Chemical Education Journal (CEJ), Vol. 17 / Registration No. 17-205 / Received July 30, 2015.
URL = http://www.edu.utsunomiya-u.ac.jp/chem/cejrnlE.html

A Strategy for High School Chemistry Teaching : The Basic and Fundamental Content

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Keywords: high school chemistry, basic and fundamental content, teaching strategy

Abstract

The basic and fundamental content in the Japanese course of study for senior high school has been studied. The purpose of this paper is to define and discuss this content, and provide ideas that may lead to a new teaching strategy for high school chemistry.

Introduction

Authorities such as the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the board of education, and school principals are often heard to say that the basic and fundamental content [1] is of great importance in school education. However, they do not explain this in any detail, and in the past thirty years of my teaching, I have never heard what that content actually is.

In my educational experience, teachers who do not understand the content or do not view chemistry as a whole tend to teach students every individual piece of information in their chemistry textbooks, not always linking it to other related information. Unfortunately, this makes it difficult for such students to understand the logic of chemistry.

The purpose of this study is to define and discuss this content, and provide ideas that may lead to a new teaching strategy for high school chemistry.

I will share information about both content and an effective strategy for teachers to teach chemistry on the basis of content knowledge.

Results

I analyzed the Course of Study [2]: the national curriculum in Japan that is a law we teachers should keep. If not, we may be punished for disobeying the law. The curriculum is the broad standards for all schools throughout Japan determined by MEXT. But MEXT does not define and explain the basic and fundamental content.

In the curriculum, chemistry has two subjects [3], Basic Chemistry and Advanced Chemistry. Most of students learn Basic Chemistry and a few of them in the science course learn one more subject, Advanced Chemistry.

In **Tab. 1**, I show the content of Basic Chemistry, which students must learn in high school, and classify its unit into three key concepts referred to below and exception.

Tab. 1. The content of Basic Chemistry (2 credits) and its key concept.

Large Unit	Middle Unit	Small Unit	Key Concept
1 Chemistry and Human Life	(1) Relationship between Chemistry and Human Life	1) Chemistry in Daily Life	Exception
		2) The Roll of Chemistry	
	(2) Exploring Matter	1) Simple Substance, Compounds, and Mixtures	Particles
		2) Thermal Motion and the Three States of Matter	Energies
	(3) Exploring Activities of this Unit		Exception
2 Composition of Matter	(1) Particles of which Matter is Composed	1) Atomic Structure	Particles
		2) Electron Configurations and the Periodic Table	
	(2) Matter and Chemical Bonding	1) Ions and Ionic Bonds	Chemical Bonding
		2) Metals and Metallic Bonds	
		3) Molecules and Covalent Bonds	
	(3) Exploring Activities of this Unit		Exception
3 Changes of Matter	(1) Stoichiometry and Chemical Equations	1) Stoichiometry	Particles
		2) Chemical Equations	
	(2) Chemical Reactions	1) Acids, Bases and Neutralizations	
		2) Oxidations and Reductions	
	(3) Exploring Activities of this Unit		

The exceptions cannot be classified into three concepts.

I classified “1) Simple Substance, Compounds, and Mixtures” of unit 1 (2)

in **Tab. 1** into "Particles", because this concept is introduction of "Classification of Matter" which leads to "Atoms."

I classified "3 Changes of Matter" in **Tab. 1** into "Particles", because "1) Stoichiometry" of unit 3 (1) depends on atomic mass and number of particles, "2) Chemical Equations" of unit 3 (1) depends on number of particles, "1) Acids, Bases and Neutralizations" of unit 3 (2) treats ions such as H^+ and OH^-, stoichiometry, and chemical equations, and "2) Oxidations and Reductions" of unit 3 (2) treats ions such as H^+ and O^{2-}, stoichiometry and chemical equations.

Thus the three key concepts cover the content of Basic Chemistry.

