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ABSTRACT

This study investigates the changes in junior high school (JHS) students' conceptions of the structure of matter as they study the subject of "materials" using a new curriculum in Science and Technology. The new instructional method is based on a student-centered constructivistic model and on a "spiral" approach to the learning of fundamental concepts. The sample consisted of an experimental group of 1,084 JHS students who studied "materials" according to the new curriculum, and a comparison group of 218 JHS students who studied this subject according to a traditional curriculum. Questionnaires, in which students were asked to represent the structure of several materials in words and pictures, were administered five times during a 3-year period. The results indicate three main mental models regarding students' conceptions of the structure of matter: Model A--materials are continuous substances; Model B--substances consist of particles; and Model C-- substances consist of various molecules. The experimental group underwent a process of conceptual change regarding the structure of materials: More than 80% of the students moved from model A to model B, and 50% succeeded to move on to model C. (Contains 16 references.) (Author/YDS)

A Longitudinal Study of Junior High School Students' Perceptions of the Particulate Nature of Matter

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This study investigates the changes in JHS students' conceptions of the structure of matter as they study the subject of "materials" using a new curriculum in Science and Technology. The new instructional method is based on a student–centered constructivisitic model and on a "spiral" approach to the learning of fundamental concepts. The sample consisted of an experimental group of 1084 JHS students who studied "materials" according to the new curriculum, and a comparison group of 218 JHS students who studied this subject according to a traditional curriculum. Questionnaires, in which students were asked to represent the structure of several materials, in words and pictures were administered five times during a 3–year period. The results indicate three main mental models regarding students' conceptions of the structure of matter: Model A– materials are continuous substances. Model B– substances consist of particles. Model C– substances consist of various molecules. The experimental group underwent a process of conceptual change regarding the structure of materials: More than 80% of the students moved from model A to model B, and 50% succeeded to move on to model C.

INTRODUCTION

In 1996 a new unified subject called "Science and Technology" was introduced to junior high schools (JHS) (grades 7–9) in Israel. The aim of this new subject is to cultivate scientific and technological literacy for all citizens as well as to prepare students with the necessary background for further studies (Israeli Ministry of Education, 1996). To this end, a new syllabus was developed. "Science and Technology for JHS" includes seven main topics: "Materials", "Energy", "Living Organisms", "Earth Systems", "Ecology", "Technology" and "Communication". The new syllabus covers three years (7–9 grade) – 180 hours each year.

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lished the MATMON group to develop a new curriculum for "Science and Technology". The new curriculum focuses on a thorough understanding of basic concepts in science and technology and emphasizes the development of independent learning skills within the subject matter. More specifically, it includes learning skills associated with knowledge acquisition, scientific and technological reading, listening and writing, as well as knowledge representation and presentation. The inquiry capabilities consist of investigation and problem–solving skills and technical skills. The acquisition of capabilities is built in the context of the units.

"Materials", one of the main topics included in "Science and Technology" is intended to cover 105 hours in grades 7–9. MATMON's new curriculum in "Materials" emphasizes the longitudinal development of several interrelated concepts frameworks along 7–9 grades – within and between disciplines. For example: learning about matter involves a major framework relating to structure, properties, and applications of materials, which can be discussed macroscopically and microscopically at different levels. One of the basic principles of materials science is the structure of matter. This subject provides students with a better understanding of daily phenomena and helps students form a solid scientific and technological basis for future studies.

The particulate nature of matter, a most fundamental concept in science, has been traditionally introduced at an early stage of JHS science. However, numerous studies have consistently shown that many JHS as well as HS students have conceptual difficulties in understanding the ideas associated with the particle theory (Anderson, 1990; Ben Zvi et al., 1986; Brook et al., 1984; Driver et al., 1994; Gabel, 1993; Johnson, 1998; Millar, 1990; Novick & Nussbaum, 1978; Renstorm et al., 1990).

We therefore decided to develop new instructional materials aimed at improving students' conceptualization of matter.

In this paper we describe a longitudinal study of junior high school students' conceptions of the structure of matter as analyzed through their learning the topic "Materials" according to our new MATMON curriculum.

