education sciences

Article

Young Children's Ideas about Heat Transfer Phenomena

Angelika Pahl [1], Hans U. Fuchs [2] and Federico Corni [3,*]

[1] Institute for Primary Education, University of Teacher Education Bern, 3012 Bern, Switzerland; angelika.pahl@phbern.ch
[2] Center for Narrative Science, 8400 Winterthur, Switzerland; hans.fuchs@narrativescience.org
[3] Faculty of Education, Free University of Bozen-Bolzano, 39042 Bressanone, Italy
* Correspondence: federico.corni@unibz.it

Abstract: In this article, we present kindergarten children's ideas about thermal phenomena before any educational intervention took place. In order to capture and account for the heterogeneity of the kindergarten group in this study, first teachers observed children's exploration behavior, task orientation, science interest, and language comprehension in everyday kindergarten life using a structured observation form. Then, 24 children aged between 3.8 and 6.0 years were interviewed individually about three situations focusing upon water temperature and its changes. The results show that interest in science and language comprehension are significantly related to children's understanding of thermal phenomena, while task orientation and exploratory behavior are not. In general, the kindergarten children did not yet use the word "heat" in their descriptions and explanations but were more or less able to describe the water temperature and its changes in a differentiated way.

Keywords: kindergarten; children; heat; temperature; ideas; experience

check for updates

Citation: Pahl, A.; Fuchs, H.U.; Corni, F. Young Children's Ideas about Heat Transfer Phenomena. *Educ. Sci.* **2022**, *12*, 263. https://doi.org/10.3390/educsci12040263

Academic Editors: Konstantinos Ravanis and Ismo T. Koponen

Received: 15 January 2022
Accepted: 4 April 2022
Published: 8 April 2022

1. Introduction

The present paper is part of an investigation of the interaction of physical and narrative experience in the construction of concepts by young children in their early encounters with thermal phenomena. Specifically, in this paper, we want to investigate pristine forms of verbal communication by kindergarten children before any deliberate concrete didactic activity has been undertaken and without bias toward particular scientific theories on the topic. We want to ascertain the children's cognitive level and linguistic abilities and, in particular, their spontaneous ability to communicate about simple thermal phenomena. This appears necessary in view of the alternative imaginative and narrative approach to natural phenomena pursued in our research project. Previous studies of children's (verbal) understanding of thermal phenomena can give some indication of what to look for. However, few of them cover very young children, and they are usually not sensitive to the variation of linguistic and general cognitive maturity. Moreover, observations appear to be influenced by expected "scientific" outcomes, i.e., by what temperature and heat ought to mean in a sanctioned approach to traditional thermal science in particular and to physical science in general.

1.1. Experiencing Thermal Phenomena

Children experience and observe natural and technical phenomena in various everyday situations, whether outdoors or indoors, and thus they are also familiar with thermal phenomena already at a young age [1]. Even though the abstract concept of "heat" (you do not see heat) may not yet be pronounced in very young children, they have already had many (indirect) experiences with it, coming from their sense of hot and cold. For example, in winter, large temperature differences can be perceived through the senses: While it is cold outside, it is warm in the heated apartment. It is even warmer in the summer when the sun is shining intensively, and long-sleeved clothing is replaced by short clothing. However, children will also have noticed that in summer, there are places where it is hotter and places where it is cooler. Water temperature in general can also vary. Water can be ice-cold or boiling hot—and there are many gradations in between because water can be heated specifically, but it also cools down. This can be perceived by children, for example, when the parent heats cold water on the stove for making tea and when it is necessary to wait until the hot tea water has cooled down enough to drink it [2]. The hotness sensors in our skin allow us to sense temperature and temperature differences, and in this subjective way, we can also qualitatively determine temperature changes [3].

Objectively speaking, the temperature is a physical quantity (quantified in Celsius or Kelvin scales) that expresses an intensity, i.e., how warm or cold an object is. The temperature can be high or low. As a physical quantity, heat is manifested and experienced indirectly via temperature. Therefore, it is important to understand how the notion of heat as something contained in objects and flowing from object to object can possibly arise—in what sense it can possibly be experienced. The need of the notion of heat arises when processes are observed that unfold over time. An object in contact with another object can become colder or hotter, meaning that heat can be transferred between objects, and doing so, causes temperature changes. The higher the temperature change is, the more heat is supplied or given off. This means that heat can be big or small. In nature, it always flows from an object of higher temperature to an object of lower temperature. Technical devices—such as the electric stove—or natural objects—such as the sun—that emit heat to their environment are called heat sources. In the case of heating water on an electric stove, for example, a certain quantity of heat is supplied to the system (pot with water) over time from the outside (electric stove). At the same time, the pot with water is also in contact with the (colder) ambient: At the beginning, the heat the pot loses to the environment is less than what it receives from the stove, so the temperature goes up. When the two heat exchanges become equal, a dynamic equilibrium is established, and the temperature of the system remains stable. If the water pot is then removed from the stove, the temperature goes down and, after a certain time, reaches the ambient temperature. Without the notion of the concept of heat, it would be impossible to interpret these processes. The process of heating is associated with heat absorption, the process of cooling with heat emission. Thus, heating and cooling are both heat transfer processes.

A more scientific (formal) treatment of heat and temperature is outside the scope of this paper. For an introduction to the foundations of a novel form of physical and narrative experience of nature by children at kindergarten level, the reader can refer to the approach to physical sciences underlying the imaginative course for kindergarten and primary school student teachers described in [4–7].

In primary physics education in kindergarten, the educational focus in the realm of heat is confined to the perception and description of heat transfer processes causing temperature differences, i.e., water and other bodies get warm or cool down. Science education standards in various countries suggest that teaching should address areas of the child's life world where change and dynamics can be observed [8]. For this reason, didactic research needs to focus on questions such as how exactly children experience changes in nature and technical artifacts and how they and their caregivers talk and generally communicate about processes (using natural language or other media at the disposal of young learners). According to learning and instructional psychology, as well as didactic theories concerned with particular topics, the conceptions that children have built up through experience in the everyday world as well as through their engagement with the social world [9–11] should always be taken into account when designing lessons [12,13]. Already Ausubel (1968) stated: "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" [14] (p. IV). Thus, learning situations should be planned in such a way that they are adapted to the learning prerequisites of the students. By connecting to children's ideas and taking their ways of thinking into account, learning in the zone of proximal development can be made possible [10,12,13].

1.2. Prior Observations of Young Children's Ideas about Heat and Temperature

Here, we present an overview of what has been observed and reported in the science education literature with regards to how kindergarten children (and their parents) speak about heat and temperature and related phenomena.

Children's conceptions of heat and temperature have been studied in [15–20]. However, studies of ideas on heat and temperature usually refer to older target groups than those targeted in this article. Only few kindergarten children were investigated on that topic, and some of these few studies are older [21]. Furthermore, it is questionable to what extent such topics are taught in early science education. Even if kindergarten and primary school teachers mention topics on heat and temperature as possible topics of physical science in kindergarten and primary school, they have little affinity for such physical-technical teaching content and are often not confident in teaching it [22–25]. None of the former research reports on ideas about heat and temperature held by kindergarten children are the result of instruction or targeted intervention in kindergarten. In the following, reference will be made to these.

