Materials Science: The Missing Piece in High School Science Curricula

Lisa Ogiemwonyi
Stoney Creek High School, Rochester Hills, MI
logiemwonyi@rochester.k12.mi.us

Abstract

The incorporation Materials Science into the High School curriculum is shown to improve knowledge, interest and understanding of science among the student body. This study focuses on effects on student perception and interest. Results demonstrate that the introduction of materials concepts into both general science and specific Materials Science courses resulted in enhanced interest and understanding of science. In addition, many students indicate an interest in careers in the materials area.

Introduction: What is materials science?

Materials Science is an area of science and technology that focuses primarily on the chemistry, physics, and engineering of solids. Solid materials are often classified into the four general areas of metals, polymers, ceramics and composites. In Materials Science, solid substances are examined for their structure and properties from a chemical, physical and engineering standpoint. Depending on their properties and behavior, materials are then chosen for their specific applications in society.

Why is it important and how does it fit into the curriculum?

Materials Science is commonly nicknamed the “science of stuff”. ASM International, the Materials Information Society, uses the slogan, “Everything is Material.” Materials Science touches every area of our lives because most of a person’s everyday life depends on and is affected by solid substances. Human beings have used solid materials for all of history, but the study of Materials Science as a specific subject is relatively new. Materials are the building blocks for many industries including aircraft, automobiles, biomaterials and electronics. Materials have become a key focus in the fields of engineering, chemistry and physics at many universities.

Because Materials Science is not often taught as a pre-college subject, many students are unaware of this field as a future career choice. The supporters of programs like the ASM Materials Camps believe that if students get excited about science and technology, then more students will choose to study science and technology careers at the university level. It should then follow that more students will also enter fields like engineering.

Traditional high school science classes address the common phases of matter as solids, liquids and gases. After a simplified version of the particle arrangement and relative amount of energy in each phase is presented, the topic of solids usually takes a back seat to the chemistry of gases and liquids. Basic chemistry courses primarily focus on things like solution chemistry, chemical properties and reactions, and the behavior of gases. From this point on, the chemistry of solids is rarely mentioned again.
Relationship to Science Standards

In 2007, Michigan introduced new High School Science Content Expectations. The new expectations focus on Scientific Inquiry, Reflection and Social Implications and then specific content area for Earth Science, Biology, Chemistry and Physics. Of particular interest is a section of eight specific Core Content Statements under the topic of Solids. These statements include the classification of solids as metallic, ionic, covalent or covalent network. Properties like malleability, conductivity, and melting point in relation to a solid’s structure and bonding are also mentioned. Another content statement specifically focuses on the ability for students to understand the process of melting of a crystalline solid at the particle level. Other content statements focus on carbon chemistry and changes of state. One content statement discusses the relationship of melting point, hardness, and electrical and thermal conductivity to the structure of a substance. These new Content Expectations show a definite increase in the amount of focus on the chemistry of solids.  

Examination of the Materials Science and Technology (MST)\textsuperscript{4} curriculum shows how it is naturally aligned with National Standards, particularly in the area of an interdisciplinary approach to education. The MST curriculum successfully makes connections between math, science, technology, social studies, the arts and technical education. The strongest correlation is seen in the areas of Scientific Inquiry and Investigations, Physical Science, and Science and Technology.\textsuperscript{5} The MST curriculum also meets School to Work guidelines set by the Federal Government to, “broaden educational and career opportunities for all students by encouraging state and local partnerships between businesses and education institutions.”\textsuperscript{4}

Successes in including materials science in schools

Many teachers have found that the content of Materials Science is useful in exciting students about science and technology. Since the initial inclusion of Materials Science and Technology into high school curricula, MST has seen much success in many states across the nation like Washington, California, Oregon, Florida, New Mexico and several states in New England.\textsuperscript{6} One study done by Guy Whittaker in 1992 at a large public high school in Washington State recorded student perceptions of an MST program. The students overwhelmingly responded with great enthusiasm to their MST course.\textsuperscript{7} Another student study in 1997 and 1998, found consistently positive results from high school students in MST programs.\textsuperscript{8} Even beyond all of the anecdotal success Materials Science Programs have generated, universities in states like Florida and Washington where secondary Materials Science programs exist are reporting a definite increase in the number of entering students interested in materials science and engineering.\textsuperscript{2}