DESCRIPTION OF THE NEW LEARNING UNITS OF "MATERIALS"

The new instructional program dealing with the topic "materials" includes several units (see table 1). The main features of these instructional units are as follows:

- Development of a fundamental understanding of central concepts such as the particulate structure of matter, the atomic model, and the relationship between the structure, properties, and applications of materials.
- Integration of the macroscopic view with the microscopic world. providing a molecular explanation for the structure and properties of materials.
- Use of models to explain the structure of matter. The students are encouraged to use a variety of models (e.g., building blocks, computer simulation, and theoretical representations) In order to understand the structure of matter, the meaning of a model,

is discussed including its advantages and limitations.

- The units integrate aspects of sciences, technology and society.
- The units encourage the development of independent learning and inquiry skills.
- The units encourage project–based learning with content knowledge.
- The units provide a wide range of learning activities in class with an emphasis on active pupil involvement in lessons.

In this paper we focus on our instructional methods aimed at developing students' understanding of the particulate structure of matter, and the relationship between the structure, properties and applications of materials. In particular we tried to emphasize, recall and reinforce these concepts and ideas in all our instructional units. This approach requires special teaching methods and necessitates an extended period of time.

Table 1: MATMON instructional units of the subject "materials" and their main topics.

Teaching unit	Academic year	Main topics
"The Structure of Matter: Vacuum and Particles" (Nussbaum, 1996)	7	Properties and applications of materials; the relationship between the properties and applications of materials. Particle model; states of matter: gas, liquid and solid; changes of state; Explaining phenomena according to the Particle theory.
"From Elementary to Complex Structure" (Scherz et al., 1997)	8	Atoms, molecules, size and units, elements, models. Structure of the atom; compounds, mixtures, the relationship between the structure and properties of materials.
"About Fibers" (Margel, 1997)	8 or 9	Structure, properties, and applications of fabrics, threads, fibers, polymers, and composites; the relationship between structure, properties, and applications of materials.

In order to improve students' understanding of the structure of matter, we integrate this subject several times, applying a "spiral" model. The spiral development of our instructional method evolves from the seventh to ninth grades in the following manner: The particulate model of matter is introduced in the seventh grade through the learning unit "The Structure of Matter: Vacuum and Particles" (Nussbaum, 1996). The central concepts are taught using a constructivistic approach including student debates and laboratory experiments. "The study of the particle model is a lengthy process of conceptual change. Conceptual changes require an extended period of time. Teachers should apply certain strategies and methods that involve students in constructing the desired meaning of scientific concepts and which help the students undergo the desired conceptual changes." (Nusbaum, 1998). In this unit there is a relatively constrained discussion of the different states of matter, emphasizing constructing the concepts of vacuum and the particulate, rather than the continuous model of matter.

The next learning unit from "Materials" is "From Elementary to Complex Structure" (Scherz et al., 1997), usually taught in eight grade. The main topics in this unit are: atoms, molecules, size and units, models, elements, structure of the atom, compounds, mixtures, and the relationship between the structure and properties of materials. Based on the particulate model of matter, this unit introduces some molecular structures related to elements: (oxygen) compounds (water) and mixtures (air). In this unit the particulate structure of matter is extended when students learn to distinguish between the types of particles. In this way, we emphasize, recall, and strengthen the particulate structure of matter within the instructional unit. At a later stage the particulate structure of matter is further developed in the unit "About fibers" (Margel, 1997). In this multidisciplinary unit, which presents major scientific and technological concepts, the students study the molecular structure of polymers, and learn the relationship between the structure, properties, and applications of materials as implemented in fabrics, threads, fibers, polymers, and composites. In all the stages, the particulate model of matter is stressed.

Other related programs, such as materials in living organisms and in earth systems are studied in a coordinated manner.