We will first refer extensively to the paper by Albert [26], even though it refers to somewhat older children because it is most useful for our purpose, and it can help in sketching the development of concepts in the course of children growing up. Albert was the first to describe "the development of the concepts of heat in children" (p. 389), but his results are not based on a longitudinal study, and in his survey, children were not confronted with concrete material nor with narratives. In an interview study with 40 children aged four to nine, they were asked for "examples of heat" or "examples of warm" (p. 390). He noted that kindergarten children aged four to six refer in their answers to "hot objects" in one of the following forms: 'X is hot' or 'X makes me (feel) hot' (p. 391)—where X stands for an object that the children named. Especially children between the ages of four and five gave examples like 'The sun is hot', '[The] fire is hot.' (p. 391). Thus, they had an idea of hot objects, but they could not yet distinguish between the object and the property of hotness which means that for young children hot objects are a unit, an "irreducible whole" (p. 391). Even between the ages 5 and 6.6, children "did not talk about heat in objects" (p. 391), but they now direct the word warm or hot not only to the heat source but use it also to express that a heat source makes the child feel hot or warm. More advanced answers, which also occur from the age of five or six years, do not only refer to one's own feeling of warmth, but make it clear that heat sources can also make other objects warm and heat is, therefore, "a very active agent" (p. 392). An example of such a statement would be "The sun makes the air and many other things hot" (p. 391). This "externalization" (p. 392) from the child makes evident that there is an awareness of a movement from the sun to the object and this recognition creates already good preconditions for a mental "distinction between an object and a property" (p. 392) in the context of heat. The idea that hotness is a variable condition in that objects can be or not is found first in statements referring to heat sources that can be turned on or switched off. A child aged 6.6. described, for example, the oven as a heat source and pointed the following out: 'When you turn it on, it is hot, and when you turn it off, it is cold' (p. 392). However, children under seven years still have the idea that heat is something that arises or disappears immediately. The idea of "hot as a process" (p. 393) that takes place over a period of time was not expressed until children were seven to eight years old. Only then they expressed statements like 'it gets hot' or 'it warms up' (p. 394). The process of heating is described either from the point of view of the heat source or the object to be heated. The former would be the case with statements like 'The sun shines and warms [the air] up', the latter with statements like 'The water gets hot' (p. 394). Furthermore, at this age, the word 'heat' sometimes appears, which suggests that children begin to differentiate "between the object of hotness and heat in the object" (p. 394), which can also be emitted. They develop the idea that "heat is something active in the object being warmed" (p. 394).

In a study by Hadzigeorgiou [21], the idea of heat as an invisible substance was detected in children aged six or seven, but only occasionally and certainly not in most children of this age group. A child explained, for example, that "there is something that moves from the hot body into my hand when I touch it" (p. 72). It is also worth mentioning that children assume that 'heat' and 'cold' are two separate invisible substances. For example, children stated that 'heat is radiated from a stove' as well as 'cold is radiated by a piece of ice' (p. 72). In a study by Piaget and Garcia [27], heat transfer phenomena were treated with the help of concrete examples. Children of different ages were shown an experiment in which a steel ball was heated and then thrown into cold water. It was found that the idea of heat as transmission from a warmer to a colder object developed rather late, i.e., only at the age of 12. Children under seven years capture the warming of an object independently of the cooling of the hotter object and thus do not have an idea of thermodynamic equilibrium.

From databases, Luce and Callenan [2] analyzed several naturalistic parent-child conversations in which heat and temperature were the subject matter. The authors investigated how and in which contexts heat- and temperature-related concepts were talked about. In these conversations, all children were aged under six years and no gender differences were evident. The results show that everyday contexts in which words related to heat and temperature occur were mainly conversations during food preparation or during the meal itself (e.g., when waiting for food to get warm or cold), during conversations about the weather (e.g., when comparing the temperature inside and outside) and one's own body temperature (e.g., when a person feels cold or gets warm) (p. 12). In most cases of the 1460 statements recorded in these contexts, heat and temperature related words were used as an adjective to express a "property", for example: 'That is a hot tea', 'The sun is hot', 'My hands are cold' (p. 6). Some statements were related to temperature change processes as well and were classified as "vague process", meaning that such expressions refer to heating and cooling in an overall sense without mentioning the word "heat". For example: 'We have to wait for it to heat up', 'It is getting warmer', 'you do not want to get cold' (p. 6). Only sporadically heat was mentioned explicitly. Luce and Callenan concluded from this study that "the word heat occurred rarely in these conversations, which suggests that children may actually be getting very few opportunities to hear about how adults conceptualize the concept of heat in everyday talk" (p. 8). However, we must draw a distinction between conversations of parents with very young children and somewhat older ones. With children aged between 2.0 and 3.5, parents used heat- and temperature-related words almost always "as properties of objects" (p. 8), while with children aged between 3.5 and 6.0, they talked "about properties and vague processes with similar frequency" (p. 9). All in all, it can be stated that the words hot and cold were the most frequently mentioned words in natural conversations, and many of these talks referred to "objects that can and do change temperature" (p. 13), but without thematizing why objects get hotter or colder.

Regarding the naming of the temperature of objects, there is evidence that already at an early age, i.e., from two years onwards, children can distinguish clearly between the extremes cold and warm (respectively hot) whose conceptualization is based on sensorial experience in which they have felt warm or cold [28]. However, children aged between four and seven use both terms, hot and warm, often synonymous, and thus do not yet differentiate between different temperature levels [26,29]. In a study by Qonita and colleagues [29], for example, children aged four to six were presented with three water glasses with different temperatures (cold, warm, hot). Even though the three glasses were named correctly and thus the different temperature levels were well distinguished, not all children succeeded in later describing the mixture temperature between the cold and hot water as warm, but often used the term hot. Likewise, they did not differentiate between the terms cold and tepid. Thus, when comparing two temperatures, they use the term 'cold and warm' rather than 'cold and tepid' or 'tepid and warm' even if the temperature difference between the two objects was not that great.

For children, estimating temperature is challenging, and its success depends on the kind of comparative task. For example, indirect proportional tasks are very demanding. In a study [30], children were asked to predict the temperature of two different amounts of water (a half-full and full water glass) when they were heated for the same time with the same number of candles (one candle per glass). The results show that only children starting at the age of nine years were able to make correct judgments about the temperature of these two amounts of water, saying that the temperature in the half-full water glass would be higher. Younger children, aged between four and eight years, gave mostly incorrect answers, namely that the water temperature would be the same. However, already kindergarten children (from about five years) were able to understand the rule "more A, more B", for example, the more candles warm the water, the higher the water temperature.

It is worth mentioning that there are a number of papers in the literature on heat-related phenomena, like thermal expansion [31], thermal conduction, and conducting/insulating materials [32,33], melting, evaporation, phase states of water [34], as well as investigations of children's familiarity with thermometers, thermal scale, and temperature representation [20,35,36]. All these papers are biased by the investigation of the ability of children to describe, predict, and interpret heat-related phenomena, and the issue of children's conceptualization of heat and temperature changes is not dealt with.

1.3. Research Aims and Questions

In this paper, we want to bring out the conceptualizations of heat transfer phenomena of a kindergarten group and present the statements and interview performance of individual children as descriptively as possible. To this aim, we investigated how young children perceive and judge different phenomena in contexts of everyday life. To be more precise, we explored kindergarten children's verbal communication concerning the heating of water by sunlight, the heating of water on a stove, and the cooling of water in a hot-water bottle. The ideas that were collected are to be understood as an expression of spontaneously developed understanding that may or may not have been enriched by extracurricular activity rather than learned as a part of prior lessons. Our report is an inventory of children's understanding, upon which basic didactic interventions can be developed.

In contrast to previous studies, this study takes account of the heterogeneity of kindergarten children. Our investigation is done with kindergarten children—from a rather heterogeneous cohort, both with regard to developmental age (between three and six, almost every month counts) and linguistic background. Thus, in this study, not only age is considered (as has been done in previous studies), but also other relevant areas of children's development as well as their (different) linguistic abilities. This seems reasonable and necessary because it is known that children also differ in their characteristics of different developmental areas, which could possibly also influence the grasp of the child's conceptions as well as the child's conceptual development. First of all, it must be stated that linguistic ability is a central factor because it is not possible to directly collect children's ideas, but only children's statements, i.e., representations of mental ideas [13]. Therefore, knowledge can never be clearly separated from the ability to describe phenomena in language [1]. Since thinking and language are inseparable, language also plays a central role in the development of higher forms of thinking [37]. In addition to language, it seems important to survey children's task orientation, because this ability shows how goal-oriented children are in mastering tasks, whether they are easily distracted or remain focused and persistent on a task [38]. A low task orientation could distort the results of the preconcept survey. Children also differ significantly in their exploratory behavior, i.e., in the way they deal with new and unknown things and situations, whether they explore the environment independently, how optimistically they approach new tasks, or whether they are rather hesitant [39,40]. It is obvious, for example, that shy and inactive children will have different experiences than active children who are open to new situations [41].

Exploration creates knowledge structures, i.e., the child learns by exploring the world [42]. Through interaction with the environment, a more domain-specific inquisitiveness and interest will develop over time. For example, scientific interest manifests itself in an active exploration and questioning of natural phenomena [39,40]. This domain-specific interest leads the children to acquire knowledge increasingly in this domain [43,44], and it could be assumed that children with a high interest in science also have more experience and knowledge in this area and that they will show a higher willingness to try to deal with science questions and activities [45].

