Children's Ideas About Matter

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Introduction

In recent years, many studies have investigated students' ideas and reasoning in science (e.g., Driver & Erickson, 1983; Gilbert & Watts, 1983; Posner, Strick, Hewson, & Gertzog, 1982). These studies found that students' preconceptions were quite different from those generally accepted in science, and that they were interfering with, and quite resistant to, teaching. These conceptions are being constructed through a process of interaction between the child's cognitive system and his/her physical, social, and cultural environment. It is thought that our knowledge about these intuitive preconceptions and how they develop with age, culture, and instruction may be helfpul in designing better teaching methods. The research reported here deals with first through seventh grade students' conceptions of matter, prior to and following instruction.

Matter is one of the fundamental concepts in science and, along with energy, the most general one. The problem of deciding on the boundaries of materiality has occupied scientists as well as philosophers throughout the history of science and philosophy (McMullin, 1978; Toulmin & Goodfield, 1962). The distinction between matter and nonmatter which is a physical agent like heat or magnetism, but with no mass--was accepted only toward the middle of the 19th century. Earlier, it was not clear whether air, steam, fire, or heat were materials. Even today, the boundaries are not very sharp and clear, and after many years of discussions about the nature of light, the idea emerged that light (and some other small particles) has a dual nature. In some instances, its behavior is better understood in terms of waves, and in other cases, its behavior is better understood in terms of particles; however, in junior high school science curriculum, matter is explicitly or implicitly treated as anything that occupies space and has mass (or weight). Even as such, matter is a highly abstract concept. The perceptual elements on which it is built are not always very salient and the variance within matter is very great.

In everyday language, matter, as many other scientific concepts, has a much more ambiguous meaning. For example, the meanings of the word matter in the *Oxford Dictionary* (1964) are, "substances of which a physical thing is made; purulent discharge; physical substance in general; particular content or proposition: material for thought or expression; substance of book, speech, etc.; thing; affair" (p. 751). The meanings of the word matter in the Hebrew language are clay, material, substance, material for thought, and, in more literary contexts, pile and severity. In general, everyday concepts are less precise and more ambiguous than scientific or school-based ones. Several authors (e.g., Bell & Freyberg, 1985) indicate that many words which express scientific concepts have different meanings in everyday language. They claim that this fact may be one of the sources of children's misconceptions because children have to map the words they hear into concepts. It is expected that young children's conception of matter would initiate with the everyday meaning of the word. This conception should shift with age and/or instruction toward the science curriculum meaning.

The science curriculum for junior high school students in Israel deals with the states of matter and with the particulate theory of matter. The curriculum was developed with the underlying assumption that, at this age, students have already acquired the scientific meaning of matter. Thus, there is no attempt to discuss or define the term as it is being used in school science. This underlying assumption is best illustrated in the way students are being taught that gases are material. They are shown that gases have weight and volume, assuming that this is enough to make them consider gases as matter.

Previous studies on students' understanding of the change of state from liquid to gas (Stavy, 1990) indicated that junior high school children might have alternative ideas about matter. The purpose of this study is to investigate the development of students' conceptions of matter. Students' ideas about matter were examined by asking students (grades 1, 3, 5, 7) to verbally explain what matter means and to classify items into matter and nonmatter.

Methodology

The Sample

The sample comprised four different age groups of students from the upper middle-class population in the vicinity of Tel-Aviv. The students were from grades 1, 3, 5, and 7 (corresponding ages: 6-7, 8-9, 10-l 1, 12-13). Seventh-grade students were tested after they had studied the course, "The Structure of Matter." Twenty students were tested in each age group, totalling 80 students. Each student was individually interviewed while being shown the materials and phenomena.

The Tasks

Explanation of the concept matter. Students were directly asked if they knew what matter means and if they could explain what it is.

Matter/nonmatter classification. Students were asked to judge whether they thought of a series (matter and nonmatter) as matter or not.

The material items were: (a) solids--rigid solids (iron cube, piece of wood, ice cube); non-rigid solids (cotton wools and metal spring); powders (sugar, flour, potassium per manganate, and soil); (b) liquids (mercury, milk, water); (c) biological materials (flower, human body, meat); and (d) gas (air). The non-material items were: (a) phenomena directly associated with matter (fire, electricity, wind, smell); and (b) other nonmatter (light, heat, and shadow).

