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Editors: Mariko KOBAYASHI, Haruhiko FUNAHASHI
Translation: Michael M. HULL

“If you Could See an Atom” is the most popular Classbook of the HEC materials; both children and their teachers greatly enjoy education regarding molecular models. In both Japan and in the West, “reading, writing, and arithmetic” was long considered to be the most basic educational content necessary for the common person. The author argued that “molecular models” should be added to this list and show the path to a bright future of education.

Reading, Writing, Arithmetic, and Molecular Models

Argument for a New Common Sense for Molecular Models

Kiyonobu ITAKURA

Teachers who are too “theory-driven”

The HEC Classbook “If you Could See an Atom” is based upon the picture book “If you Could See an Atom” in the Dr. Itazura’s Science Books [Vol. 7, Kokudo-sha, 1971]. For the Classbook, we added an introductory section where students color models of molecules on paper and make molecular models using polystyrene spheres. Strictly speaking, we should not consider the class actually to be a “Hypothesis–Experiment Class”. Rather, it is an example of “Image Verification Class”, which is part of HEC in a broader sense.

However, it serves as a foundation of common knowledge that the public should be educated in. As such, it has been welcomed by students and disseminated by teachers to a degree that surpasses my expectation when I wrote the book. I think part of the reason for the success of this class is that it was not a “Hypothesis–Experiment Class” in the strict sense of the definition.

School science teachers are much more theory-driven than teachers of other topics. Although that might generally be a positive attribute, it can also have a negative impact. The other day, I was surprised at the negative reaction I received from sciences teachers who were already familiar with our materials. I told them that we are teaching the molecular model in the first grade of elementary school and, in some cases, even in kindergartens, with great success, and they looked at me like I was a madman wreaking havoc in the school system. For me, this was a strong reminder of how revolutionary our proposal to introduce molecular models to young children was.

Teachers who are theory-driven (be they science teachers or not) may be assuming that teaching about atomic and molecular models implies teaching also why those models are appropriate and accurate. Their argument perhaps goes like "Since elementary school teachers likely do not have that understanding themselves, how can they teach that to their students? To try to teach molecular models would just be cramming meaningless knowledge into students' heads." We argue that it is incorrect to argue that everything should be taught from first principles, drawing upon scientific reason. Certainly, there are some topics where reason should be utilized in the students' learning. However, there are other topics where that need not be the case. In the end, the value of the lesson is determined by how enjoyable the children find the lesson.

"Reading and Writing" education takes precedence over logic.

Let us consider the "Reading, Writing, Calculation" that is taught to all humans as the most fundamental education. Is there any teacher who teaches children why letters are written the way that they are? Although the Japanese letter あ has a historical connection to the Chinese character 安 that some adults may know about, this connection is never taught to children when they are learning the alphabet. This is a prudent decision, because children don't need to know this, nor are they interested. They are motivated just to be able to read and write the letters that are used in their society quickly. No one will argue that you are "forcing children to learn something without allowing them to make personal sense of it."

It is old-fashioned to oppose early education of the molecular model.

The molecular model that we use, the "space-filling model" should be distinguished from the "ball and stick model" that is preferred by chemists. The ball and stick model represents the center of an atom as a small sphere or polyhedron, connected to other atom centers via long rods. The model is frequently used, so it is likely that non-chemists have seen it as well. It has the benefit that, in the case of a complex molecule, the structure is easier to see than the space-filling model that we use. Despite its popularity among chemists, I have avoided it and adopted instead the space-filling model because it seemed less complicated in appearance and more friendly while also being more accurate.

Fortunately, experts have recently consented that the space-filling model is often easier to understand, and models similar to our own appear in various places. Like us, scientists are making molecular models when enlightening the world of molecules. I am happy about this because it suggests that we can think of molecular model education as being a fundamental requirement of a person's education, together with "reading, writing, and calculation".

The existence of atoms and molecules was long debated by scientists. During this period, if you would suggest that all elementary school children should be educated about atoms and molecules, it should be expected that scientists who denied their existence would raise their voices in opposition. However, in the second half of the 20th century, even the most stubborn of scientists came to recognize the existence of atoms and molecules. It is an anachronism to assume that teaching children about atoms and molecules today is the cramming.

When I wrote the picture book "If you Could See an Atom", I intended it for readers in "4th grade or more". However, thanks to Megumi Ito (Elementary School in Tokyo) boldly using the Classbook with 1-2 graders ["Little Atomists", Kasetu-sha,1998], it is no longer uncommon for the book to be used in lower grades. It has been found that first graders who want to learn to absorb knowledge about molecules just as eagerly as they learn alphabet and calculations.

The importance of atomistic thinking and the attractiveness of molecular models

In fact, the main reason why people who continue to oppose the early education of molecular models do so because they cannot imagine how widespread the effects of such education can be.

Even when I first wrote the book "If you Could See an Atom", I could not say how useful that knowledge would be. When I was in 5th or 6th grade, I happened to read a book that mentioned being able to "see atoms and molecules when using *chemistry glasses*" and I found that I could then imagine atoms and molecules to be visible. Although the education I received at that time was generally not very good, the image given to me by this book was effective. So when I came to specialize in science education, I thought "first of all, I want to write a book titled 'If you Could See an Atom' ".

Furthermore, since I first decided to specialize in science history in my first year at the university, I came to consider that atomistic thinking contributes to the development of scientific research far more than normally thought. I hence decided to aim the Classbook "If you Could See an Atom" at children, thinking it to be better to teach about atoms early on.

So, in hindsight, more than most people, I should have anticipated the importance of teaching about atoms and the popularity of the book I wrote. But when I saw people around me becoming obsessed with molecular modelling and how to teach it, I realized that I had underestimated its importance.