In conclusion, in our study, we focused on the following research questions:

- how do kindergarten children grasp heat transfer phenomena?
- to what extent do they correctly estimate, predict, or even explain temperature differences or changes in various situations?
- what is, apart from age, the role of children's developmental areas like exploratory behavior, science interest, task orientation, and language comprehension?

2. Materials and Methods

2.1. Research Design

According to the research aims, an exploratory approach was followed in this study. Since young children's ideas should be explored in detail to obtain a deeper understanding of their thinking, only a small sample of kindergarten children could be investigated (we are aware that limitations of the generalizability of the results had to be accepted). This study involved a naturalistic environment and was conducted with a standardized observation instrument and a semi-structured interview technique. The use of both quantitative and qualitative methods makes it a mixed-methods study, but it must always be considered first and foremost as a case study [46,47]. The sampling and data collection procedure are explained below.

2.2. Procedure

The sample was recruited from a kindergarten in the province of Bolzano (Italy) where children from three to six years learn, play, and interact together and, due to territorial characteristics, have heterogenous mother tongs. With the school principals' permission and thanks to the teachers' cooperativeness, teachers at that school collaborated in this study by taking over the data collection. As children's caregivers, they could observe and interview them in a familiar environment. For the validity of the study results, it was beneficial that the kindergarten teachers collected the data. The assessment of children's behavior, interests, and abilities, for example, requires a long period of observation and knowledge of each child. The kindergarten teachers are those who see the children every day and know the whole kindergarten group and its individuals best. If the observation and rating had been carried out by an outsider, the risk to observe and not correctly distinguish non-typical from typical scenes would be greater and the validity of the observation doubtful, as the outsider would not have the same observational material available and thus the expertise for conducting the rating assessment would be limited [46–48]. Observation is one of the professional activities of kindergarten teachers, and several observational instruments are specifically designed for this professional group [48,49]. Also, the interview was conducted by the teachers and not by researchers. It is known that young children have difficulties in forming interpersonal relationships with strangers [50] and that shy or inhibited children have difficulties expressing themselves in interviews [51]. "Many researchers have commented on the difficulty of engaging young children in the interview process" [52] (p. 2) and emphasize that children must "feel comfortable" [53] (p. 354). Therefore, a person with whom a secure attachment relationship exists was used as the interviewer, namely the kindergarten teacher as a kind of secondary caregiver. In this way, the results of interviews should be collected in a manner and an environment that does not suppress children's thoughts by an alienating situation. Generally, the method of interview has the advantage that an exchange between interviewer and child is possible, and thus, the validity of the statements is increased by the possibility of asking how something is meant [54]. However, in the literature [52], interviews with very young children are considered "a significant challenge" (p. 1), and it is emphasized that the "child-adult interaction is central to these challenges" (p. 7). To standardize the observations and interviews as much as possible, the teachers were given the questions and illustrative material for the interview with the children and were briefed in detail on how to use the observational instrument and data collection techniques. Before starting the investigation, parents were informed about the planned study by an informed consent document and were asked to submit their signed consent to the teacher. Only those children who had parental consent were included in the study.

The teacher collected all the data and assigned each participating child a case number. Participants were first observed by predefined aspects of their behavior, abilities, and interests (see Section 2.4) during daily kindergarten life with free and structured activities in and outside the classroom. After several weeks and before conducting the interviews, two teachers of the kindergarten group independently completed a structured observation sheet for each child. Then, a consensus rating of both teachers was used for analyses to improve the quality of the assessments. The interviews (see Section 2.5) took place during the morning time in a separate room at kindergarten. Thus, the interviews could be carried out undisturbed in a familiar environment. The room was prepared with the illustrative materials to be used during the interview. Additionally, a video camera and audio equipment were prepared to record the interviews. The teacher conducted the interviews with all children individually and created an atmosphere as natural and trusting as possible. The children were informed that the teacher wants to explore different situations and is interested in knowing what they think about them. During the interview, care was also taken to ensure that children themselves showed willingness to participate, otherwise, it was stopped, or some interview questions were skipped. In total, an interview took approximately eight minutes.

The sample composition as well as the technique, materials, and contents of the observation and the interview are now described in more detail.

2.3. Participants

All participants of this study were part of a heterogenous kindergarten cohort in an Italian kindergarten institution of the province of Bolzano. Children with sufficient language comprehension in Italian were included in the sample. Due to COVID-19 quarantine measures during the survey, not all children could participate. In total, 24 kindergarten children—17 girls (70.8%) and 7 boys (29.2%)—were interviewed. On average, they were 4.9 years old (*SD* = 0.89): Half of the children (50%) were aged between 3.8 and 4.7 years, and the other half (50%) between 5.2 and 6.0. Italian was the mother tongue of 12 children (50%) and the second language of the other 12 children (50%). In both age groups, composed of 12 children each and aged either over or under 5 years, there were 6 children (25%) with Italian as their mother tongue.

2.4. Observation

To provide structured information about the behavior, abilities, and interests of the children who were interviewed, the following scales of the standardized observation sheet KOMPIK [39] were used: Exploratory Behavior, Science Interest, Task Orientation, and Language Comprehension. The KOMPIK instrument can be used to systematically observe kindergarten children aged between 3.5 and 6.0. The assessment should be made after an observation period of several weeks on a 5-point Likert scale (1 = low level, 5 = high level). With the four selected KOMPIK scales, kindergarten teachers had to assess a total of 24 statements for each child. The first scale Exploratory Behavior captures how curious and inquisitive the child generally is and how open-minded a child is in exploring unknown things and situations. The second scale, Science Interest, focuses on the area of natural sciences and describes how active and interested a child is in exploring and investigating natural phenomena. The third scale, Task Orientation, indicates the extent of how well a child can complete tasks in a goal-oriented and concentrated manner. Finally, the scale Language Comprehension shows the level of the child's ability to implement calls to action and answer questions appropriately [39,40].

The KOMPIK observation instrument was designed especially for kindergarten teachers and can be used with children who are well known to pedagogical professionals. The assessment of a child's behavior, interests, and abilities does not occur in a direct observational situation but from memory based on several observations. These observations should be made as part of the regular kindergarten routine without creating special (test) situations [41].

KOMPIK is a scientifically validated observation tool developed in collaboration with scientific experts and educators from the field. The content validity is given by expert assessment and confirmed by external validation. Some KOMPIK scales show, for example, significant correlations (from 0.28 to 0.47) with Petermann's, Stein's, and Macha's [55] development test for children from 6 months to 6 years (ET 6-6) which indicate a convergent validity of the instrument. According to the authors of the observation sheet, the KOMPIK scales have high reliability in the sense of internal consistency. Furthermore, the retest reliability evidenced scores between 0.90 and 0.96 and the interrater reliability scores between 0.74 and 0.92 [56]. Nevertheless, the KOMPIK authors recommend that kindergarten teachers discuss their assessments of each child [40].

2.5. Interview

A semi-structured clinical interview was carried out to gain insights into young children's prior knowledge and ideas about the concepts of temperature and heat. This qualitative interview procedure is characterized by careful questioning aimed at gradually eliciting ideas [57,58]. The interviewer adopts an interested, questioning attitude and encourages the children to give an answer, but does not correct them [13]. An interview guideline, in which topics and questions are defined in advance, served to structure the interview and enabled later comparisons between different participants [59]. Nevertheless, this interview technique allows enough openness in questioning. Thus, the language and question design can be adapted to the level of the respondents, which is particularly important with younger children [60]. According to Bierman [61], children could have difficulties "in expressing ideas in an open-ended interview format", while "they may be able to communicate their thoughts through tasks that require less complex response options" (p. 232). Interviews with young children should, therefore, be well structured with small-step questions.

The study's interview addressed heat transfer phenomena and included three concrete situations for which several questions were asked. Each situation was introduced with stimulus material, which should not only motivate the children to express their ideas but also help them to comprehend the situation better [58]. The order in which the questions were set was clearly defined and could not be changed by the teachers. Likewise, the teachers were not allowed to resolve the individual questions in order not to influence the child's response behavior for the next questions. Now, the three situations are presented together with the corresponding questions.

