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THE EXPANSION THERMOMETER IN PRESCHOOLERS' THINKING

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Abstract. *Children form representations of concepts, physical phenomena and technical objects which are critical to teaching and learning. In addition, they are familiar with the everyday usefulness of many particular objects, although it is not certain that they associate them with the scientific aspects of their function. In this research, preschoolers' representations of the expansion thermometer were explored, as well as their ability to distinguish it as a specialized technical tool. The sample consisted of 111 children (53 boys and 58 girls) aged 5-6 years from 9 public kindergartens in Patras, Greece and data were collected through semi-structured individual interviews. The results demonstrated that although some children replied in a satisfactory way to all interview questions, the majority of the children were not able to distinguish the thermometer as a particular object and struggled with its function, so the suggestion for it to be used in curricula and/or educational activity books should be made cautiously.*

Key words: *preschoolers' representations, expansion thermometer, preschool education, science and technology education.*

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Introduction

Over the last twenty years considerable efforts have been made regarding the approach to the natural world by children aged five to seven years old. As a result of this researching activity a field denoted as Early Childhood Science Education has been formulated. In parallel, a research tradition which combines Science Education, the branch of Psychology that deals with learning and the Early Childhood Education has risen (Ravanis, 2005; Fleer & Pramling, 2015; Christidou, Dimitriou, Barkas, Papadopoulou & Grammenos, 2015). In this framework, preschoolers' mental representations about the phenomena and the concepts of Natural Science are usually issues under study. In some cases, the focus is also on teaching interventions aiming at the construction of cognitive schemes compatible with scientific knowledge in children's thought. As well as with older children, for preschoolers also a number of measuring processes are often necessary for approaching natural phenomena and concepts. For example, in the study of astronomical phenomena the celestial bodies' sizes are needed (Kampeza, 2006; Küçüközer & Bostan, 2010; Saçkes, 2015). In addition, approaching optical phenomena a need for the comparison of shadows' length is also noted (Ravanis, 1998; Resta-Schweitzer & Weil-Barais, 2007; Gallegos-Cázares, Flores-Camacho & Calderón-Canales, 2009; Herakleioti & Pantidos, 2016). Working with issues related to the properties of matter quantitative calculations need to be made (Hadzigeorgiou, 2002; Vellopoulou & Ravanis, 2010). Respectively, studying biological or meteorological phenomena there is a need for quantitative estimated values for plant's development or the distance between clouds and Earth (Zogza & Ergazaki, 2014; Fragkiadaki & Ravanis, 2015). However, both the measuring processes and the particular objects for measurement cannot be used without a prior research because of the preschoolers' cognitive limitations.

Within this framework, an interesting area of specialized study is that of thermal phenomena. Topics such as evaporation, melting, solidification (Bar, 1989; Tytler, 2000; Ravanis, 2014) or the thermal expansion and contraction of metals (Ravanis, Papandreou, Kampeza & Vellopoulou, 2013) are often the focus of research and development of teaching activities. In terms of pedagogical practices, activities from the field of thermal phenomena are interesting, given that they link children's thinking not only to related concepts, phenomena and materials, but also to a series of particular objects, such as electrical heating systems, refrigerants, camping gas, etc. While children are familiar overall with the everyday usefulness of these objects, it is not certain that they associate them with the thermal aspects of their function.