THE RESEARCH

The main goal of this research was to study the changes in JHS students' conceptions of the structure of matter when they learned the topic "Materials" using the new MATMON curriculum. One question that was addressed was whether students who studied the subject "Materials" by using the MATMON curriculum had a better understanding of the concepts and fewer learning difficulties than those who studied the same subject using the traditional materials. Another question was whether and to what extent students retained what they had learned 6–12 months after they finished learning the topic "Materials"

The research sample consisted of two groups of junior high school students: (1) an experimental group of 1084 junior high school students who studied this topic according to the new curriculum using the units "The Structure of Matter: Vacuum and Particles", "From Elements to Complex Structure", and "Fibers"; (2) a comparison group of 218 students who studied "Materials" according to the old curriculum, which covers the same topics and concepts but uses a different learning approach.

The principal research tools were questionnaires in which students were asked to describe in words and to draw the structure of several materials: iron, water, air, nylon, strawberry juice, wool, oxygen and paper. The students were specifically asked to relate to the structure of those materials as if they were looking at them through "magic glasses" which enable them to "see" their structure.

The questionnaires were administered five times to the students during a 3–year period (grades 7 –9).

Test A: Given at the beginning of 7th grade before studying "Materials".

Test B: Given after students in both groups had studied about the particulate nature of matter.

Test C: Given after students in both groups had studied about atoms, molecules, elements, compounds, and mixtures.

Test D: Given to the experimental group after they had studied "About Fibers".
No test was given to the comparison group because the students did not study a similar program..

Test E: Given in 9th grade, 6 months after both groups had studied the subject "Materials"

MAIN FINDINGS

Most students expressed the particle nature of matter in drawing better than they explained it in words. Therefore, we decided to concentrate on the findings from students' drawings.

The macroscopic view: Figure 1 depicts the percentage of students who drew the structure of materials using the macroscopic view.

The results indicate that at the beginning of JHS (7Th grade) 60%– 80% of the students described the structure of materials on a macroscopic level. (The remaining 20% did not answer the question). In the experimental group the description gradually became less macroscopic, and toward the 9Th grade the structure of materials was rarely described by using the macroscopic view.

In the comparison group, even at the end of the study, 25% drew the structure of most materials in a macroscopic view and 10% of this group drew the macroscopic view of the well studied materials air and oxygen.

The particle structure: Figure 2 depicts the percentage of students who drew the particle structure of matter in tests A–E as they learned the topic "Materials".

Test A: The results indicate that at the beginning of JHS, students in both groups had no knowledge about the particulate nature of matter.