The initial situation, "Water in the sun, water in the shade", drew on experience (e.g., children have experienced that it is colder in the shade than in the sun in summer) and had to capture whether the child could identify the sun as a heat source and estimate its influence on the water temperature. For this purpose, the teacher presented a picture showing one glass with water standing under a tree and another glass with water standing in the sun. The interviewer asked the child to estimate the temperature of the water in both glasses: "Is the water in one glass warmer than in the other? If so, which one and why?" After providing an estimation, the child could check it. Therefore, the teacher placed two water glasses on the table, one with lukewarm water (with a sun symbol to make it clear that this water was in the sun) and one with cold water (with a tree symbol to symbolize that it was in the shade). The children had to feel the water and describe its temperature in both glasses and, finally, try to explain why it differed, asking, for example, "Why is the water in the sun warmer than the water in the shade?"

In the second situation, called "water cooking", another familiar (but now controllable) heat source—the stove—was highlighted to investigate whether the children could already estimate the influence of different levels of heating power on the water temperature. In addition to directly proportional relationships (the higher the power of heating, the faster the water boils), an indirectly proportional task was set to find out whether they were aware that the temperature change also depended on the amount of water to be heated (the less water in the pot, the faster the water boils). At the beginning of this sequence, it was ensured that the child understood how a stove works. Therefore, a toy stove was presented, and the child was asked to demonstrate what to do when heating a pot of water. The child had to put it on the stove and turn the stove on. Once the cooker was "turned on", the child had to try to explain why it could make the water hot. Specifically, they were asked, "Why does the water heat up when it is on the stove?". Then, more specific questions were asked while demonstrating these situations repeatedly on the toy cooker. The child was asked, "What happens when the stove is turned on only halfway and not fully? Does the water boil faster if you turn the stove fully or halfway? Why?" The child was also asked what would happen when the stove was turned on fully, but the amount of water in the pot was different: "Where does the water warm up faster: In a pot with more or less water? Why?"

In the third situation, called "the hot-water bottle", the child was confronted with a warm hot-water bottle—a container of hot water that radiates heat and by so doing loses its ability to heat over time. First, the interviewer had to determine whether the child was familiar with a hot-water bottle and its functionality (i.e., heat transfer). The child could feel and hold the hot-water bottle and guess what might be in it—namely, hot water. Then, the child was asked whether the water bottle keeps you warm even with cold water in it. The child should also try to provide a reason for his or her answer. Finally, the child was asked what would happen if the hot-water bottle with hot water was left for a while: "Is the water in the hot-water bottle after a while still hot, or does it change? Why?" The aim was to find out whether children were aware that a warm hot-water bottle is only a temporary source of heat and that its temperature falls due to heat dissipation.

2.6. Data Analysis

All data were available in anonymized form and were entered into a sav-data-file created in SPSS 27. For the general description of the sample, data on age, gender, and mother tongue were analyzed.

Before considering the observational data for analyses, the reliability of the KOMPIK scales composed by the raw data of the two observers was checked: For each KOMPIK scale, the interrater reliability was evaluated considering the Interclass Correlations and interpreted according to Cicchetti [62]. The degree of agreement among the two observers who assessed children's behavior, interests, and abilities could be considered fair to excellent for the scales Science Interest (0.53), Task Orientation (0.82), and Language Comprehension (0.90) with the exception of the scale Exploration (0.32), which evidenced a poor Interclass Correlation. For further analysis in this study, a consensus rating of the two observers was used. Thus, from the combined assessment of the statements of the KOMPIK observations sheets, the four scales Exploratory Behavior, Science Interest, Task Orientation, and Language Comprehension, were formed for each child. The calculated mean scores of the scales determined children's level in the areas listed above, where a score of 1 was low and a score of 5 high. It was also important to consider children's age when interpreting their mean scores since younger children generally have developmentally related lower scores than older children. For this reason, the mean scores and standard derivations were not only made evident for the entire group but also separately for two age groups formed.

The video-recorded interviews were transcribed by the teachers, taking care that data was anonymized and that the transcribing teacher was not the interviewer one. In the transcripts, the teacher's and the child's statements were recorded verbatim. Non-verbal information in the video records was only noted if relevant to the content—for example, if an answer was provided by nodding or pointing to a picture or material. By reviewing the transcripts, it was also possible to determine that the teacher adhered to the interview rules. Due to the structured interview procedure involving three situations, all interviews could be divided into three sequences. For each sequence, the children's answers to the various questions were categorized and finally illustrated with examples from the interviews. In addition to qualitative data analysis, answers were categorized more generally to allow quantitative data analysis. Thus, qualitative data were quantified using the same category system for each interview content. The numerical category system formed determined the extent to which a content has been grasped by the children: 2 points were provided for a correct prediction with a plausible explanation, 1 point for a correct prediction without a plausible explanation, and 0 points if the prediction was wrong or if no idea was expressed at all. Individual questions that the interviewer did not ask a child were not scored. The frequencies and valid percentages were calculated for all categories (not solved, predicted, explained). To represent the whole interview performance of each child, an average score was calculated from the points achieved for their answers to all questions they were confronted with.

Due to the small sample size, only nonparametric tests were used in bivariate analysis. For correlation analysis, Spearman's rank correlation coefficients were calculated, which required only ordinal scaled data and provided information about the relationship of variables. The significance tests of Spearman's rank coefficients also had the advantage that they are more robust than significance tests of parametric correlation coefficients. Likewise, the partial correlation analyses were conducted with Spearman's correlation coefficients. The method of partial correlation was used to describe the relationship between the KOMPIK variables and the interview performance whilst controlling, i.e., taking away the effect of age.

3. Results

3.1. Participant's Behavior, Abilities, and Interests

The results of the KOMPIK observations sheets produced the following score range: Between 2.2 and 4.3 on the Exploratory Behavior scale, between 2.1 and 5.0 on the Task Orientation scale, between 2.8 and 5.0 on the Language Comprehension scale, and between 1.4 and 5.0 on the Science Interest scale. All means and standard deviations are shown in Table 1 for both the sample and the two age group subsamples.

Table 1. Means (standard deviations) of the sample's behavior, abilities, and interests (n = 24)—also differentiated by age group.

KOMPIK Scales	**Sample** *M* (*SD*)	**Aged < 5** [1] *M* (*SD*)	**Aged > 5** [1] *M* (*SD*)
Exploratory Behavior	3.60 (0.58)	3.44 (0.74)	3.77 (0.32)
Science Interest	3.86 (0.86)	3.34 (1.01)	4.27 (0.44)
Task Orientation	3.27 (0.69)	2.95 (0.51)	3.60 (0.72)
Language Comprehension	4.04 (0.67)	3.72 (0.73)	4.37 (0.43)

[1] Aged < 5 = Subsample with children aged under 5 years (n = 12); Aged > 5 = Subsample with children aged over 5 years (n = 12).

3.2. Interview Answers

In the following sections, participants' answers to the interview questions are described in detail, and the valid percentages of the response frequency are provided in each case. Accordingly, questions that were not individually posed to children were not considered.

3.2.1. Answers Referring to "Water in the Sun, Water in the Shade"

Seventeen children (70.8%; n = 24) could correctly predict that the water placed in the sun would be warmer than the water placed under a tree. The children mostly described the situations one by one, for example: "This is warm, this is cold". Four children (16.7%) first assumed that the water in the sun would be cold but changed their answers to "warm". Three children (12.5%) stood by their opinion that the cold water was in the sun without explaining this further.

When asked why the water in the sun is warmer, 17 children (70.8%) provided one of the following answers: "Because the sun is warm", "Because the sun warms it up", or "Because it is in the sun, it warms". Thus, the children referred in their answers to the sun as a warm source. Four children (16.7%) with correct predictions gave no explanation.

On the other hand, when asked why the water under the tree is cold, seven children (29.2%) justified this simply with the fact that the water glass is in a different place, for example, they replied, "Because there is the tree" or "Because it is under the tree" but could not explain their descriptive answer further. Two children (8.3%) gave only the one-word answer "cold", and one child (4.2%) could not provide a reason. Those answers were evaluated as correct predictions without explanations.

The following dialogue shows an advanced answer of a child who contrasts the different locations in his attempt to explain:

Interviewer: "Why is this water cold?"

Child: "Because it is in the shade".

Interviewer: "Why is the water in the shade cold and the water in the sun warm?"