Beyond its self-evident cognitive, emotional and practical aspects, the appropriation of the nature, the role and function of technical tools has primarily cultural dimensions. Indeed, a smoothly running life and the ability to adapt to our social environment presuppose the appropriation of a wide range of technological applications and products. However, access to these is not automatic, since neither their significance nor their operational characteristics are self-evident (Papamichael, 1993; Impedovo, Andreucci, Delserieys-Pedregosa, Coiffard & Ginestié, 2015). It is therefore clear that technical tools as cultural products must also form part of educational processes. For example, the curriculum in force for preschool education in Greece states that opportunities should be given to children to "start recognizing the relationship between science and daily life, and to recognize the usefulness of simple machines and inventions in our lives" (Greek Ministry of National Education and Religious Affairs – Greek Pedagogical Institute, 2002, p. 602). Thus, certain technical tools support the work carried out at school and become the objects of systematic or symptomatic teaching. However, the approach to those tools which are also used in daily life is mediated by children's experience, i.e., the representations which they have already formed in their minds regarding the tools' role and function. The study of these representations is necessary in order to highlight the wealth of children's ideas, as well as to identify potential problems, difficulties and obstacles with regard to comprehension and, based on these, to develop appropriate educational processes. Children's ideas are especially rich and composite, as they are influenced by the multi-dimensional socio- cultural environment in which children live and develop. Therefore, exploring and studying their mental representations can shed light on the various aspects of experiences with respect to the use of tools and to bring to the fore issues which may be related to the cognitive requirements that characterize the function of these tools. In fact, the younger the children and the more limited their experiences, the greater the necessity to carefully adapt to their cognitive and educational needs.

The expansion thermometer is a technical tool whose use is often recommended in books and websites featuring Natural Sciences activities for kindergarteners and preschoolers (Brown, 1981; Hildebrand, 1981; Chauvel & Michel, 1990; The Math Learning Center, 2009; The Pathfinder Post, 2013). The appropriation of this tool is linked to a series of concepts and processes, such as the use of measurement scales, the concept of number, the concept of temperature, the thermal expansion of fluids, and thermal balance.

In the related international literature, the issue of understanding the thermometer appears very rarely and mainly with regard to secondary school students (Maskill & Pedrosa de Jesus, 1997; Akatugba & Wallace, 2009). In these studies, questions are posed about the kind of substances used in thermometers, the reasons for expansion and contraction, the factors which affect measurement and the upper and lower fixed points of a thermometer. In a research with children aged 8-11 (Appleton, 1985), the majority of the children recognize that the thermometer shows us how warm or cold something is. Moreover, when asked how it works, 1/3 of the children claimed that it is simply sensitive to heat, while the rest attributed the change in reading to heat in general or to mechanical factors such as pressure or some kind of propulsion. In another research with children aged 5-9, an effort was made to study the use of the thermometer in relation to the seasons (Havu-Nuutinen, 2007). The results showed that children aged 5-6 years are not able to comprehend its function and use, since they cannot intellectually handle the basic thermal concepts involved. In contrast, in another research with 3- to 5-year-olds, it is stated that "the preschoolers understood the measurement of temperature, use the weather-related terms properly and use a tool to measure temperature" (Inan, Trundle & Kantor, 2010, p. 1204). However, upon studying the data presented in the paper, it becomes clear that the children may be merely reproducing the words of their teachers and imitating their practices.

Therefore, it is noted that research in the field of preschool children' s understanding of the thermometer is limited and does not provide detailed data about the nature of the representations that children of this age have. Hence, there is not enough information to support early childhood educators' practice according to the

use of the thermometer and boost children's engagement with it. Moreover, the provided data from the present corpus of research related to the potentials of preschool children to reflect on and use the thermometer are rather contradictory. Consequently, in order to come to a conclusion according to the possibilities and the procedures through which thermometer can be used in educational programs for preschool children, further research is required.

In this research, an exploration of preschoolers' representations of the thermometer is presented. The research questions were the following:

1. Do children recognize the thermometer and do they distinguish it as a specialized technical tool?
2. How do they approach the use and the function of the thermometer?

Providing responses on the above questions the research aimed at illustrating preschoolers' ideas about the thermometer and featuring the potentials and the cognitive boundaries of using thermometer in every day science activity in kindergarten.

Methodology of Research

A qualitative research approach was adopted since the main objective of the research was rather exploratory, due to the lack of extensive data (Patton, 2002). A content analysis was undertaken with interview transcriptions. Categories derived from areas of interest devised in advance of the analysis and were modified by reference to the empirical data. As Cohen, Manion and Morrison suggest "content analysis involves coding, categorizing (creating meaningful categories into which the units of analysis – words, phrases, sentences etc. – can be placed), comparing (categories and making links between them), and concluding" (Cohen et al., p. 476).