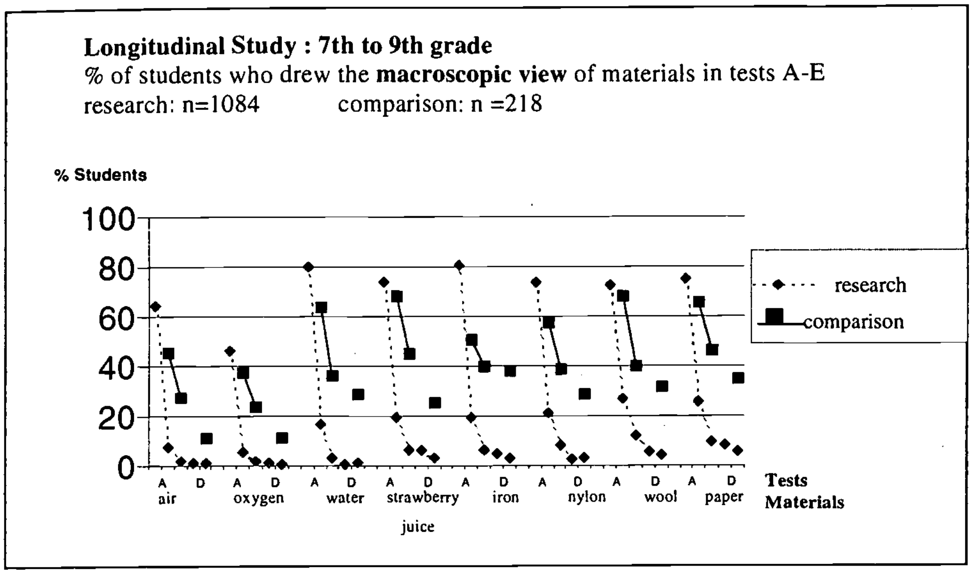

Figure 1: Students drawing the structure of materials in a macroscopic view

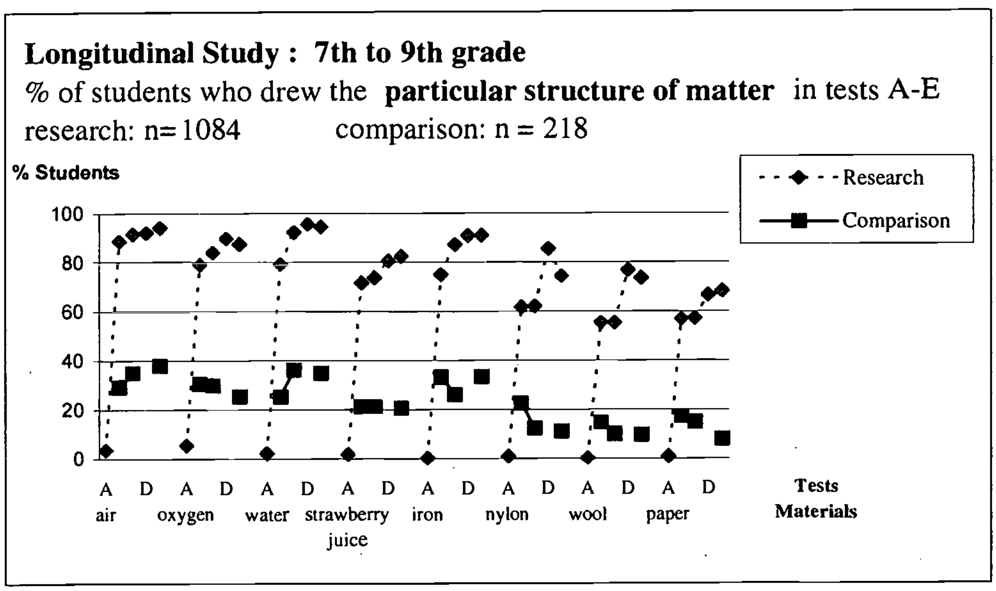

Figure 2: Students drawing the particle structure of matter

Test B: 60%– 80% of the students in the experimental group drew pictures of materials according to the particle theory. Only 30% of the comparison group students drew pictures of materials according to the particle theory.

Test C: There was another slight increase in the percentage of students in the experimental group who drew the structure of materials according to the particle theory, especially water and iron. Less than 40% of the students in the comparison group drew a particle picture of materials.

Test D: There was another slight increase in the percentage of students in the experimental group who drew the structure of materials. A more significant increase was evident in drawing the structure of nylon and wool according to the particle theory.

Test E: No significant change was observed in the experimental group's performance. Most of the students in the experimental group (70%–90%) drew materials according to the particle theory. A slight decrease was apparent in students' drawing of nylon and wool. Less than 40% of the students in the comparison group drew the particle structure of materials mentioned in class such as iron, water, and oxygen and less than 20% drew nylon, wool, and paper according to the particle theory.

The molecular structure: Another aspect of the particulate structure of matter is the "Molecular Structure of Materials". In this model students consider the particulate structure of materials and distinguish between the types of particles. Figure 3 depicts the percentage of students who drew the molecular structure of materials in tests A–E when they learned the topic "Materials".

Tests A and B: The results indicated that in the 7th grade, students in both groups had no knowledge about the molecular structure of matter.