The basic content

Like the groundwork [4] of a building shown in **Fig. 1**, the basic content is scientific properties [5]: rules such as cause and effect, logic, law, repeat, replication, and verification common to all sciences in a sense.

Besides, most readers must have learned at university that chemistry treats properties and changes of matter. They may think that it is the basic content. However, I choose the former, because the former is a base throughout chemistry and science too. We cannot build a sturdy house on bad groundwork. Lack of the basic content makes students acquire snippets of knowledge. I will mention the latter below.

Fig. 1. Groundwork of a building: an assembling cage for reinforced-concrete.

The fundamental content

Fig. 2 shows the structural materials of a building: pillars [6] and walls on the groundwork. Like those materials, the fundamental content is defined as key concepts [7] as follows:

1. Particles: atoms (atomic nucleuses, electrons, protons, and neutrons), molecules, and ions.
2. Chemical bonding: covalent bonds, ionic bonds, metallic bonds, and intermolecular

forces.

3. Energies: energy of state changes and energy of chemical changes.

These concepts include and are related to treating properties and changes of matter.

For example, hot copper burns in chlorine to form copper chloride [8].

$Cu + Cl_2 \rightarrow Cu^{2+} + 2Cl^-$

This reaction shows properties and changes of matter. However, it also includes concept of particles: atoms(Cu) molecules(Cl_2) ions(Cu^{2+}, Cl^-), concept of chemical bonding: metallic bonds(Cu), covalent bonds(Cl_2), ionic bonds(Cu^{2+}, Cl^-) and concept of energy: energy of chemical changes. Chemical changes need energy. Thus the key concepts cover treating properties and changes of matter. So, the basic content should be scientific properties: rules common to all sciences referred to above.

Fig. 2. Structural materials of a building: pillars and walls on the groundwork.

Discussion

The relationship between the basic and fundamental content

According to the Dictionary of School Education [9], pre-learned fundamental content is post-learned basic one. I disagree with this idea, because we cannot strictly distinguish the basic content from the fundamental one.

Chemistry is, so to speak, cloth; a woven fabric that is composed of the warp and the weft. The warp is to the weft as the basic content is to the fundamental content shown in **Fig. 3**.

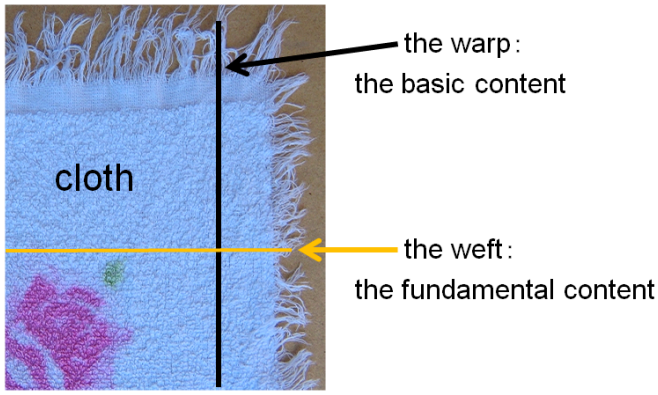

Fig. 3. Cloth: a woven fabric composed of the basic content as the warp and the fundamental content as the weft.

Like the spiral curriculum of Bruner, J. S. [10], both of the contents make a spiral model.

I do set the basic content in the vertical direction of the model as follows.

In **Fig. 4**, the basic content existing in the vertical direction is periodic law and the fundamental content existing in the horizontal direction of every stage is a concept of particles. The higher the stage is, the more complex the concept is. But the law is consistently the same from atoms to ions. The law contains electron configurations, valence electrons, the chemical reactivity of the elements, atomic radii, electron affinity, ionic radii, ionization energy, electronegativity, and so on.