Research Design

Semi-structured individual interviews were conducted from April to June 2015. After showing the children a common expansion thermometer for measuring body temperature, they were asked to identify it (1st question). A discussion with them followed about its use and necessity (2nd question), and about the markings used in order to see how it works (3rd question). Finally, the children were asked to compare the thermometer to other objects of everyday use, namely pens, pencils and straws because of their similarity to external characteristics, aiming to find out whether they attribute particular properties to it (4th question). Questions 1 and 4 provided data to study the first research question; questions 2 and 3 provided data to study the second research question.

Sample

The participants formed a convenience sample. Specifically, in the research participated 111 children (53 boys and 58 girls) aged 5-6 years (average age: 5 years and 8 months), from 9 classrooms of public kindergartens in an urban area of Patras. The children that took part in the research were willing to participate, had ensured their parent's agreement to it and had not previously experienced any organized contact with the thermometer at school. All socio-economic levels (low, middle, and high) and all levels of children's performance (low, middle, and high) were represented in the sample since the classes were typical of classes in the public state schools in the area of Patras.

Data Collection and Analysis

The gathering of data was carried out through semi-structured individual interviews (based on a stable question structure) lasting 9-12 minutes. During the interviews, protocols of nonverbal observations were followed. The interviews were audio recorded and transcribed and the data analysis was carried out by two independent researchers. The participants were labeled "research subjects" and were incidentally represented with a number from 1 to 111. The transcribed replies of the children to the interview's questions were coded in order to form relevant categories based on the research questions and allow analysis.

Research Results

The results obtained following the analysis of the interviews are presented below.

1. Identifying the thermometer

Preschoolers' answers regarding the identification of the thermometer were classified into three categories:

1. Answers in which the thermometer was identified immediately. For example, "This is a thermometer... We have one at home..." (S. 24).
2. Answers in which the thermometer is not identified in the first answer given, or it is identified as a different tool. For example, "...it's for injections" (S. 56), "a pen or a pencil... at home we use one for drawing" (S. 109). Following such an answer, an effort was made to lead the conversation to the experience of illness, with which the children are familiar from their daily life. Included in this category were answers in which the discussion led to the identification of the thermometer. For example, "(Researcher): A pencil... Do you remember when it is that we would choose this? S. 87: When we want to draw? R: When we want to draw or when we're ill? S. 87: ...When we have a fever? R: What do you think? S. 87: …When we're ill... It's a thermometer."
3. Answers in which, throughout the discussion, the thermometer is not identified as a distinct object. For example, "S. 12: It's a pencil that tells my mum if I'm ill... R: Do we use it to write with, or does it just tell us if you're ill? S: 12. I think you can use it to write something... Maybe to write down if someone's ill?"

Table 1 shows the frequency with which the children succeeded or failed in identifying the thermometer, as well as the relative percentage.

Table 1. Frequency and percentage of preschoolers' answers regarding the identification of the thermometer.

Categories	Research Subjects	f	Percentage %
Immediate identification of the thermometer	1, 2, 4, 6, 7, 9, 13, 17, 22, 24, 25, 32, 35, 39, 40, 42, 44, 47, 49, 50, 52, 53, 55, 57, 59, 61, 62, 64, 69, 72, 75, 76, 77, 80, 81, 82, 86, 88, 90, 92, 93, 94, 95, 97, 100, 102, 103, 108, 111	49	44
Identification of the thermometer following a discussion	3, 8, 10, 16, 19, 20, 21, 26, 28, 31, 33, 34, 37, 38, 43, 45, 51, 54, 56, 60, 63, 66, 67, 68, 74, 78, 85, 87, 98, 104, 105, 106, 107, 109, 110	35	32
No identification of the thermometer	5, 11, 12, 14, 15, 18, 23, 27, 29, 30, 36, 41, 46, 48, 58, 65, 70, 71, 73, 79, 83, 84, 89, 91, 96, 99, 101	27	24
Total		111	100