This Study

Between the years of 2006 and 2008, a study was performed at a small charter school in an urban area of Michigan. The study involved two phases of including Materials Science into the high school science curriculum. In the first phase, Materials Science activities were added to the science curriculum in grades eight though twelve in the areas of Physical Science, Earth Science, Biology, Chemistry and Physics. In the second phase, a one-semester Materials Science elective course was developed for tenth through twelfth graders.
Approach

The inclusion of Materials Science offered a hands-on approach to science and with a focus on cooperative learning. The elective course also provided some technical education in a school that does not offer any other vocational education within the building. The class was also meant to give students a new avenue of choices for future studies and careers in science.

Students were first introduced to the basic concept of materials as seen from a Materials Science perspective. Students were given common classroom and household objects to classify into the four general areas of metals, polymers, ceramics and composites and asked to justify their reasoning. This activity led to a discussion of the chemical, physical and mechanical properties of solids. Students became familiar with the chemical bonding of solids and their classification as either crystalline or amorphous. Methods of crystallization were explored including creating crystals from a solution by cooling or evaporation, performing a chemical reaction, or freezing from a melt. Students learned about different crystal structures and the defects and imperfections that can occur within crystals. Students grew single crystals from supersaturated solutions of copper (II) sulfate or potassium alum with the largest crystals reaching 2-3 inches in length. Experiments were done to work harden and heat treat a thick piece of copper wire, a bobby pin and a paper clip to demonstrate how changing the crystal structure of the copper changed its properties.

Next, students examined the physical and chemical properties of metals. The chemical reactivity of metals was determined experimentally to develop a basic activity series. Through this students learned the concepts of oxidation and reduction and basic reaction types. Common topics like corrosion and the mining of metals from ore were used to explain practical applications. The physical properties of malleability and ductility were explored in drawing copper wire and rolling a penny. Students created alloys of tin and bismuth, and of copper and zinc. Solid tin was melted and poured to demonstrate the process of casting and the effect of temperature on the rate and size of crystal growth. Students were also introduced to the memory metal, Nitinol, and its applications.

In studying polymers, students became familiar with the basic structure and properties of polymers including simple carbon chemistry. Students experienced the expanding and shrinking of plastics using heat. A heated milk jug was used to show the amorphous or crystalline structure of plastics. Students learned about the formation of polymers through either addition or condensation polymerization. Condensation polymerization was demonstrated by making Nylon 6-10. Styrofoam and starch packing peanuts were used to demonstrate the differences between natural versus synthetic polymers. Bonding between polymer chains was shown through cross-linking which students did by creating slime from a polyvinyl alcohol solution and a sodium tetraborate solution. Students also created “gluep” by mixing a white glue solution with sodium tetraborate. Students learned about the classification of polymers as either thermosets, thermoplastics, or elastomers. Students created a polyurethane resin and foam. Two forms of sodium polyacrylate were used to show some common uses of polymers.

Students were able to see the formation of a ceramic as oxide coatings were created in the iron wire demonstration and melting an aluminum wire. Metal and ceramic properties were also compared by heating an aluminum and alumina rod in contact with each other. In the lantern mantle demonstration, students learned more about the properties of a ceramic. Finally, students worked through glass stations where they could heat and manipulate glass by bending, stretching and blowing.
Results

In both phases of including Materials Science in the curriculum, written surveys were given to quantify the impact on students’ learning, interest level, and future plans. In the first phase, students who had been exposed to Materials Science experiments or demonstrations in all science courses (Biology, Chemistry, Earth Science, and Physical Science), grades 8-11, overwhelmingly responded that they remembered the activities that were done over a year later from the time they were presented. In many cases, the number of students who remembered a particular activity was 100%.