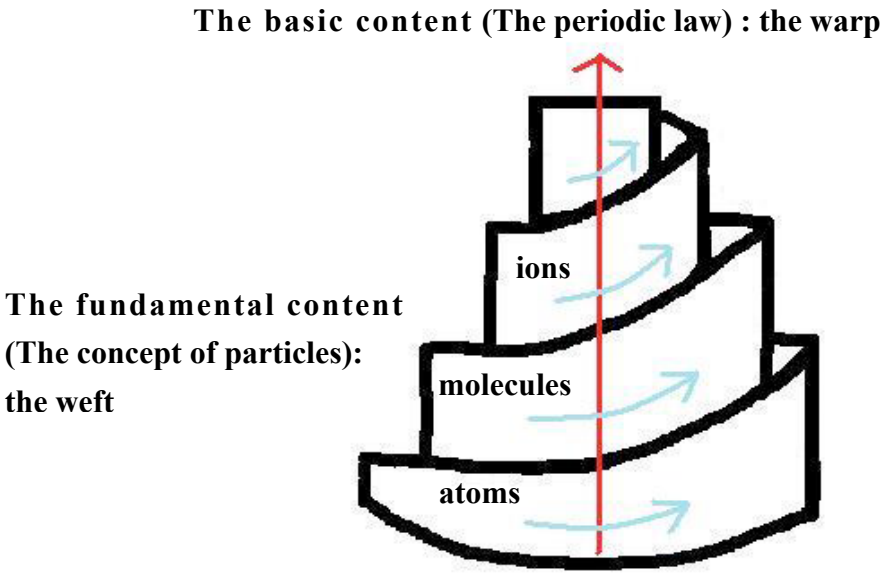

Fig. 4. A spiral model of the relationship between the basic content (the periodic law) and the fundamental content (the concept of particles).

As student's learning advances to the next stage, they meet new content, which obeys the periodic law and belongs to the same concept of particles learned before. In the same way, teachers can treat chemical bonding: one of the fundamental content shown in **Fig. 5**.

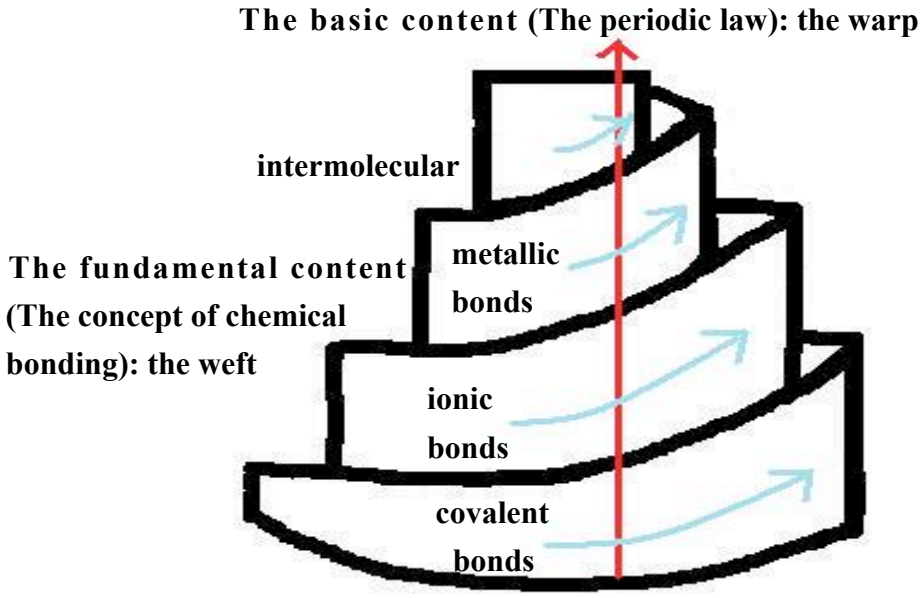

Fig. 5. A spiral model of the relationship between the basic content (the periodic law) and the fundamental content (the concept of chemical bonding).

A new strategy

The first step of a new strategy for high school chemistry teaching is that teachers recognize that chemistry is like cloth composed of the basic content as the warp and the fundamental content as the weft.