2. The use and necessity of the thermometer

Children were asked to explain when and why we use a thermometer, and their answers were classified into the following four categories:

1. Answers in which the use of the thermometer is associated with illness and detecting a fever, which is associated with a sensation of internal heat. For example, "We put it here [under the arm] to check for a fever... I'm ill and I'm burning up" (S. 64), "When the fever makes me hot, they use a thermometer on me... (R. Why?) …to find out how warm I am" (S. 4).
2. Answers in which the use of the thermometer is associated with illness and fever, without correlating the fever to a sensation of internal heat. For example, "When I have a tummy ache... I have a fever... I'm in a bad mood and I feel cold" (S. 78).
3. Answers in which the thermometer is associated only to illness, without any references to fever. For example, "when you're ill" (S. 19), "how many degrees of illness we have" (S. 101).
4. Answers in which the need for use of a thermometer is not recognized.

Table 2. Frequency and percentage of preschoolers' answers regarding the use and necessity of a thermometer.

Categories	Research Subjects	f	Percentage %
Illness and fever associated to a sense of internal heat	1, 4, 6, 7, 9, 13, 21, 24, 35, 39, 49, 53, 61, 62, 64, 72, 80, 86, 92, 93, 94, 95, 97, 103, 108	25	23
Illness and fever without other correlations	2, 11, 15, 17, 18, 20, 22, 25, 26, 28, 31, 33, 34, 37, 38, 40, 42, 44, 47, 52, 54, 56, 57, 59, 63, 68, 69, 71, 74, 77, 78, 87, 90, 100, 102, 105, 109, 111	38	34
Illness	3, 8, 10, 16, 19, 29, 32, 43, 45, 48, 50, 55, 60, 66, 67, 75, 76, 81, 82, 85, 88, 91, 98, 106, 104, 107	26	23
Not recognizing the need to use the thermometer	5, 12, 14, 23, 27, 30, 36, 41, 46, 51, 58, 65, 70, 73, 79, 83, 84, 89, 96, 99, 101, 110	22	20
Total		111	100

3. Recognizing the markings of the function of a thermometer

Based on the questions "how does a thermometer measure fever", for the children who associate fever with the thermometer, and "what do we look for... what do we see on the thermometer", for the children who do not make the association, discussions were carried out, and their analysis led to the following answer categories:

1. Answers in which it is recognized that all measurements are carried out based on the thermometer's markings, such as the lines, the numbers, but also the level of the liquid which moves. For example, "When we are ill, we put the thermometer here [under the arm] and when we take it out, a red line goes up and shows the fever" (S. 35), "The numbers... and the color that moves tells us how high it is... when I put my hand on my forehead and it burns" (S. 77).
2. Answers in which the lines and/or the numbers on the thermometer are simply mentioned without any reference as to the way in which we process these data (44 children). For example, "There's a kind of straw that sucks up the fever and we see it" (S. 55), "With the letters and numbers and a line... (R. What does the line do?) ... Nothing... it doesn't do anything" (S. 81).
3. Answers in which the markings on the thermometer are not addressed. For example, "This here... we shake it up and down... (R. And what happens then?) I don't know… it's just what we do…" (S. 26).

Table 3. Frequency and percentage of preschoolers' answers regarding the markings of the thermometer and the level of the liquid.

Categories	Research Subjects	f	Percentage %
Reference to thermometer readings and the level of the liquid	1, 4, 6, 24, 35, 49, 61, 72, 77, 80, 103, 108	12	11
Reference to thermometer readings	2, 5, 7, 9, 10, 11, 13, 16, 17, 18, 21, 22, 29, 32, 38, 40, 45, 48, 51, 52, 55, 56, 60, 62, 66, 68, 71, 73, 76, 78, 81, 85, 86, 87, 92, 96, 102, 104, 105, 106, 107, 109, 110, 111	44	40
No reference to thermometer readings and/or the level of the liquid	3, 8, 12, 14, 15, 19, 20, 23, 25, 26, 27, 28, 30, 31, 33, 34, 36, 37, 39, 41, 42, 43, 44, 46, 47, 50, 53, 54, 57, 58, 59, 63, 64, 65, 67, 69, 70, 74, 75, 79, 82, 83, 84, 88, 89, 90, 91, 93, 94, 95, 97, 98, 99, 100, 101	55	49
Total		111	100

