
Living	24
Non-living	9
Don't know	2

that this initial conceptualization might have for the development of a learning environment towards a better one.

The word 'germs' appeared to be closely related with health and hygiene issues. In accordance with this, children defined germs mainly as 'things that have to do with our health and our body', they created stories with germs being engaged in instances of bad hygiene and/or illness, and they spontaneously characterized germs as 'bad', showing that the idea of 'good germs' was not familiar to them. Thus, there seems to be a need for destabilizing this rather exclusive, superficial association of germs with illness and hygiene on behalf of the children, by focusing on germs as living entities and promoting the idea that such tiny creatures may be very useful to us in food production.

Germs were located in several places, the most usual of which were the 'external environment' and 'our body'. Some of our informants did combine places like the above with 'house', 'food' or 'animals', but since they did not really seem to think of germs as being everywhere, it would be purposeful to help them with this idea as well.

Although considering germs as invisible to the bare eye, almost half of the children did not come up with 'abstract' representations of germs in their drawings, but with 'human-like' or 'animal-like' ones. Attributing 'human-like' shape to entities they had never seen, may be considered as one possible way of expressing their anthropomorphic conceptualization of germs, which has actually been reported as persistent in time (Byrne et al. 2008). Thus, facilitating young children to start building a meaningful understanding of germs as biological entities seem to involve dealing fruitfully with the anthropomorphism upon which they preferably draw (Kattmann 2008). This attempt could possibly include providing children with realistic representations of germs with the aid of the microscope.

Taking into account the above and their implications with regard to young children's needs and abilities in the specific context, we shaped the first part of our learning environment with three educational activities. The aim is to provide children with the opportunity to: (1) get familiar with the idea of extremely tiny creatures possibly found everywhere ('introductory activity'), (2) have visual contact under the microscope with some of these on the basis of the assumption that they have been isolated by scientists from different places such as soil, water, air and human body ('microscope activity'), and (3) consider the possibility of germs' usefulness for humans ('puppet-show activity').

In the 'introductory activity' children are required to think of gradually smaller animals until reaching the idea of really tiny creatures, non visible to the bare eye but found in several places such as soil, water, air or even our body. According to the educational scenario, searching in such places, scientists are able to find the different tiny creatures and observe them under their microscopes. So, the 'microscope activity' that follows, engages children in a researcher-aided, microscopic observation of five slides (daphnia, euglena, paramecium, yeast and bacteria of different shapes) which–according to the scenario and not necessarily the truth–are supposed to be germs found in soil, water, air and human body.

The introduction of the idea of germs' multiple locations as well as children's visual contact with them are followed by the production of a shared drawing where children

jointly represent all the different places they can imagine as 'germs' homes' in order to reach the 'everywhere' conclusion. Finally, in the 'puppet-show activity' children get emotionally involved in the learning context by watching a puppet-show where a 'good germ' blames a 'bad' one for the unfair negative reputation of all germs because of the 'bad' ones and explains that 'good germs' actually help people to make their bread, milk or wine.

Going back to our findings and their implications, it is worth noticing that our informants seemed to encounter difficulties in the attribution of biological functions to germs: more than half of them attributed to germs less than two biological functions. Furthermore, many of those who did attribute to germs most of the biological functions in question or even all five, could not actually warrant their claims. Thus, it seems purposeful to familiarize children with the idea that germs do actually perform biological functions.

Moreover, most of the few 'full' models–in particular, 6 out of the only 11 models that dealt with almost all the biological functions in question–apart from being 'inconsistent', did not show any instances of 'biological' reasoning at all. This indicates the need of supporting children towards reasoning about germs' biological functions through a reasoning device other than the 'human-based' (i.e. 'germs do not breath because they don't have a nose like we do') or the 'psychological' one (i.e. 'germs breath because they want to live'), which seem to be rather frequent in the context of children's anthropomorphic conceptualization of germs.

Taking into account the above, we shaped the second part of our learning environment with two educational activities that give children the opportunity to: (1) predict the performance of biological functions by germs ('category-based reasoning' activity), and (2) experience and discuss it ('yeast activity').

More specifically, children are required to think of familiar living creatures–preferably animals–and state how we know that these creatures are 'living'. After reaching the idea that all creatures in question perform certain biological functions (breathing, eating, moving, reproducing, dying), children are engaged in 'category-based reasoning' about germs, since Gelman et al. (1986) argue that preschoolers–despite their young age–are capable of this type of reasoning. Children are asked to consider as true that 'germs are living entities' and then predict whether germs perform certain biological functions or not.

Finally, in the 'yeast activity' children (a) first get familiar with necessary ideas about requirements and consequences of germs' biological functions which underlie the activity (i.e. 'germs need food in order to survive and reproduce', 'reproduction results in more germs, more germs result in more breathing, and more breathing results in more air bubbles'), (b) watch and discuss several demonstrations of rising/'falling' dough with more or less sugar, in order to experience germs' 'breathing' and presume germs' 'eating' & 'reproducing' as well as germs' 'dying' when soap is added, by making meaning of the demonstrated facts in the light of the (already explored) underlying ideas, and (c) observe and discuss a microscope slide prepared from the rising dough to have a microscope-mediated experience of germs' 'moving'.

Going back to our last findings and their implications, we note that germs were mainly recognized by our informants as members of the ontological category of 'living', but this was carried out on the basis of criteria such as germs' 'activity', which could be characterized as animistic.

Exploring whether the attribution of several biological functions to germs was performed consistently or not with their classification as 'living', we located nine informants who did recognize germs as living entities despite attributing to them only 'a few' of the biological functions in question (1–2) or even 'none' of them. Moreover, we located two informants

that considered germs as non living entities despite attributing to them 'a few' or even 'several' (3–4) of the biological functions in question.

This finding, taken into account in the light of the rather promising fact that several informants showed consistency between the ontological categorization of germs as 'living' or 'non-living' and the attribution or non attribution of biological functions to them (15 out of 24 children who classified germs as 'living', attributed to them 'all' or 'several' of the biological functions in questions, while 7 out of 9 who classified germs as 'non-living' attributed 'none'), makes the association of germs' biological functions to their ontological status not only a significant but also a rather realistic objective of a learning environment about germs.

Considering this, we organized the third part of the learning environment with one educational activity that provides children with the opportunity to practice how to make decisions about the ontological status of several entities. In this 'table activity' children are engaged in constructing a table where several animals (man, dog, bird, fish, insect), human-made objects (table, chair, book, bicycle), natural objects (stones, clouds, sun) and germs are plotted against the biological functions of breathing, eating, moving, reproducing and dying, and finally decide about the ontological status of each entity by examining if it shows all five functions or not.

The implementation of this evidence-based learning environment and the exploration of its learning impact on small groups of preschoolers (Ergazaki et al. 2008) made rather legitimate for us to claim that the development of quite satisfactory reasoning strands about invisible entities like germs appears to be within young children's potential.

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