And then, teachers should always teach chemistry with the viewpoint of the basic and fundamental content that compose chemistry like cloth.

I show two examples to teach my students in my lessons. Unfortunately, I have never taught at excellent high school such as Super Science High School which is "the system MEXT specifies for high schools that focus their education on science and math, and the Japan Science and Technology Agency supports them" [11].

Most of my students were slow learners. Many teachers told those students who did not understand their lessons to memorize the content of lessons and not to try to understand the rules of chemistry. But in my strategy it is a wrong way to teach chemistry, because the students did not understand the basic content: the groundwork of chemistry. Lack of it makes them acquire snippets

of knowledge. They could not build a sturdy chemistry on that bad groundwork. It is important for the teachers using the strategy to continue telling students in every lesson that chemistry is like cloth composed of rules: the basic content as the warp and concepts: the fundamental content as the weft.

Example 1 : "(1) Particles of which Matter is Composed" of unit 2 in **Tab. 1**.

In order to reinforce the image that chemistry is like cloth composed of rules: the basic content as the warp and concepts: the fundamental content as the weft, what I repeat my students in every lesson are as follows: Electrons control chemistry, because it is a rule leads to the periodic law: one of the basic content. And particles form matter, because it is a key concept: one of the fundamental content.

First of all, I teach atomic structures and atomic symbols.

Secondly, I teach history of discovering the periodic table and require the students to memorize twenty atomic symbols, names and atomic numbers from H to Ca in the table.

Thirdly, I teach electron configurations from H to Ca and the periodic table and law. In the viewpoint of electrons controlling chemistry: the periodic law, I make the students focus on the changing electron configurations with increasing atomic numbers, emphasize that valence electrons play a great role in determining chemical properties, and ask them not to forget the stable octet of a noble gas.

Example 2 : "(2) Matter and Chemical Bonding" of unit 2 in **Tab. 1**.

Every time I teach lessons of this unit, what I always ask my students to remember are as follows: Electrons control chemistry, particles form matter, and the electron configuration of a noble gas is stable that I have taught the students before. Moreover, rearrangement of atoms through the breaking and making of the bonding between atoms cause chemical changes, because electrons such as valence electrons and free electrons play an important part on chemical bonding.

First of all, I teach history of discovering the Avogadro's principle, which contains the Dalton's atomic theory and the Gay-Lussac's law, because it is introduction of the concept of molecules that solved the problem with the theory and the law. And then, I teach molecules and covalent bonds. I emphasize that sharing electrons produces the stable octet of a noble gas.

Secondly, I teach ions and ionic bonds. I emphasize that by gaining and losing electrons to achieve a noble gas configuration, each atom forms an ion.

Thirdly, I teach metals and metallic bonds. I emphasize free electrons.

The historical case studies of chemistry such as discovering the law of conservation of mass, the law of definite composition, the law of multiple proportions, and the periodic law are good teaching materials to teach the basic content.

We can use these teaching materials to teach students the common scientific properties, for example, cause and effect, logic, law, repeat, replication, and verification. It makes up student's groundwork of chemistry.

Student's experiments are suitable for the basic content, because students learn scientific rules: cause and effect, logic, and so on through their experiments and reports.

In the thematic projects, students researched, wrote and presented papers on subjects such as the electrolytic dissociation of bivalent acids and bases, the water quality of rivers, and so on. Through their researches and presentations, they acquired how to study and present their findings.

Conclusion

Considering the results of my study, I conclude the followings:

Firstly, the basic content is scientific properties: rules such as cause and effect, logic, law, repeat, replication, and verification common to all sciences.

Secondly, the fundamental content is defined as key concepts as follows: Particles, chemical bonding, and energies.

Thirdly, chemistry is like cloth composed of the basic content as the warp and the fundamental content as the weft.

Fourthly, the strategy is the effective way for teachers to teach chemistry with the idea "cloth" on the basis of content knowledge referred to above.

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