Child: "Because it is cold in the shade, while in the sky, the sun is warm".

Moreover, other children mentioned that the water is cold, "Because the tree makes shade". The children often believed that the water under a tree's shade cools down or gets colder and not necessarily that the water does not get warmer while the sun is missing. This assumption is reflected in the two following statements: "In the shade, the water becomes colder", "It is becoming cold because it is in the shade". Some of the answers to the question of why the water under the tree was cold referred to a specific activity that allegedly took place there: "Because the ice is coming", "Because the cold is coming", "Because the tree makes it colder", "Because the leaves … they are making wind", or "Because there [in the tree] is wind". As "explained" were classified those answers of children who found a plausible explanation, even if it was not entirely accurate. The answers of 11 children (45.8%) were scored as "explained".

3.2.2. Answers Referring to "Water Cooking"

In the second sequence of the interview, a toy stove and a toy pot with water were presented. Almost all children, namely 22 (91.7%; n = 24), were aware that they had to turn on the stove to bring the water to a boil. The following dialogue shows the best answer to the question of why the water gets hot:

Interviewer: "What does it happen when the cooker is turned on?

Child: "The water boils. It gets even hotter".

Interviewer: "And why does it boil in your opinion?

Child: "It boils because the stove is hot".

Interviewer: "What makes the water boil?"

Child: "The one where you cook".

Interviewer: "Why does the water heat up if it is on the stove?

Child: "Because it is hot underneath. And above is the pot. The heat comes and makes it boil".

The word "heat" was used here for the first and last time. This child did not only identify the stove as the source of heat but referred also to the movement of heat from the stove to the pot of water. Apart from this one child, three other children (12.5%) explained the cooking of water referring in their answer to the stove, for example: "Because of the stove, the pot gets hot" or "The stove is getting hot" and "The stove—it heats up". One of them added the following comparison: "Then, the same thing happens as with the sun. It gets hot there too". Children's descriptive answers considering only the water temperature (e.g., "It gets warm") were not rated as explanations because the stove was not included in this consideration. Answers that described the effect of cooking, but not the heating process were also not evaluated as explanation, for example: "Then you can put something in it so that you can cook" or "To make pasta".

In the following, the children were asked to estimate what happens with a pot with water when the stove is turned on only halfway and not fully. Correct predictions were provided by 18 children (81.8%; n = 22) in the form of the following answers: It boils "later" or "it boils a little bit later", as well as "it boils a little" or "then it gets medium hot". While the first two of these answers refer to a longer period needed for warming up, the last two answers express different levels of temperature that would be reached. Asked for reasons, the four children (18.2%) who answered responded as follows: "Because you only have a small flame" or "Because you have to wait". Wrong predictions, such as "It takes less time" or "It boils first", were provided only by three children (13.6%) and were also not justified.

In the last phase of this sequence, where the boiling of water (with the same heating power, that is, with the stove fully turned on) was compared for different amounts of water, the children's opinion was divided: nine children (47.3%; n = 19) correctly assumed that water boils faster "where there is less water" but could often not justify this assumption ("I do not know"). Only six children (31.6%) could give a simple justification, for example: "Because there is less water in it". Wrong predictions, such as that the container "where there is more water" would boil faster, were mentioned by 10 children (52.6%) and thus almost equally often as the correct answer. The latter children could not provide any reasons ("I do not know").

3.2.3. Answers Referring to "The Hot-Water Bottle"

The interview answers indicate that 17 children (73.9%; n = 23) were not familiar with the hot-water bottle, whereas six children (26.1%) were able to describe its function, as the following example shows: "When you are cold, you put warm water in it, and you put it on yourself—it warms you". Frequently, the functionality of the hot water bottle was associated with stomach aches: "I use it when I have a stomachache—it warms my stomach". Based on previous knowledge or tactile sensation in the interview situation, almost all children (95.6%) could describe the hot-water bottle as warm and containing hot or warm water. Only one child (4.3%) said that the hot water bottle was "cold".

When asked whether the hot-water bottle would also warm when it contains cold water, 18 children (78.3%; n = 23) answered correctly that this was not the case. The provided reasons were relatively simple: "Because it is cold" or "Because it does not work with cold water". Sometimes, in their explanations, they made comparisons between cold and warm water: "If you put cold water in here, it is cold. If you put warm water in there, it is warm" or "It does not warm because the warm water is stronger than the cold water". Some children referred in their answer to a hypothetical effect that cold water would produce: "If you put cold water in here and you put it on, you will be ill even more", "The hand will cool down" or "The body will freeze". Eight children (34.8%) could not provide any reason for their correct prediction. Wrong prognoses, namely that the hot water bottle would also warm with cold water, were expressed only by five children (21.7%). Two of them later revised their answer to a "no".

In the last interview question, when asked whether the hot-water bottle filled with warm water would still be warm after a while or whether something would change, 14 children (63.6%; n = 22) correctly answered that the hot-water bottle would then be "cold" or would "become cold" or "a little bit cold". As the reason for cooling down, most children simply cited the waiting time: "Because if you wait, it becomes a little bit cold". In a few answers, it became clear that cooling takes time and involves several temperature gradations: "It is hot, and if we wait a bit, it starts to get cold". One child expressed explicit different gradations of temperature:

Child: "It is getting colder, colder and colder, freezing".
Interviewer: "Why?"
Child: "Because there is not new water flowing in here".
Interviewer: "No new warm water? And if you do not warm it?"
Child: "Then it gets cold".

In total, only four children (17.4%) came up with a plausible, more profound explanation. Many unspecific or wrong answers were provided as a reason for the cooling of water, such as, "Because there is water in it" or "Because there is shade". Eight children (34.8%) could not make even a correct prediction. Most of those children said, for example, that the hot-water bottle would still be "warm" or "still warm" even after a long time. When asked why, no reasons could be given. One child mistakenly assumed that the water would "boil" after waiting for a while and probably used statements from the previous situation involving the cooking of water. One child said that he or she did not know what would happen.

3.3. Solution Frequency

In the interview, children were generally more able to give a correct prediction about the water temperature or temperature change of water as to find an explanation for why this is so or why this is happening. However, the solution frequency varied depending on the content of the interview. Table 2 shows for each interview content the number of children who could not give an answer to a question (not solved), who were able to give a correct prediction, and who were also able to give an explanation. Since the interviewer did not set every question for each participant, the sample size (*n*) was smaller for some question contents.

Table 2. Solution frequency of all questions.

Questions Referring to ...	*n* [1]	Not Solved [1]	Predicted	Explained
Warm water in the sun	24	3 (12.5%)	21 (87.5%)	17 (70.8%)
Cold water under the tree	24	3 (12.5%)	21 (87.4%)	11 (45.8%)
Water heating on stove	24	2 (8.3%)	22 (91.6%)	4 (16.6%)
Halfway turned-on stove	22	4 (18.2%)	18 (81.8%)	4 (18.2%)
Less water heating on stove	19	10 (52.6%)	9 (47.4%)	6 (31.6%)
Water bottle with cold water	23	5 (21.7%)	18 (78.3%)	10 (43.5%)
Hot-water bottle after a while	22	8 (36.4%)	14 (63.7%)	4 (18.2%)

[1] *n* = number of children who were confronted with this question; not solved = answer was wrong, or no answer was given.

Most children had difficulty answering questions regarding the prediction of the content "Less water heating on stove" and "Hot-water bottle after a while". Here, the number of children who named an incorrect solution is comparatively high, and the number of children who were able to give a prediction is comparatively low. In contrast, the questions referring to predictions about "Water heating on stove", "Warm water in the sun", "Cold water under the tree", and "Halfway turned-on stove" were solved correctly by more than four-fifths of the children. From the explanation questions, most children correctly answered those of "Warm water in the sun". Only a few children could find an explanation for questions in the content "Water heating on stove", "Halfway turned-on stove", "Hot-water bottle after a while", and "Less water heating on stove".

3.4. Participant's Interview Performance

The interview performance indicates how well the children mastered the three interview situations overall. The highest possible mean score of interview performance was 2.0, and the lowest 0.0. From the sample, 75% of the participants (18 children) achieved a score greater than 0.6, 50% (12 children) a score greater than 1.14, and 25% (6 children) a score greater than 1.43. Each participant's individual score is shown in Figure 1. The lowest score of the participant's interview performance was a mean of 0.29, and the maximum score was a mean of 1.86. The average sample's interview performance is given by a mean score of 1.11 and a standard deviation of 0.49. As Figure 1 shows, the distribution of interview performance across the age groups is quite heterogeneous, although there are tendencies for lower performances among younger children (see also Section 3.5.2).

