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Where Do Our Students Encounter Materials: Everywhere and Rarely

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ABSTRACT

In our increasingly digitized and safety conscious society, we tend to shield our children form real contact with the material world and tend to steer them increasingly to only virtual experiences. Appliances are not repaired but replaced. So are materials used in everyday life. As a consequence, we cannot assume experiences with materials which were a given in the past. In this article, we will concentrate on both K-12 and Undergraduate education with examples of the necessity of consciously encountering "materials" in our increasingly digital society, and how students can be taught to realize the properties and necessity of consciously encountering materials. We will draw our examples from the lack of that experience students bring to undergraduate research, and how that deficiency can be remedied.

INTRODUCTION

Teaching and learning are very complex subjects, as is the differentiation between what is being taught and what is being learned. Most of us will agree that many of the teaching methods currently used will work well with some students, and that some students will learn no matter what the teaching method. Education does not start in school or even pre-kindergarten. It starts at a very early age. This article is written to call attention to a trend in the developed world which deprives some of our youngsters of the experiences which enhance Materials learning in STEM (Science, Technology, Engineering, and Mathematics). There are now many efforts to supplement and/or remedy this: computer simulations, robotics activities such as FIRST Robotics (usfirst.org), Project Lead the Way (pltw.org) and the Infinity Project (smu.edu/Lyle/Institutes/CaruthInstitute/K-12Programs/InfinityProject) and hands-on experiences. Lately there has been some recognition that these practices should be a basic element in the curriculum. Those efforts are, however, not universal.

For years many of us have deplored the state of STEM education in the United States. The TIMSS study ranks U.S. fourth graders in 11th place in mathematics and eighth graders in 15th place in 2003. The scores were somewhat better in science with U.S. students in 6th and 8th place.[1] The 2007 statistics are similar in mathematics: 11th in fourth grade and 15th in eighth grade; in science we came in at 8th and 11th, respectively, behind countries such as Latvia, Hungary, Slovenia. The results were somewhat better in the 2011 reports with some states coming in near the top.

Despite many initiatives by the federal government,[2] scientific organizations,[3] and numerous efforts by teachers and local school districts, we still see newspaper articles such as "CEO caught in hiring dilemma,"[4] describing the difficulty of the CEO of the Raytheon

Corporation to find qualified people to fill its technical staff positions. Such shortfalls exist despite the current state of unemployment.

DISCUSSION

I suggest that Materials education in the U.S. will not improve until we recognize that our children enter the lower grades with a lack of certain experiences that are useful for understanding materials as well as the subjects which are taught in the overall STEM curriculum, and this lack of experience is exacerbated by the ways we try to convey and treat Materials and STEM subjects in the early school grades. We need to structure our curriculum to address this problem. This restructuring will not necessarily increase the STEM workforce, but we would have a better educated workforce in any case.

We need to recognize that the handicap is partially caused by the ubiquitous technology which, despite making our lives easier, hinders our children from learning the skills that are prerequisite for Materials and STEM careers. Although that technology is useful for the development of other skills and understanding and in circumstances where real life hands on activities are not possible or available, as of now, it is not applied completely effectively. Because the technology replaces many of the necessary processes such as counting, weighing, exchanging money, etc., our children are not exposed to activities which, in previous years, were part of everyday life, and are still necessary today, especially in STEM. Many technology teaching initiatives are now available, however, in many cases they are used for remedial and supplementary purposes. The Atlantic magazine asked: "Is Google making us stoopid?"[5] It is not only Google, but much of our modern technology that contributes to this lack of early experiences.

How are we to understand this? An analogy is that of driving a car. It is necessary to know how to unlock the car, start it, and know where the steering wheel, accelerator, and brake pedal are, as well as how to turn on the lights. No knowledge is required of the workings of the internal combustion engine, the alternator, battery, or the computer system that controls the functioning of the car. Most people can get along well without this knowledge as long as nothing goes wrong. If something does go wrong, we need to repair it, and often it takes only the knowledge of a phone number or an e-mail address to get help to fix the problem. The repair is often a replacement of a part, which is done by a technician whose knowledge often is confined to which part to replace. Some technicians do not really understand the principles on which the appliance – a car in this case – is based.

In contrast, it is necessary for Materials and STEM education to understand the bases and principles, both qualitative and quantitative, on which our technology is built. Ordinary people, much less children, do not to need that knowledge in their day-to-day life, and if people do, all they need is to know is how to contact someone who can fix a problem, as cited above. We live in a non-quantitative society.

Most of the older STEM workforce grew up in an environment quite different from the present. If you grew up 50 or more years ago, you went to a grocery store, chose the produce, weighed and bagged it, and went to the cashier to pay. The grocer would reweigh the items, figure the cost, often writing on the bag with a pencil, and you would pay with cash, either by giving the correct change or making sure that you received the correct change back.

These experiences gave us a sense of mass, weight, and quantity. The consumer had to use arithmetic to make sure that he or she or the grocer did not get shortchanged. Similar skills were acquired by shopping for other goods, such as clothing when it was made to order. These experiences were still available and necessary a few decades ago in Europe, when supermarkets were still a rarity. I am reminded of my experience in Holland, in 1989, where I spent a sabbatical. I had to go to a butter shop to buy butter, a cheese shop to buy cheese, and a bakery to buy bread, etc.

Today, we go to a supermarket, take a box, bottle, packaged vegetable, or fruit off the shelf, put it into a shopping cart, bring it to the checkout counter where it is scanned and payment is made with a credit card or a smart phone. There is usually no encounter with weight, mass or numbers, or any other physical and mental attributes necessary for either Materials or STEM education.