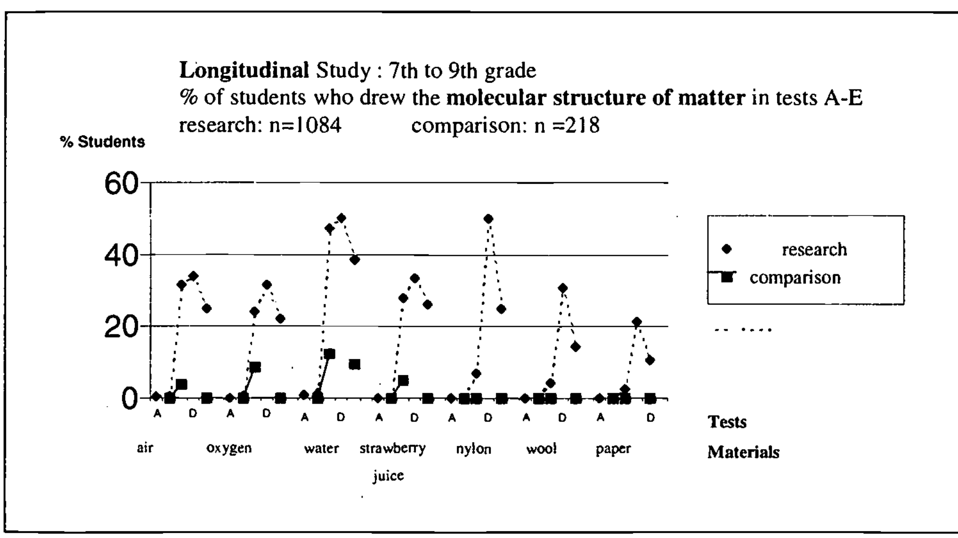

Figure 3: Students drawing the molecular structure of materials

Test C: There was an increase in the percentage of students in both groups who drew the molecular structure of air, oxygen, and water. The students' drawings referred to the differences between the molecules of the substances. Specifically, the students drew water as molecules of three atoms (two identical and one different) and oxygen as a material consisting of molecules of two identical atoms. 50% of the experimental group students drew the molecular structure of water, and more than 30% of this group drew correctly the molecular structure of air, oxygen and strawberry juice as a mixture. However, only 10% of the students in the comparison group drew correctly the molecular structure of air, oxygen and water. The students in both groups did not draw differently the structure of nylon, wool and paper and other solids.

Test D: There was a significant increase in the percentage of students in the experimental group who drew the molecular structure of nylon and wool correctly.

Test E: There was a decrease in students' ability to draw the molecular structure of materials. 40% of the experimental group and only 10% of the comparison group students drew the molecular structure of water. Most of the comparison group students did not draw differently the particles of most materials.

DISCUSSION

The research results indicated that the students who studied "Materials" according to the new Science and Technology curriculum underwent a process of conceptual change regarding the structure of materials.

Students' view of matter moved from the macroscopic level toward the microscopic level.

All students entered JHS (7th grade) without any knowledge of the particulate nature of matter. Their description of the structure of materials was always on a macroscopic level. Gradually the description became less macroscopic, and toward the 9th grade the structure of materials was always described using the microscopic view.

In the comparison group, who used different teaching units for this topic, there was a slight increase in the percentage of students who described the particulate view of materials, with a significant difference between the two groups in favor of the experimental group.

We can identify three main mental models regarding students' conceptions of the structure of matter:

Model A: "Continuous substance". According to this mental model students consider materials as continuous substances. They draw the structure of materials using the macroscopic view.

Model B: "Basic particle model". According to this mental model, students consider materials as substances consisting of particles without distinguishing between the types of particles.

Model C: "Molecular structure model". According to this mental model, students elaborate the particle model and distinguish between different types of particles.

Clearly, students in the experimental group improved their understanding of the structure of matter in their 3 years of studying materials in JHS. More specifically, 75%–95% of the experiment group students changed from the continuous substance model (model A) to the basic particle model (model B). For example, they changed in considering water as a continuous substance (model A), to its being composed of particles (model B). The retention of the basic particle model was very high. These results show that students understood and internalized the basic particle model.

About half of the experimental group students changed from model A to model C. For example, these students correctly described the molecular structure of water and even the structure of polymers, such as nylon. However their retention of the molecular structure model was less than that of the basic particle model. The possible explanations for this finding are: (a) The molecular structure of matter was studied at a later stage (8th grade). (b) The students had to use their memory in order to draw the molecular structure of different substances. They succeeded in doing it close to the actual instructional period, but had difficulties in drawing the detailed molecular structure a few months later. We believe that most of these students do have a correct concept of the molecular structure of matter even if they cannot draw the specific molecular structure.