4. The thermometer as a distinct technical tool

In an effort to understand whether the children distinguish the thermometer as a specialized tool, we asked them to explain whether a pen or some other object can be used as a thermometer. The children's answers were classified into the three following categories:

1. Answers in which the children recognize the qualitative differences between the two tools and distinguish the thermometer as a specialized tool. For example, "No, they are different, we use the pencil to write with... we use the thermometer to see if we're ill" (S. 72).
2. Answers in which the children do not distinguish between the functions of a pen and a thermometer. For example, "Yes, because they both have a tip... they're the same" (S. 54), "Yes, they're both long and thin" (S. 93).
3. Answers in which the children stated that they could not assess any possible differences or similarities. For example, "They look alike when we hold them in our hand and we look at them... but... I don't know" (S. 101).

Table 4. Frequency and percentage of preschoolers' answers with regard to distinguishing the thermometer from other objects.

Categories	Research Subjects	f	Percentage %
Distinguishing the thermometer from other objects	1, 4, 6, 8, 9, 13, 15, 17, 19, 20, 23, 24, 25, 28, 31, 32, 33, 34, 35, 37, 39, 40, 41, 42, 43, 44, 45, 46, 47, 49, 50, 52, 53, 54, 55, 57, 59, 61, 62, 63, 64, 66, 67, 69, 72, 75, 76, 77, 80, 81, 82, 84, 85, 86, 88, 90, 91, 92, 93, 94, 95, 97, 100, 103, 106, 108, 109, 111	68	61
Inability to distinguish between the function of the thermometer and that of other objects	2, 3, 5, 7, 10, 11, 16, 18, 21, 22, 29, 38, 48, 51, 56, 60, 68, 71, 74, 78, 87, 98, 102, 104, 105, 107, 110	27	24
Don't know	12, 14, 26, 27, 30, 36, 58, 65, 70, 73, 79, 83, 89, 96, 99, 101	16	15
Total		111	100

The above analysis proceeded to determine to what extent the children consisting the sample are able to recognise and distinguish the thermometer as a particular object and how they manage to describe its use and function. To summarize the findings, although the majority of the children seem to be able to recognize and distinguish the thermometer from other objects, it is noted that they encountered serious difficulties mainly related to several aspects of its use and function. A detailed and comprehensive discussion of the findings follows.

Discussion

According to previous research young and also older children seem to face difficulties with the concepts of heat and temperature as well as their measurement (Appleton, 1985; Maskill & Pedrosa de Jesus, 1997; Havu-Nuutinen 2007). In addition, few studies set the issue of understanding the thermometer in early childhood education. Havu-Nuutinen (2007, p. 96) argues that very young children describe their ideas using adjectives such as cold or hot and warm but "they did not have any clear or solid understanding of temperature and did not have the ability to read the thermometer". On the other hand, it is suggested that the preschoolers can understand the measurement of temperature and use a tool to measure it if classrooms provide children with a science-rich context (Inan, Trundle & Kantor, 2010).

In this research an effort was made to explore whether 5-6-year-old children can identify the expansion thermometer which measures body temperature and whether they distinguish it as a specialized technical tool (1st research question). With regard to identifying the thermometer, 76% of the children identified the thermometer immediately or following an effort on the part of the researchers to associate the thermometer with an instance of illness (See Table 1). Moreover, 61% of the children identified the thermometer as a particular object, which is distinct from other objects with similar external characteristics (See Table 4). A combined approach to the discussions held with the children regarding questions 1 and 4 shows that 4/10 of the children immediately recognize the thermometer and clearly distinguish it from tools made for other purposes, such as pens, pencils or straws (See Tables 1 and 4, subjects 1, 4, 6, 8, 9, 13, 17, 19, 20, 24, 25, 28, 31-35, 37, 39, 40, 42-45, 47, 49, 50, 52-55, 57, 59, 61-64, 66, 67, 69, 72, 75-77, 80-82, 85, 86, 88, 90, 92-95, 97, 100, 103, 106, 108, 109 and 111). This finding is interesting in and of itself, as it underlines the fact that 6/10 children are not able to distinguish the thermometer.