During the interview, students were concretely presented with all substances. Questions about the human body were related to the child's own body, and questions about air referred to the air in the room. Some of the phenomena and nonmatter items were also concretely presented. For example, fire--a match was lit, and the child was asked if he/she saw the fire and whether he/she thought fire was material or not; smell--the child was presented with an open, empty perfume bottle and he/she was asked to smell it and to judge whether smell was material or not; light--the light was switched on in the room, and the child was asked if he/she thought light was material or not. Other phenomena and nonmatter items (wind, electricity, heat, and shadow) could not be concretely presented. Questions about them were as follows: "Do you know what wind (electricity, heat, shadow) is? Could you tell me whether it is material or not?"

Results and Discussion

Verbal Explanations of Matter

Students were directly asked if they knew what matter means and if they could explain what it is. Most of the students in all age groups could do so. Students' responses could be divided into several categories (see Table 1).

1. *Explanation by means of example.* This type of response appeared in most of the groups but was more popular in the lower grades (1, 3). The characteristic examples give were plasticene, clay, glue, cleaning materials, building materials, sugar, wood, and iron.

2. *Explanation by means of function.* This type of response also appeared in all grades. Students explained matter as something you work with or use. For example, "Something that one uses," "A thing that you work with," "Something from which you create (or make, or build) things," or "Something

Table 1

Students Explanations of Matter (Percent in Each Grade)

Explanation	Grade 1	Grade 3	Grade 5	Grade 7
By example: clay, plasticene	40	45	20	20
By function: something that one uses, or works with, or creates something else with	45	20	25	15
By structure: made from components	0	15	25	15
By properties:				
1. hardness, color, tangibility, etc.	0	0	0	10
2. state (solid, liquid, gas, powder, crystals)	0	0	35	35
3. weight and/or volume	0	0	0	10
Other kinds of matter: learning, reading, etc.	0	35	5	0

that helps us."

3. *Explanation by means of structure.* This type of response appeared from grade 3 onwards. Students explained matter as something which is "made (built or constructed) of things."

4. Explanation by means of properties. This type of response appeared in the upper grades (5th grade and on). It could be divided into three subgroups: (a) specific properties such as hardness, tangibility, color, etc; (b) state of matter such as solid, powder, etc., and (c) properties of weight and/or volume. These appeared only in 10% of the seventh graders (usually only with one of the properties).

5. Other kinds of matter, usually learning materials, reading materials, etc.

It seems that children (especially in the lower grades) tend to verbally explain matter by giving typical examples or by describing function and not by defining features. Their responses indicate that the mental model they have with regard to matter is associated very strongly with moldable or useful solid materials such as plasticene, clay, cement, or iron. This model persists until the seventh grade. From third grade on, children start to think of matter also in terms of structure and properties, but only 10% of the 7th graders relate to the properties of weight and volume which are relevant in scientific context.

Classification of Different Items into Matter and Nonmatter

Children were asked to judge whether they thought of a series of items (matter and nonmatter) as matter or not. Figure 1 shows how children in the different age groups relate to the different groups of items. It seems that the different groups of items can be ordered according to their being regarded as matter in the following ways: solids (72.6%; the order of the subgroups was powders--78.4%, rigid solides-69.1%, and nonrigid solids--(66.2%), liquids (57%), biological materials (48.7%). phenomena associated with matter (29%), gas (23.7%), nonmatter (10.8%). Figure 1 also shows that children's classification of items into matter and nonmatter improves with age, and by the seventh grade, the majority of children regard solids, liquids, and biological materials as matter and don't include in the matter group nonmatter items. Even though there is a remarkable increase in classifying gases as matter at this age, children still have some problems with classifying gas and with