Although today's technology makes our lives easier and in some makes experiences available which might not be otherwise accessible, it deprives students of the early opportunities that would help them to master the skills on which they are tested for adequate performance in STEM subjects. We test our students about numbers and quantities which were necessary in the past for living in our society. Today those going into STEM subjects need visceral hands-on experiences with the physical world, and these experiences are lacking. A curriculum needs to be developed to bring such experiences into the early grades.

In order to prepare our children for Materials and STEM careers, we need to expose them to more play and hands on activities. That can be done in kindergarten playrooms, playgrounds, as well as having our children go shopping with their parents. The latter should be structured in ways other than the child just sitting in a shopping cart. The child should consciously participate in the shopping experience and be told how much the products cost, how heavy they are, for instance a gallon of orange juice, and how that differs from the weight of another product of equivalent volume. Examples of such early preparation for Materials and STEM consciousness are suggested in the acceptance speech for the 2000 Oersted Medal by John King, of MIT.[6] In that article there is a wish list for the better early preparation of students for careers in Physics, which can equally apply to careers in Materials. That wish list includes:

1) "Play with better toys than are presently available"
2) "Play in playgrounds that gently develop quantitative views"
3) "Use tools and kits to make introductory projects"
4) "Acquire information from small things: wrappers, posters, etc."

This lack of early experiences is exacerbated by some of the latest educational practices and philosophy which embrace the notion that the teacher can get a better understanding of students' ways of thinking by encouraging them to express their preconceived ideas, without the teacher criticizing, approving or disapproving. This practice is essentially the Socratic method applied inappropriately. The Socratic method is to teach reasoning through questioning, and to arrive at the correct answer through such reasoning, while, as currently applied, the procedure consists of only the questioning. This leaves the student without the concept of correct methods, facts, or answers. This often occurs to the detriment of teaching essential facts about the world, correct reasoning, and accepted ways of thinking. It also hinders the development of reasoning necessary for the correct quantitative conclusions.

An additional hindrance is the teaching of advanced subjects, such as algebra and calculus, before the prerequisite arithmetic and manipulation of numbers have been adequately addressed. By "putting the cart before the horse" students run into many difficulties in understanding the world around them and the Materials and STEM subjects.

An example of this philosophy is the following quotation from the Massachusetts Mathematics Teaching Standards[7]: "For children to develop confidence in their problem-solving abilities, teachers should be supportive in responding to "wrong" answers. In estimation, for instance, teachers should reassure children that being absolutely correct is unnecessary — children may need the opportunity to change their estimates as the activity evolves." A similar philosophy is expressed in the "Conceptual Framework for New Science Education,"[8] although the latter also recommends a "hands on" curriculum which might improve our current STEM curriculum. Estimation should not be taught to the exclusion of quantitative calculation.

The lack of background experience is particularly visible in college students. My experience is with college students who major in engineering and physics, and who have passed several physics and engineering courses with good grades. They know the principles of physics and have had several labs to demonstrate those principles, those procedures and the results which followed.

In my research lab, which is somewhat disorganized, on purpose, contains functioning instruments and electronics, electrical components, tools, etc. In addition, I have collected chargers from computers, phones, pads and other electronics which have been discarded because they no longer function or have been replaced by more recent versions. When a student who volunteers to work with me first comes into my lab, I ask him/her to break one of the chargers. This is both a test and a learning experience. It also makes the students realize that those mysterious boxes can be understood and demystified.

I give the student a large screwdriver, a hammer, and point him/her toward a vice. Very often the students have not consciously seen any of the instruments. They are unfamiliar with working with those instruments as well as with pliers, wires etc. Moreover, they have never broken anything on purpose. Usually, with some help and prompting, the student manages to break a charger and see what is in it. Generally there is a transformer, some diodes, capacitors and resistors. When I ask the student what those components are, they generally are not able to recognize them, although they have seen them, or their symbols, in their course books and know how they function. We need to connect book knowledge with a conscious recognition of the visual and tactile reality. My last student, when asked to break a charger, went on Google to find out how to do it. Amazingly, there was a clip which showed a charger being broken. It was not sufficient to help him in his task, and he needed some more instructions to succeed.

I hope that the example illustrates how one can remedy the lack of experience students bring to Materials and STEM education. In the words of A.N. Whitehead[9], our understanding of reality should be based on a visceral experience, and one should realize that "The connection between intellectual activity and the body, though diffused in every bodily feeling, are focused in the eyes, the ears, the voice, and the hands."

Our present situation might be compared to past educational reforms, which, taken to extremes, had negative outcomes for STEM education. In the preface to a physics text published in 1892,[10] the authors write: "During the past decade the teaching of Physics in high schools and universities has undergone radical revision. The time-honored recitation method has gone out and the laboratory method has come in. As a natural reaction from the old regime, in which the teacher did everything, including the thinking, came the method of original discovery; the textbook was discarded and the pupil was set to rediscovering the laws of Physics. Time has shown the fallacy of such a method, and the successful teacher, …has already discovered the necessity of a clearly formulated, well digested statement of facts, a scientific confession of faith, in which the learner is to be thoroughly grounded before essaying to explore for himself. The maxim, 'That only is knowledge which the pupil has reached as the result of experiment,' has been found to have its limitations. With no previous instruction, the young student comes to the work without any ideas touching what he is expecting to see … He has no training in drawing conclusions from his own experiments. He …will not be apt to discover little beyond his own ignorance, a result, it must be confessed, not necessarily without value. Before the pupil is in any degree fit to investigate a subject experimentally, he must have a clearly defined idea of what he is doing, an outfit of principles and data to guide him, and a good degree of skill in conducting an investigation."

CONCLUSION

In summary, to make Materials and STEM education more effective we need a greater emphasis on practical skills, and we must recognize and correct the lack of experience necessary for an effective understanding of Materials and STEM.

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