The number of students who reported that doing these experiments increased their interest in science class was entirely positive, as expressed in Figure 1. On the average, 96% of the students agreed that their interest level in science increased and 5% of the students said that they were not sure. No one responded that the experiments did not increase their interest in science.

![Figure 1: Student Responses in General Courses Grades 8-11](image)

Similar results were found for students who felt the experiments increased their understanding of science concepts. An average of 92% of students said that their science understanding was increased and 8% were not sure. No one reported that their understanding science had not increased as a result of the activities.

In the second phase of the study, students in a one-semester elective Materials Science course were surveyed at the end of the course. 54% of students stated that they were currently interested in science and planning to pursue a career in science. 38% of students said that they were not planning to pursue a career in science before this course, but now they are. 54% said that they are now specifically considering a career in Materials Science or a related field because of taking this course. 92% of the students reported that the Materials Science course has helped them develop skills in using tools or equipment they did not know how to use before. These results are presented in Figure 2.
Figure 2: Student Responses from Materials Science Course

Figure 3: Student Responses from Materials Science Course
Students agreed at the 92% level (54 + 38 in Figure 3) that taking the Materials Science class had increased their interest in science. One student (8%) said that he or she already had a high interest in science. 100% of the students agreed that taking the Materials Science class had increased their understanding and knowledge in science.

Students were asked to rate their interest level before and after taking the Materials Science course. 85% reported a positive change in their interest level. One person did not have a real change in interest level because they started out interested and finished interested.

Students also reported that the Materials Science class had given them new skills that would probably be helpful in a future class, job or college (54%, see Figure 4). 46% of students said they were unsure on this point, while no students directly said they had not gained skills that would help in the future. 92% of the students said that they would recommend this class to others while 8% said they were not sure.

Some students responded to how this class had helped them in other places. Four students mentioned that Materials Science class had helped them on standardized testing on the ACT and the Michigan Merit Exam (MME). Five students said Materials Science helped them with their chemistry class and two other students mentioned English and another science class. Five people said that Materials Science helped with their everyday understanding of things in general.
When asked what students liked about Materials Science class, two answers that came up most often were that the class was fun and that students were able to do things they had never heard of before. Students used words like “awesome” and “cool” and “interesting”. Students also mentioned the hands-on learning. One student even mentioned that it changed his or her perception of their future career.

Some examples of comments were:

“I thoroughly enjoyed this semester of Materials Science. I’ve learned so much and did so much. It is one of the best electives I have taken and I am the school offered it.”

“Amazing class! I love lab activities and all the random things we made. I was so happy how this class helped me in my Chemistry class. I definitely did better in Chemistry after taking Materials Science.”

Conclusions and recommendations

Materials Science is a very important area of science that is rarely focused on in high school curricula. Hopefully, this study will increase awareness for teachers to include Materials Science in their normal science courses. I would also like to encourage teachers and schools to offer Materials Science as an elective. The ASM International Educational Foundation, MatEd, and other similar organizations offer a tremendous amount of curriculum materials and training to make this a reality for teachers. Materials Science as a pre-college course can offer many opportunities. Materials Science not only applies to many careers, but also to the common things students encounter in life like sports products, hobbies transportation, building materials, etc. There is the possibility for team teaching or interdisciplinary projects between technology, art, woodshop, metals, and history departments. The course can be offered as a vocational or science class.

Most importantly, as can be seen from this study, the student results are incredible. The students are excited about science in a new way. They have gained skills and experiences that they would not have otherwise had. Some students have discovered an interest in science while for others, this has opened a whole new door for the future.

References

5. Material Science and Technology Alignment with the National Science Education Standards, by Vicky Lamoreaux, Pacific Northwest National Laboratory Office of Science Education Programs, Richland, WA http://www.materialseducation.org/ealrs/ns_hm.htm


9. ASM Materials Education Foundation, http://www.asminternational.org/portal/site/www/foundation/; see especially the ASM Teachers Camp program listed under "Educators."


Acknowledgements

Special thanks to ASM International and National Resource Center for Materials Technology Education (MatEd) for their assistance with this project.