Figure 1. *Classification of different groups of items as matter (in percent).*

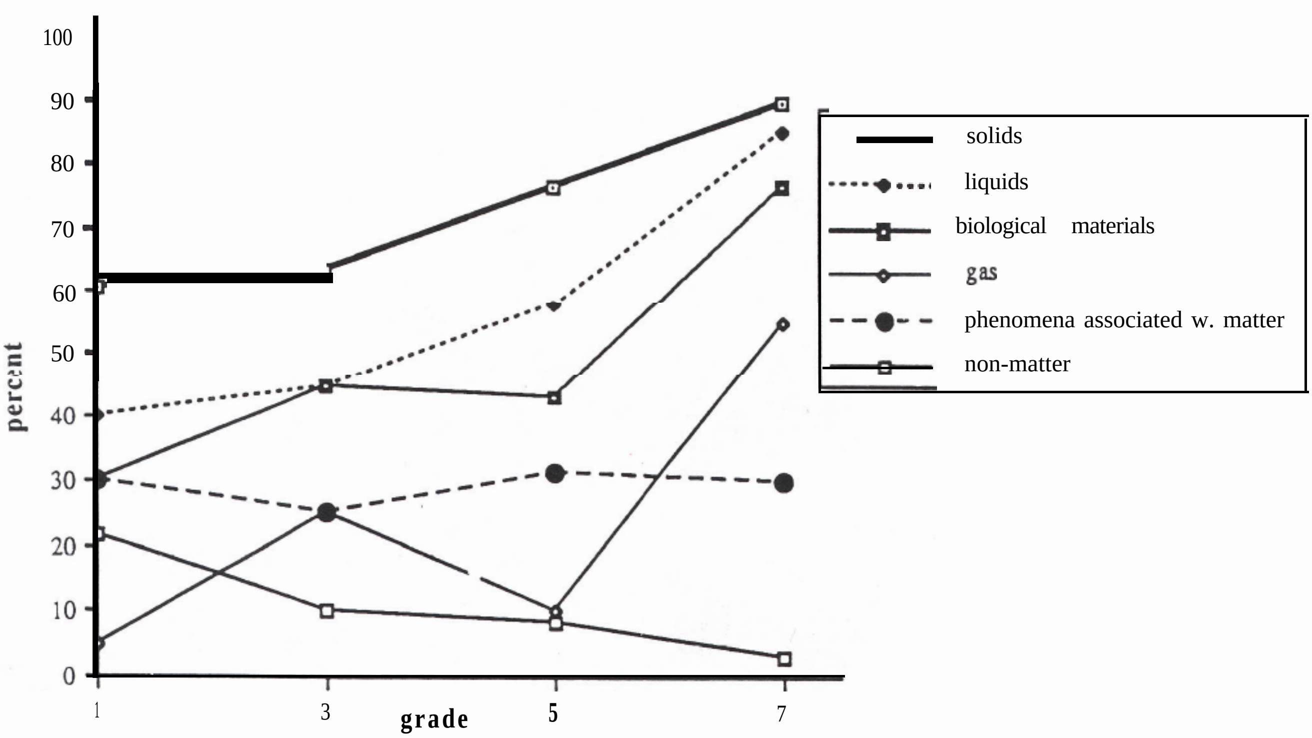

Table 2

Percentage of Students Who Classified Each of the Items as Matter

Item	Grade	1	3	5	7	Total	Average
solids powders	sugar	75	85	75	90	81.2	
	flour	75	95	95	85	87.5	78.4
	$KMnO_4$	60	70	95	100	81.2	
	soil	45	70	65	75	63.7	
rigid	iron	60	35	75	100	67.5	
	wood	65	70	75	95	76.2	69.1
	ice	50	65	65	75	63.7	
non-rigid	cotton wool	50	55	70	90	66.2	66.2
	iron spring	65	30	75	95	66.2	
liquid	milk	45	50	50	80	56.2	
	mercury	45	60	80	100	71.2	57.0
	water	30	25	45	75	43.7	
biological materials	flower	35	50	60	75	55.0	
	human body	25	70	40	90	56.2	48.7
	meat	30	15	30	65	35.0	
phenomena associated with matter	fire	60	45	40	45	47.5	
	electricity	35	40	45	30	37.5	29.0
	wind	20	5	5	40	17.5	
	smell	5	10	35	5	13.7	
gas	air	5	25	10	55	23.7	23.7
nonmatter	heat	30	15	10	5	15.0	
	light	30	15	10	0	13.7	10.8
	shadow	5	0	5	5	3.7	

classifying phenomena associated with matter. Table 2 describes the classification of each of the items by the different age groups.