For example, I have observed a first-year elementary school student who has learned the molecular model walks outside the school, point at a red traffic light, and exclaim "ah, it's an oxygen atom!" The children who learned using this HEC Classbook not only familiarized themselves with the water molecule, affectionately calling it "red hotpants", but also came to learn about it, as evidenced by statements such as "the real name of the water molecule is dihydrogen monoxide". Although we did not teach molecular nomenclature, children inferred it for carbon monoxide, carbon dioxide, sulfur dioxide, etc. Teachers have seen children playing with the models, claiming "I am poison!" while holding a carbon monoxide model, and declaring that "I will change you to carbon dioxide!" with an oxygen molecule model in his hand. It is no surprise that these children were a fan of the manga "Atomic Man" by Satoshi Ogasawara (Special School for Young Children in Hokkaido). I could not have imagined such effects at first.

Nor is that all. Playing cards called "Mole Q", developed by Mr. Matsudaira (Elementary School in Iwate) has become a favorite children's game. It is so enthralling that even kindergarten children find and play the game. This was far beyond my expectations of how popular a molecular model could be for children.

The effectiveness of knowledge about atomic and molecular models

It is not just children in the lower grades who seem obsessed with molecular models. Children in the upper grades of elementary school, junior high school students, and high school students similarly become immediately obsessed when they first learn about molecular models, and they enjoy assembling molecules as they come to see their world as comprised of molecules. Their fascination is driven by an awareness of the usefulness of thinking in terms of these models for solving many problems in the world.

The fact that “sugar and salt seem to disappear when dissolved in water, but they are actually still there“ is easy to grasp if one thinks in terms of sugar and salt molecules mixing with water molecules. It is difficult even for many adults to be convinced that their body will increase in weight exactly by the weight of the food they have just ingested. However, if one thinks in terms of the atoms and molecules in the food, it becomes easily understood. The mystery of water increasing in volume as it freezes is explained when one learns the crystalline model of ice. Similarly, the mystery that “the volume of water mixed with alcohol does not necessarily equal the sum of the parts, although the weight does” can be explained with the molecular model.

Knowledge of molecular models is useful in learning other branches of science as well. When learning about the influences of forces in the Classbook “Springs and Forces”, for example, a student’s understanding can be deepened by viewing the force in terms of the molecular structure of the substance.

Most people forget how to add and multiply fractions soon after they learn it in elementary school. That is because the knowledge is of little use in real life. The basic knowledge of “reading, writing, and arithmetic”, however, will never be forgotten, because it is constantly used in real life. In the same way, knowledge of molecular models is constantly useful.

That is not, however, the impression one gets when one looks at past textbooks of science and other fields, which are not written on the assumption that children are already interested in molecular models and knowledgeable about them. Even if science textbooks do discuss something concerning with atoms or molecules, it does not necessarily utilize molecular models. This is because the textbook authors themselves are unaware of how those models could potentially be useful.

School children are not the only ones interested in molecular models. When Mr. Shichiro Yoshimura is invited to discuss environmental issues, he brings molecular models with him to explain how materials change when they are burned. His audience are largely elderly men and women with marginal academic background. As such, despite having much everyday knowledge, they have little scientific knowledge. When they listen to the lecture, however, they often express appreciation for the molecular models, saying “Oh, we can understand it easily if you explain it like that. Why wasn’t it explained this way to me much earlier?”

These are results I never expected when I created a Hypothesis–

Experiment Class and corresponding Classbook titled “If you Could See an Atom”. I am very proud that our research has been demonstrated to be so successful. As a result, I believe that the most basic education of the public should consist of “reading, writing, calculating, and molecular models”. Since everything is comprised of atoms and molecules, the molecular models represent a language to describe all substances. Therefore, the usefulness of molecular models can be constantly demonstrated in school not only in science class, but in home economics, mathematics, social studies, etc.

The atomism or the atom/molecule model?

Some may contend that “atomism” is what should be added to “reading, writing, and arithmetic” rather than “atomic or molecular models”. At one point, I was also inclined to agree. However, I am concerned that people might think that the “atomism” is too difficult to teach to children. We must also remember the result that it was the atomic and molecular “models” (and not the “theory”) that far surpassed my expectation in capturing the fascination of all, young and old alike.

I have always been an avid “atomist”. I think natural sciences today, Archimedes’ buoyancy theory, Galileo’s heliocentric theory, Newtonian mechanics, and so on, are based upon the atomism. That is why the Classbooks that teach these topics are based upon atomism.

However, it is the molecular model that we developed that succeeded in instilling in people an image of atoms and molecules far beyond what I had imagined. It is for this reason that I think it is better to say “reading, writing, arithmetic, and molecular model”.

Actually, Japanese physics textbooks for elementary school students in the early Meiji era, about 120 years ago, did contain descriptions of molecules. Nevertheless, knowledge of atoms and molecules did not become the common sense of the people, although knowledge of spherical Earth did. I think the key was that, while the whole Earth is too big to see, a small globe on the desk is a visible object that can appeal to our senses. This is what was lacking for molecules. If we wish to have atomism become part of society’s common sense, we must produce and disseminate the equivalent of the globe: namely, molecular models.

The education of molecular models has had a dramatic influence on our own teaching and on the students we teach; on the other hand, the world just outside our classrooms is a world where molecular models can scarcely be found at all. However, there is nothing particularly unique about us, nor about our students or their learning environments. When we consider that, it becomes clear that the education of molecular models has the potential to transform not only our students but the world around them as well.

Teaching about molecular models clearly captures the hearts of children. As such, education like ours is a powerful way to convince people that the future of education is dark not because children of today refuse to learn, but rather because schools don't teach children what they deserve to learn.

(End)