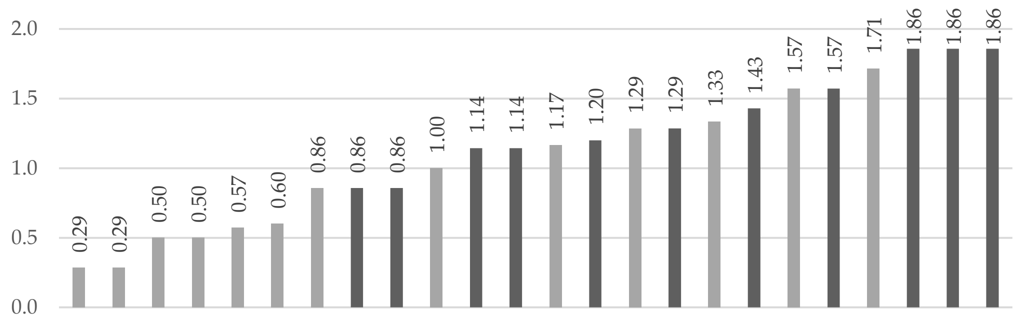

Figure 1. Overview of the interview performance (mean) of the single participants ($n = 24$). The color of the bars indicates their age group (grey = aged under 5 years; black = aged over 5 years).

3.5. Results of Bivariate Analysis

3.5.1. Correlations: Behavior, Abilities, Interests, and Age

In bivariate analysis, the different KOMPIK scales evidenced partly significant, partly not significant correlations with children's age: Task Orientation correlated significantly with age ($r_{sp} = 0.48$; $p < 0.05$), as well as Science Interest ($r_{sp} = 0.47$; $p < 0.05$). The variable Language Comprehension showed a tendency to a significant correlation with age ($r_{sp} = 0.40$; $p < 0.10$), whereas Exploration did not correlate significantly with age ($r_{sp} = 0.20$; n.s.).

3.5.2. Correlations: Age and Interview Performance

The calculated correlation by Spearman shows a tendency but not a significant correlation between Age and Interview Performance ($r_{sp} = 0.36$; $p < 0.10$).

3.5.3. Correlations: Behavior, Abilities, Interests, and Interview Performance

When the different KOMPIK scales were related to children's Interview Performance, it became evident that some KOMPIK scales correlated while others did not: Science Interest correlated very significantly with Interview Performance ($r_{sp} = 0.66$; $p < 0.01$), and Language Comprehension correlated significantly with Interview Performance ($r_{sp} = 0.51$; $p < 0.05$). Task Orientation did not correlate significantly but showed a tendency to a correlation with Interview Performance ($r_{sp} = 0.36$; $p < 0.10$), neither did Exploration correlate with Interview Performance ($r_{sp} = -0.05$; n.s.).

3.5.4. Nonparametric Partial Correlations: Behavior, Abilities, Interests—Controlled with Age—And Interview Performance

In the calculations of the nonparametric partial correlation, all scales of KOMPIK were included that correlated with Interview Performance. Age was used as a control variable.

Controlled with Age, again, a very significant correlation was calculated between Science Interest and Interview Performance ($r_{sp\ \text{controlled by age}} = 0.60$; $p < 0.01$). Without the influence of Age, Language Comprehension still correlated significantly with children's Interview Performance ($r_{sp\ \text{controlled by age}} = 0.51$; $p < 0.05$). Task Orientation, controlled by Age, did not correlate with Interview Performance ($r_{sp\ \text{controlled by age}} = 0.23$; n.s.).

4. Discussion

The aim of this study was to explore kindergarten children's ideas about thermal phenomena with a focus on water temperature and changes caused by heat transfer. In the context of the investigation, heat sources like the sun, a stove, and a hot water bottle were addressed. The study took place before any didactic intervention at kindergarten had been undertaken. We were simply trying to capture the spontaneous everyday concepts of young children, considering the heterogenous development areas of a kindergarten cohort.

The result of this study shows that kindergarten children use the terms "warm" and "hot" to describe a higher water temperature. The synonymous use of these two terms has also been observed in other studies [26,29]. Thus, as in other studies, a distinction between warm and hot is not always made. However, this does not necessarily mean that kindergarten children generally are not capable of distinguishing between warm and hot, but perhaps that the situation did not call for it. In some interview situations, it became apparent that some children were able to express temperature gradations and could thus describe how something gradually became warmer or colder. In certain situations, they also used terms that expressed a temperature of medium degree.

In the present study, we often recorded statements such as "it gets hot", referring to heating vaguely as a process [2]. These results are not in line with Albert's research, who mentioned that children express such statements, not before the age of seven or eight. Moreover, expressions such as "you have to wait" indicate that some children have already developed an understanding that temperature changes do not happen from one moment to the next. According to Albert's research [26], children aged under seven years think that thermal changes happen immediately.

As in other studies [2,26], in our investigation, it became clear as well that almost no kindergarten child used the word "heat" in their spontaneous expressions. Their attempts at explaining were generally more descriptive and referred to what is directly experienced. Only sporadically, a child referred to a process that takes place invisibly, i.e. heat transfer, as well. Overall, we can say that questions asking for a prediction of thermal phenomena were easier than questions asking for an explanation. The children found a simple explanation, particularly in the tasks concerning the temperature of the water in the sun or under the tree, as well as when confronting the effect of a cold hot-water bottle. In contrast, it was very difficult for the kindergarten children to find an explanation why the stove warms the water, why a half-turned-up stove does not warm so much (or so fast), as well as why the hot water bottle becomes colder after a while. This may be due to the fact that in these cases, explanations require a conceptualization of heat, something that still seems difficult for kindergarten children to achieve.

The indirectly proportional task of this study, namely the heating of a small amount of water compared to the heating of a greater amount of water on a stove (at the same heating power), was particularly difficult for the kindergarten children. It was the question for which children were least often able to make a correct prediction. That this would be a difficult task is not surprising, given what we know already from previous studies [30]. However, it must be mentioned that there were also individual children who were able to make correct predictions or explanations of this phenomenon—this observation is not in accordance with the results of [30], who concluded that only children at the age of nine were able to give correct statements referring to indirect proportional tasks.

In contrast to former studies, this study focused only on children of kindergarten age. In this group, an age effect was found. Data show a tendency to a significant correlation between age and the interview performance, which indicates that older kindergarten children are generally better able to give correct predictions and explanations than younger ones. Nevertheless, this did not mean that younger children were not at all capable of giving the right answers to particular questions. Some of the younger children even achieved better interview performance than older children, which also highlights the performance heterogeneity in this age group. However, overall, it is clear that the ability to predict and explain thermal phenomena depends to a significant degree on children's age.

In addition to age, other developmental aspects such as exploratory behavior, task orientation, as well as interest in science, and language comprehension and their possible influence on interview performance were considered in this study. The results of the teacher ratings indicated that the investigated group of children is heterogeneous with regard to those different developmental areas. However, since these characteristics were often related with age (except for exploratory behavior), the influence of age had to be excluded first to elaborate on the role of these developmental areas. Therefore, partial correlations were studied, and it has become evident that science interest, in addition to language comprehension, had a significant influence on interview performance, while task orientation and exploratory behavior were not significant. Thus, the results of this study confirm the relationship between a strong interest in natural science and a better understanding of natural and technical phenomena. In the literature [43,44,63], it is well known that a person's interest plays a significant role in how much one turns to certain phenomena and engages with them. Accordingly, more knowledge and experience can build up in those areas of interest. Early science education should pick up on and promote interest in science but also promote concept creation because what is experienced must also be put into cognitive structures and expressed in words. Thus, the linguistic ability to communicate about simple thermal phenomena should also be promoted in class. This study showed clearly that kindergarten children with weaker language comprehension were not as capable of answering the interview questions about thermal phenomena as their peers having stronger linguistic abilities. This means that for some children, the experience and understanding of thermal phenomena may be greater than could be expressed in an interview.