Powders were regarded as matter by the majority of students. It is interesting to note that soil is less regarded as matter than other members of this group. It may very well be that soil is not regarded as something one can use, or it may be that since soil is a very common and everyday substance it is not regarded as matter. Rigid and non-rigid solids were also regarded as matter by most students. Similar to soil in the powders group, ice in the rigid solids group was classified less as matter that the other members of the group. This is probably because it is also a common everyday substance. Only 57% of the liquids were regarded as matter. Here as well, water, the most common liquid, was the least to be regarded as matter. Biological materials were regarded as matter less than 50% of the time. Apparently it is very hard for the human mind to believe that the living body is made out of ordinary matter (Stavy, Eisen, & Yaakobi, 1987). In 30% of the cases, phenomena associated with matter were regarded as matter where students did not differentiate between matter itself and the phenomena it supports. Similar to other findings (Furio Mas, Perez, & Harris, 1987; Sere, 1985; Stavy, 1988), accepting gas as a material was found to be very problematic. Nonmatter was not problematic in general, only in the lower grades did some 30% of the students regard heat and light as materials.

The results from the classification experiment suggest that young children's core concept of matter is, on the one hand, underextended, not including some solids, most liquids and biological materials, and all gases, and on the other hand, overextended, including some phenomena associated with matter and nonmatter items. Similar results were reported by Anderson (1989) in Sweden.

During development and instruction, there is a gradual shift in the classification pattern toward a more scientific one, but it seems that this shift is not a consequence of a parallel shift in the nature of explanation or definition of the term matter. The improvement of explanation of the term matter lags behind the ability to classify items into matter and nonmatter in terms of the properties of weight or volume. Similar phenomena of improvement in the ability to classify without parallel improvement in defining ability was also observed with regard to the concepts solid and liquid (Stavy & Stachel, 1985).

Education Implications

The results presented in this paper indicate a major difficulty students have with regard to concept of matter. This is expressed both in their ability to explain what matter is and in their ability to classify. Apparently, matter for many children is something they can see and grasp. It is preferably solid and inanimate. It is also difficult for them to differentiate between matter itself and the phenomena it supports.

It seems that there is no point in teaching the particulate nature of matter when students don't know what we mean by matter and don't believe that gas, for example, is material (Stavy, 1988). There is also no point in teaching biological concepts such as photosynthesis, breathing, nutrition, etc., when students don't regard biological objects as material.

It is therefore suggested that prior to teaching the particulate nature of matter one should discuss and clarify the meaning of the concept of matter with students. One should start with items which are regarded by student as matter (e.g., solids) by searching for common features (mass or weight if students were not introduced to the concept of mass and volume). Then one should proceed to items usually not regarded by students as matter (liquids, biological materials, and gases) by testing whether they possess the common features. One should also discuss nonmaterial items which are regarded by students as matter, trying to show these don't agree with the common features.

Often in the course of science teaching, we tend not to pay enough attention to the very basic and fundamental concepts or ideas. As they are so basic, they seem to us self-evident. This apparently is not the case. It is true that many of these basic concepts are concepts which are used in everyday life and language and develop spontaneously, but their common, everyday meaning does not exactly coincide with the scientific one. Since these concepts are so very basic, leaving them unattended may result in difficulties in understanding of any advanced concept, principle, or theory.

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By recognizing children's rights in this way, the Convention firmly sets the focus on the whole child. The Convention recognizes the fundamental human dignity of all children and the urgency of ensuring their well-being and development. It makes clear the idea that a basic quality of life should be the right of all children, rather than a privilege enjoyed by a few. Course: Child rights and why they matter. Interested in learning more about child rights? Take this short course to transform your understanding of child rights and a child rights approach, introduce you to UNICEFâ€™s mandate as Early Ideas about Matter: From Democritus to Dalton. by Anthony Carpi, Ph.D. Reading.Â Empedocles argued that all matter was composed of four elements: fire, air, water, and earth. The ratio of these four elements affected the properties of the matter. Stone was thought to contain a high amount of earth, while a rabbit was thought to have a higher ratio of both water and fire, thus making it soft and giving it life. Empedocles's theory was quite popular, but it had a number of problems. Remember that child no matter what happened. He will look at mom and will decide whether to cry or not. If she was scared, then expect the child's reaction.Â If he loves cartoons and already has an idea about aliens, then he may be afraid of the moon, which shines in the window. His imagination will begin to think of aliens that are watching him. This can be attributed to fear of Koschei, Baba Yaga, and even the Sink.