In the comparison group, a smaller number of students changed from model A to model B, but very few reached model C, and were not able to distinguish between the types of particles.

Piaget and Inhelder (1974) reported on the development of "atomistic" ideas in children's thinking, at ages 11–12. Fensham claimed that particle concepts are "too difficult" (Fensham 1994). The evidence presented in this study suggests that the particle concept can be successfully taught in junior high school using meaningful learning and appropriate methods of teaching. One method is to teach the particle theory constructivistically. The study of the particle model is a lengthy process of conceptual change (Nusbaum, 1998) which requires an extended period of time. Teachers should apply appropriate strategies and methods that involve students in constructing the desired meaning of scientific concepts and which help them undergo the desired conceptual changes.

An additional method is to teach this subject based on a "spiral" model, which involves teaching the topic in several steps, so that at each step, the basic ideas are presented, repeated, and refined, and consequently, a deeper and more meaningful understanding is acquired.

REFERENCE

Andersson, B. 1990. Pupils' conceptions of matter and its transformations. *Studies in Science Education,* 18, p 53–85.

Ben-Zvi, R., Eylon, B. & Silberstein, J. 1986. Is an atom of copper malleable? *Journal of Chemical Education*, 63,p 64–66.

Brook, A., Briggs, H. & Driver, R. 1984. Aspects of secondary students' understanding of the particulate nature of matter (Leeds: Center for Studies in Science and Mathematics Education, University of Leeds). *Education*, 71 (4), p 615–628.

Driver, R., Squires, A., Rushworth, P. & WoodRobinson, V. 1994. *Making Sense of Secondary Science – Research into Children's Ideas*. (London: Routledge).

Fensham, P. 1994. Beginning to teach chemistry. In P. Fensham, R. Gunstone and R. White (eds.), *The Content of Science: A Constructivist Approach to its Teaching and Learning* . (London: Falmer), p 14–28.

Gabel, D.L. 1993. Use of the particle nature of matter in developing conceptual understanding. *Journal of Chemical Education*, 70, p 193–194.

Israeli Minestry of Education, (1996). *Science and Technology Curriculum for Junior High Schools*, Jerusalem, Israel . In Hebrew.

Johnson, P. 1998. Progression in children's understanding of a "basic" particle theory: a longitudinal study. *International Journal of Science Education*, 20 (4),p 493–412.

Margel, H. 1997. *About Fibers* . Weizmann Institute of science. Rehovot, Israel. In Hebrew.

Millar. R. 1990. Making sense: What use are particle ideas to children? In Lijnse, P., Licht, W., De Voss &.Waarlo, A.I. (Eds). *Relating macroscopic phenomena to microscopic particles.* Utrecht, The Nethwrlands: (University of Utrecht).

Novick, S. & Nussbaum, J. 1978. Junior high school pupils' understanding of the particulate nature of matter: an interview study. *Science Education*, 62 (3), p 273–281.

Nussbaum J. 1996. *The Structure of Matter: Vacuum and particles*. Weizmann Institute of science, Rehovot, Israel. In Hebrew.

Nussbaum J. 1998. History and philosophy, philosophy of science and the preparation for constructivitist teaching: The case of particle theory. Chapter 6 in *Teaching Science for Understanding: a Human Constructivitist View.* (Academic Press).

Piaget, J., Inhelder, B. 1974. *The Child's Construction of Quantities*: *Conservation and Atomism.* (London:Routledge & Kegan Paul).

Renstrom, L., Andersson, B. & Marton, F. 1990. Students' conceptions of matter. *Journal of Educational Psychology*, 82 (3), 555–569.

Scherz Z., Margel, H., Yayon, M & Shacrae, Z. (1997) *From Elements to Complex Structure*, Weizmann Institute of Science, Rehovot, Israel. In Hebrew.

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