Learning About “Materials” in Junior High School: Development of Curriculum Materials, and a Longitudinal Study of Students’ Conceptions

Thesis for the degree Doctor of Philosophy

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August, 2002

Submitted to the Scientific Council of the Weizmann Institute of Science

Rehovot, Israel

Abstract

One of the main topics of material sciences is the structure of materials. A meaningful understanding of the structure of materials can help students to form a solid scientific and technological basis for future studies, and assist them in decision-making processes as future citizens.

This thesis focused on students’ conceptions of the structure of materials in Junior High School (JHS). This study investigates the changes in JHS students’ conceptions of the structure of matter in conjunction with the development and implementation of new learning materials and instructional methods aimed at developing students’ conceptualization of matter.

The first goal of this thesis was to study students’ conceptions about the structure of materials as they learn the topic “Materials” (grade 7-9). This was accomplished by a longitudinal study on students’ conceptions of this topic. The longitudinal study investigated the changes in JHS students’ conceptions of the structure of matter while studying a new series of three units about ‘Materials’. The first unit ‘The Structure of Matter: Vacuum and Particles’ develops a thorough understanding of the particulate nature of matter using a constructivist approach. The second unit ‘From Elementary to Complex Structure’ extends this model into an atomic/molecular model. The third unit ‘About Fibers’ consolidates the understanding of the structure of materials, by using the Science-Technology-Society (STS) approach. 1300 students, from experimental and comparison groups, represented the structure of several materials verbally and visually in questionnaires administered five times during a 3-year period. About 85% of the experimental group reached a microscopic model, and 36% reached a molecular model versus 23% and 5% in the comparison group, respectively. Six months after studying ‘Materials’, about 83% of the experimental group represented a microscopic model versus 22% in the comparison group, and about 23% of the experimental group represented also a molecular model versus 1% in the comparison

group. Five qualitatively different development profiles of students' conceptualisation were found.

The second goal of this thesis was to develop, implement and evaluate new learning/ teaching materials and instructional methods relating to the structure of materials.

This was accomplished by:

1. Development, implement and evaluate the third unit of the new "Materials" curriculum: 'About Fibers'.
2. An exploratory study aimed to examine the feasibility and the potential contribution of using the Scanning Tunneling Microscope (STM), which enables inspection of materials at atomic level resolution, as a learning tool on JHS students' conceptions and convictions of the structure of materials.

"About Fibers" is a new interdisciplinary learning unit for JHS that uses the STS approach, emphasizes the macro/micro view of materials, and consolidates understanding of the structure of materials.

"About Fibers" has three main goals. The first one is to understand the basic concepts of the structure, properties, and applications of materials as well as the relationship between them with regard to fabrics, threads, fibers, polymers, and composites. The second goal is to cultivate scientific and technological literacy for all citizens by emphasizing the interaction between science, technology, and society with respect to the world of fibers. The third goal is to develop inquiry and learning skills. This is accomplished by evolving students in asking questions, planning, and participating in scientific experiments, as well as reading scientific literature, presenting and representing knowledge. Different kinds of projects are used in conjunction with the unit, enabling students to learn about topics that interest them in the ways that they prefer, enhancing the basic understanding of the structure, properties, and applications of polymers and fibers.

The implementation of the unit "About Fibers" was in conjunction with the professional development of the teachers. Several types of in-service workshops were conducted. During the years 1998-2001 this unit was implemented in 40 schools, in different school districts throughout Israel, including 170 classes, totaling about 5000 students. The results indicate that the students who studied "About Fibers" underwent a process of conceptual progression regarding the structure of materials: A significant improvement was observed in students' descriptions of the particulate model and molecular structure of materials. The students found most topics of this unit important, interesting, and not difficult. The teachers expressed their satisfaction from the unit.

The second way to improve JHS student's conceptions of the structure of matter was an exploratory study, which examined the feasibility and potential contribution of using the STM as a learning tool in JHS to support instruction about the particulate nature of matter. For this purpose, Fifteen JHS science teachers and sixty students visited a materials research laboratory at the Weizmann Institute of Science. After hearing a short introduction about the functions of the STM and its applications, the teachers and students performed several tasks. The results of this study showed that although the teachers were concerned about possible difficulties in using the STM with JHS students, this activity contributed to the students' understanding of the particulate nature of matter, and to their conviction of its existence. Students who demonstrated a particulate conception of matter before the STM activity were succeeded in "seeing" atoms, although what they actually saw were bright and dark areas. Students who did not demonstrate a particulate conception of matter before the STM activity were more convinced about the existence of atoms after the activity.

The evidence presented in this study suggests that the particulate nature of matter can be learned provided appropriate curricula and methods of teaching are applied.

The results of this study suggest that it is useful to include the following components in a curriculum whose aim is to enhance a meaningful conceptualization of the structure of matter:

- Building a solid foundation of the particulate nature of matter by using a constructivist approach.
- Teaching the structure of matter in several steps using a 'spiral' approach.
- Integrating macro/micro views of materials
- Using knowledge-integration activities such as concept mapping and special organizing tools to enhance students' understanding of the relationship between the structure, properties, and applications of materials.
- Using new instructional methods such as STS to enhance the understanding of the structure of materials.
- Using high-resolution microscopy as a learning tool can enhance students' understanding and conviction in the particulate nature of matter but cannot replace in-depth instructional methods leading to conceptual change.