All in all, it must be kept in mind that the study sample is composed of only 24 children. Thus, the results of this study must be considered as rather dependent upon the subjects in the sample. Therefore, generalizations of conclusions to the whole age cohort of kindergarten children should only be made very cautiously, if at all.

The knowledge gained here is of great importance for planning a suitable learning situation in kindergarten. Furthermore, it will allow us to assess the effect of the intervention we are designing for promoting the understanding of thermal phenomena in children. In a follow-up paper, we shall present a critical review of typical interpretations of children's understanding of thermal (and other physical) phenomena found in the tradition of science education and conceptual change research. This will be contrasted with a model of learning and understanding based upon an embodied/enactive approach that makes use of imaginative (in particular, narrative) forms of meaning-making interacting with direct physical experience.

Author Contributions: All three authors have contributed equally to all parts of the article. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by the Open Access Publishing Fund of the Free University of Bozen-Bolzano.

Institutional Review Board Statement: The data used in this study were collected and anonymized by the school teachers according to the school policy, and do not allow any conclusions to be drawn about the participating individuals. The procedure complies with the data protection law (GDPR).

Informed Consent Statement: Informed consent was obtained from the parents of all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors would thank the teachers taking part to this study as well as their school director for the valuable collaboration and support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Steffensky, M. *Frühe naturwissenschaftliche Bildung*; KiTa Fachtexte: Berlin, Germany, 2018; Available online: https://www.kita-fachtexte.de/fileadmin/Redaktion/Publikationen/KiTaFT_Steffensky_2018-Fruehe_naturwissenschaftliche_Bildung.pdf (accessed on 10 March 2022).
2. Luce, M.R.; Callanan, M.A. Family Conversations about Heat and Temperature: Implications for Children's Learning. *Front. Psychol.* **2020**, *11*, 1718. [CrossRef] [PubMed]
3. Ezquerra, A.; Ezquerra-Romano, R. From Thermosensation to the Concepts of Heat and Temperature: A Possible Neuroscientific Component. *Euroasia J. Math. Sci. Technol. Educ.* **2018**, *14*, 12. [CrossRef]
4. Corni, F.; Fuchs, H.U. Primary Physical Science for Student Teachers at Kindergarten and Primary School Levels: Part I—Foundations of an Imaginative Approach to Physical Science. *Interchange* **2020**, *51*, 315–343. [CrossRef]
5. Corni, F.; Fuchs, H.U. Primary Physical Science for Student Teachers at Kindergarten and Primary School Levels: Part II—Implementation and Evaluation of a Course. *Interchange* **2021**, *52*, 203–236. [CrossRef]
6. Fuchs, H.U. From Image Schemas to Dynamical Models in Fluids, Electricity, Heat, and Motion. An Essay on Physics Education Research. 2007. Available online: http://www.hansfuchs.org/LITERATURE/Literature.html (accessed on 12 January 2022).
7. Fuchs, H.U.; Corni, F.; Pahl, A. Embodied Simulations of Forces of Nature and the Role of Energy in Physical Systems. *Educ. Sci.* **2021**, *11*, 759. [CrossRef]
8. Deutschschweizer Erziehungsdirektoren-Konferenz. *Lehrplan 21*; Gassmann Print: Biel/Bienne, Switzerland, 2016.
9. Piaget, J. *Das Erwachen der Intelligenz beim Kinde*; Klett-Cotta: Stuttgart, Germany, 1996.
10. Vygotsky, L.S. Mind in Society. In *The Development of Higher Psychological Processes*; Harvard University Press: Cambridge, MA, USA, 1987.
11. Duit, R.; Treagust, D.F. Learning in Science—From Behaviorisms towards Social Constructivism and Beyond. In *International Handbook of Science Education*; Fraser, B.J., Tobin, K.G., Eds.; Kluwer Academic Publishers: London, UK, 1998; pp. 3–25.
12. Möller, K. Die Bedeutung von Schülervorstellungen für das Lernen im Sachunterricht. In *"Wie ich mir das denke und vorstelle . . . " Vorstellungen von Schülerinnen und Schülern zu Lerngegenständen des Sachunterrichts und des Fachbereichs Natur, Mensch, Gesellschaft*; Adamina, M., Kübler, M., Kalcsics, K., Bietenhard, S., Engeli, E., Eds.; Verlag Julius Klinkhardt: Bad Heilbrunn, Germany, 2018; pp. 35–60.
13. Hartinger, A.; Murmann, L. Schülervorstellungen erschließen—Methoden, Analyse, Diagnose. In *"Wie ich mir das denke und vorstelle . . . "Vorstellungen von Schülerinnen und Schülern zu Lerngegenständen des Sachunterrichts und des Fachbereichs Natur, Mensch, Gesellschaft*; Adamina, M., Kübler, M., Kalcsics, K., Bietenhard, S., Engeli, E., Eds.; Verlag Julius Klinkhardt: Bad Heilbrunn, Germany, 2018; pp. 51–62.
14. Ausubel, D.P. *Educational Psychology: A Cognitive View*; Holt, Rinehart and Winston: New York, NY, USA, 1968.
15. Lewis, E.L.; Linn, M.C. Heat Energy and Temperature Concepts of Adolescents, Adults, and Experts: Implications for Curricular Improvements. *J. Res. Sci. Teach.* **1994**, *31*, 657–677. [CrossRef]
16. Kartal, T.; Ötztürk, N.; Yalcac, H.G. Misconceptions of Science Teacher Candidates about Heat and Temperature. *Procedica Soc. Behav. Sci.* **2015**, *15*, 2758–2763. [CrossRef]
17. Chi, M.T.H. Commonsense Conceptions of Emergent Processes: Why Some Misconceptions are robust. *J. Learn. Sci.* **2005**, *14*, 161–199. [CrossRef]
18. Slotta, J.D.; Chi, M.T.H.; Joram, E. Assesing Student's Misclassifications of Physics Concepts: An Ontological Basis for Conceptual Change. *Cogn. Instruct.* **1995**, *13*, 374–400. [CrossRef]
19. Gerhátová, Ž.; Perichta, P.; Drienovský, M.; Palcut, M. Temperature Measurement—Inquiry-Based Learning Activities for Third Graders. *Educ. Sci.* **2021**, *11*, 506. [CrossRef]
20. Havu-Nuutinen, S.K.S. Young Children's Conceptions of Temperature and Thermometer. *Int. J. Learn. Annu. Rev.* **2007**, *14*, 93–102. [CrossRef]
21. Hadzigeorgiou, Y. Young Children's Ideas About Physical Science Concepts. In *Research in Early Childhood Science Education*; Trundle, K.C., Sackes, Eds.; Springer Science and Business Media: Dordrecht, The Netherlands, 2015. [CrossRef]
22. Pahl, A.; Tschiesner, R. What Influences Attitudes and Confidence in Teaching Physics and Technology? An Investigation in Kindergarten and Primary-School Trainee Teachers. *Sustainability* **2022**, *14*, 87. [CrossRef]
23. Tschiesner, R.; Pahl, A. Trainee Teachers' Preferences in the Subject 'Human-Nature-Society': The Role of Knowledge. *ICERI Proc.* **2019**, *12*, 3167–3176. [CrossRef]
24. Pahl, A.; Tschiesner, R.; Adamina, M. The 'Nature-Human-Society'—Questionnaire for Kindergarten and Primary School Trainee Teachers: Psychometric Properties and Validation. *ICERI Proc.* **2019**, *12*, 3196–3205. [CrossRef]
25. Pahl, A. Teaching Physics in Kindergarten and Primary School: What do Trainee Teachers Think of This? In *Physics Teacher Education—What Matters*; Borg Marks, J., Galea, P., Gatt, S., Sands, D., Eds.; Springer: Berlin, Germany, 2022; Volume 1, *in press*.
26. Albert, E. Development of the Concept of Heat in Children. *Sci. Educ.* **1978**, *62*, 389–399. [CrossRef]
27. Piaget, J.; Garcia, R. *Understanding Causality*; Norton and Company: New York, NY, USA, 1977.
28. Carlton, K. Teaching about Heat and Temperature. *Phys. Educ.* **2000**, *35*, 101–105. [CrossRef]
29. Qonita, E.; Syaodih, A.; Suhandi, B.; Mafthu, N.; Hermita, H.; Handayani, H.; Nurafifah, R.; Ningsi, A.R.; Gumala, Y.; Maulana, D. Identifying Kindergarten Children's Idea about Heat and Temperature Concept. *J. Phys. Conf. Ser.* **2019**, *1280*, 052018. [CrossRef]