With regard to the use and function of the thermometer, which is the 2nd research question, it seems that even though during the discussions the children associate it with fever and, even more so, with a general and undistinguished state of being ill, only 23% of the children referred to some type of sensation of heat (See Table 2). Indeed, referring to a "fever" does not automatically signify an association with qualitative changes along a scale of warm-cold, but with the recognition, overall, of a deviation from a normal state of health. Even fewer (11%) were the children who were able to adequately identify the markings which will allow the reading of the thermometer, i.e., symbols such as the numbers and graduations on its surface, while at the same time referring to the level of the liquid (See Table 3). Even though 4/10 of the rest of the children recognized that in order to read a thermometer we have to look at the symbols that appear on its surface, they were still very far from being able to tackle its function. A combination between the answers to the 2nd and 3rd questions, shows that that only 1/10 of the children were able to discuss the movement of the column of liquid in the thermometer and fever as a sensation of increased internal heat (See Tables 2 and 3, subjects 1, 4, 6, 24, 35, 49, 53, 61, 72, 80, 103, and 108). From the analysis of this data, it is clear that the use of the thermometer presents serious problems when it comes to preschoolers, as shown by Havu-Nuutinen (2007). It also reinforces the results of Maskill & Pedrosa de Jesus (1997) where children's questions requested for additional information about the process of temperature measurement and revealed children's ignorance of "the expansion or contraction of mercury with variation in temperature" (p. 790) and the relationship between the heating time and the numerical increase in temperature.

Nevertheless, it is worth mentioning that, 11 children replied in a systematically satisfactory way to all four questions. This remark underlines the fact that the expansion thermometer can form the object of a qualitative approach in kindergarten. In this respect, it might be of interest to explore the effectiveness of educational activities facilitating children to approach the use and function of the thermometer and engaging them in meaningful problem-solving situations.

Conclusions

Regarding the first research question, it seems that the majority of the preschoolers taking part in this research do recognize the thermometer (See Table 1) and they distinguish it as a specialized technical tool (See Table 2) different from other similar objects with similar characteristics (See Table 4). Nevertheless 6/10 children (combination of data presented in Table 1 and 4) have difficulties in immediately recognizing the thermometer and clearly distinguishing it. This finding reinforces the results of Maskill & Pedrosa de Jesus (1997) where children's questions revealed an uncertainty about the process of temperature measurement with a liquid in glass thermometer (p 790) and suggests that the use of the thermometer in preschool education curricula and/or educational activity books should be examined very carefully.

As far as the second research question is concerned, it seems that the use and function of the thermometer presents serious problems for preschoolers, since only 1/10 children of the research sample (combination of data presented in Table 2 and 3) referred to the level of the liquid and to a sensation of heat. This finding is in accordance with the findings of the research of Havu-Nuutinen (2007) regarding preschoolers' difficulty in using the thermometer in relation to the seasons.

Nevertheless, despite all the difficulties, the results of this research suggest that some preschoolers have access to certain thermometer's characteristics, and thus using a thermometer in preschool education settings seems possible from a cognitive aspect. The questions remaining to be answered by further research on the subject concerns the possible didactical prerequisites, the circumstances that would facilitate preschoolers to use the thermometer, possible necessary modifications of the tool (e.g. quality temperature measurement scale), in other words the appropriate for this age group of children didactic transposition (Chevallard, 1989; Vellopoulou & Ravanis, 2010) of the specific tool.

In any case, this research underscores the seriousness with which we ought to deal with technical tools, considering them as complex cultural products, the appropriation of which should constitute the subject of educational research and educational process, and not merely an automatism stemming from daily life.

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