30. Stavy, R.; Tirsosh, D. *How Students (Mis-)Understand Science and Mathematics: Intuitive Rules*; Teachers College Press: New York, NY, USA, 2000.
31. Ravanis, K.; Papandreou, M.; Kampeza, M.; Vellopoulou, A. Teaching Activities for the Construction of a Precursor Model in 5-to 6-Year-Old children's Thinking: The Case of Thermal Expansion and Contraction of Metals. *Eur. Early Child. Educ. Res. J.* **2013**, *21*, 514–526. [CrossRef]
32. Kaliampos, G.; Ravanis, K. Thermal Conduction in Metals: Mental Representations in 5–6 Years Old Children's Thinking. *J. Ilm. Pendidik. Fis. Al-Biruni* **2019**, *8*, 1–9. [CrossRef]
33. Fragkiadaki, G.; Armeni, A.; Zioga, S.; Ravanis, K. Dramatic Play as a Means to Explore and Support Preschool Children's Thinking about Thermal Insulation. *J. Child. Educ. Soc.* **2021**, *2*, 220–234. [CrossRef]
34. Kambouri-Danos, M.; Ravanis, K.; Jameau, A.; Boilevin, J.M. Precursor Models and Early Years Science Learning: A Case Study Related to the Water State Changes. *Early Child. Educ. J.* **2019**, *47*, 475–488. [CrossRef]
35. Kampeza, M.; Vellopoulou, A.; Fragkiadaki, G.; Ravanis, K. The Expansion Thermometer in Preschoolers' Thinking. *J. Balt. Sci. Educ.* **2016**, *15*, 185–193. [CrossRef]
36. Cain, R. Kindergarteners' Conceptions and Representations of Temperature: An Exploratory Study on How Young Children Perceive Air Temperature. Ph.D. Thesis, Utah State University, Logan, UT, USA, 2019.
37. Vygotsky, L.S. *Denken und Sprechen*, 3rd ed.; Fischer: Frankfurt, Germany, 1971.
38. Mayr, T.; Ulrich, M. Seelische Gesundheit bei Kindergartenkindern. In *Elementarpädagogik nach PISA*; Fthenakis, W.E., Ed.; Herder: Freiburg, Germany, 2003; pp. 190–207.
39. Mayr, T.; Bauer, C.; Krause, M. *KOMPIK—Beobachtungs- und Einschätzungsbogen für Kinder von 3.5 bis 6.0 Jahren*, 2nd ed.; Bertelsmann Stiftung und Staatsinstitut für Frühpädagogik: München, Germany, 2012.
40. Mayr, T.; Bauer, C.; Krause, C. *KOMPIK—Eine Einführung. Begleitendes Handbuch für pädagogische Fachkräfte*; Bertelsmann Stiftung und Staatsinstitut für Früherziehung: Gütersloh, Germany, 2014.
41. Dolasse, R. Entwicklungspsychologische Grundlagen des kindlichen Weltverstehens. In *Kinder auf dem Weg zum Verstehen der Welt*; Köhnlein, W., Marquard-Mau, B., Schreiner, H., Eds.; Klinkhardt: Bad Heilbrunn, Germany, 1997; pp. 16–38.
42. Siegler, R.; Eisenberg, N.; de Loache, J.; Saffran, J.; Pauen, S. *Entwicklungspsychologie im Kindes- und Jugendalter*; Springer: Heidelberg, Germany, 2016.
43. Krapp, A.; Hidi, S.; Renninger, K.A. Interest, Learning, and Development. In *The Role of Interest in Learning and Development*; Renninger, K.A., Hidi, S., Krapp, A., Eds.; Lawrence Erlbaum: Mahwah, NJ, USA, 1992; pp. 3–25.
44. Holland, J.L. *Making Vocational Choices: A Theory of Vocational Personalities and Work Environments*, 3rd ed.; Psychological Assessment Resources: Odessa, Ukraine, 1997.
45. Lichtblau, M. *Kindliches Interesse beobachten und fördern*; KiTa Fachtexte: Berlin, Germany, 2018; Available online: https://www.kita-fachtexte.de/fileadmin/Redaktion/Publikationen/KiTaFT_Lichtblau_II_2018_kindlicheInteressenbeobachtenundfoerdern.pdf (accessed on 10 February 2022).
46. Döring, N.; Bortz, J. *Forschungsmethoden und Evaluation in den Sozial- und Humanwissenschaften*; Springer: Berlin/Heidelberg, Germany, 2016.
47. Hussy, W.; Schreier, M.; Echterhoff, G. *Forschungsmethoden in Psychology und Sozialwissenschaften für Bachelor, 2nd ed*; Springer: Berlin/Heidelberg, Germany, 2013.
48. Viernickel, S.; Völkl, P. *Beobachten und Dokumentieren im pädagogischen Alltag*; Herder: Freiburg im Breisgau, Germany, 2017.
49. Koglin, U.; Petermann, F.; Petermann, U. *Entwicklungsbeobachtung und -dokumentation. EBD 48-72 Monate. Eine Arbeitshilfe für pädagogische Fachkräfte*, 7th ed.; Cornelsen: Berlin, Germany, 2020.
50. Denker, H. *Bindung und Theory of Mind. Bildungsbezogene Gestaltung von Erzieherinnen-Kind-Interaktionen*; Springer: Wiesbaden, Germany, 2012.
51. Kagan, J.; Snidman, N. *The Long Shadow of Temperament*; Harward University Press: Cambridge, UK, 2004.
52. Ponizovsky-Bergelson, Y.; Dayan, Y.; Wahle, N.; Roer-Strier, D. A Qualitative Interview with Young Children: What Encourages or Inhibits Young Children's Participation? *Int. J. Qual. Methods* **2019**, *18*, 1–9. [CrossRef]
53. Fleer, M.; Li, L. A Child-Centered Evaluation Model: Gaining the Children's Perspective in Evaluation Studies in China. *Eur. Early Child. Educ. Res. J.* **2016**, *24*, 342–356. [CrossRef]
54. Vogl, S. *Alter und Methode*; Springer: Wiesbaden, Germany, 2012; pp. 40–55. [CrossRef]
55. Petermann, F.; Stein, I.A.; Macha, T. *Entwicklungstest für Kinder von 6 Monaten bis 6 Jahren*; Pearson: München, Germany, 2008.
56. Mayr, T. KOMPIK—Kompetenzen und Interessen von Kindern in Kindertageseinrichtungen. *Frühe Bild.* **2012**, *1*, 163–167. [CrossRef]
57. Niebert, K.; Gropengrießer, K. Leitfadengestützte Interviews. In *Methoden in der naturwissenschaftsdidaktischen Forschung*; Krüger, D., Parchmann, I., Schecker, H., Eds.; Springer: Berlin/Heidelberg, Germany, 2014; pp. 121–132.
58. Pahl, A. Research Methods for Investigating Young Children's Learning with Science Experiments—An Overview. *ICERI2019 Proc.* **2019**, *12*, 3177–3186. [CrossRef]
59. Misoch, S. *Qualitative Interviews*; De Gruyter Oldenbourg: Berlin, Germany, 2015.
60. Loosen, W. Das Leitfadeninterview—Eine unterschätzte Methode. In *Handbuch nicht standardisierte Methoden in der Kommunikationswissenschaft*; Averbeck-Lietz, S., Meyen, M., Eds.; Springer Fachmedien: Wiesbaden, Germany, 2016; pp. 139–156. [CrossRef]

61. Bierman, K.L. Cognitive Development and Clinical Interviews with Children. In *Advances in Clinical Child Psychology*; Lahey, B.B., Kazdin, A.E., Eds.; Springer: Boston, MA, USA, 1983; Volume 6, pp. 217–250. [CrossRef]
62. Cicchetti, D.V. Guidelines, Criteria, and Rules of Thumb for Evaluating Normed and Standardized Assessment Instruments in Psychology. *Psychol. Assess.* **1994**, *6*, 284–290. [CrossRef]
63. Bergmann, C.; Eder, F. *Allgemeiner Interessen-Struktur-Test mit Umwelt-Struktur-Test (UST-R), Revision*; Hogrefe: Göttingen, Germany, 2005.