Original Research Article

Pre-concept Inquiry of "Matter State Changes" in Junior High School Science

ABSTRACT

The junior high school science course is a subject closely related to the reality of life, and before starting the formal learning of science concepts, students have formed many pre-concepts, which play a very important role in the formation of science concepts. In junior high school science teaching, it is necessary to explore students' relevant pre-concepts and the reasons for their formation, so that appropriate transformation strategies can be adopted to enable students to deeply understand science concepts, which is conducive to improving the effectiveness of science teaching. In this paper, a questionnaire survey was conducted to understand the pre-concepts embedded in students' minds before they learn the content related to matter state changes in junior high school science, and the reasons for the formation of erroneous pre-concepts were analyzed. In general, the formation of students' pre-concepts first comes from their own life experience and intuitive feelings, and is preceded by common sense of life. Second, through their own intuitive reasoning, they make wrong speculations about nouns. By identifying students' existing correct and wrong pre-concepts, it provides a basis for transforming vague and wrong pre-concepts in students' minds into science concepts in the subsequent teaching design.

Keywords: pre-concept; junior high school science; matter state changes; questionnaires.

1. INTRODUCTION

Junior high school science course is a subject closely related to the reality of life, before starting the formal science concept learning, students have formed many pre-concepts, which play a very important role in the formation of scientific concepts, and should not be ignored in science teaching [1-6]. Therefore, in order for students to deeply understand science concepts and to transform vague and erroneous pre-concepts in their minds into science concepts, we need to explore students' relevant pre-concepts, how they are formed, and the reasons for their formation.

The name of what we now call the pre-concept also varies according to the scholar's theoretical views and the focus of emphasis. In a large number of studies, the term "pre-concept" often appears with "science concept", but the two terms are not completely opposite. Pre-concepts are the basis for students' formation of science concepts and aid in the learning of science concepts, but the knowledge and experience that students have formed in their minds for a long time and that students regard as treasures may hinder the learning of correct science concepts [7-10].

2. CHARACTERISTICS OF THE PRE-CONCEPT

2.1 Extensiveness

Students have seen all kinds of scientific phenomena, and have their own unique views on common intuitive things in life, of course, this extensiveness also exists a certain one-sidedness. There are more pre-conceptions of things that are intuitive, visual, audible and felt. And for those more abstract, theoretical scientific phenomena, there will be relatively fewer pre-concepts. Therefore, pre-conceptions are inevitably present in the minds of the educated, regardless of nationality, race, gender, or age.

2.2 Spontaneity

The pre-concepts in the students' minds are all their own set of theoretical systems based on their own life experiences and cognitive theories. Its formation is spontaneous, relying only on their own experience to build, and no one tells him whether it is right or wrong.

2.3 Tenacity

Pre-concepts have been acquired by students for decades of life experience, and in the long term, these concepts are constantly reinforced, playing a deep-rooted role in students' cognition, and it is not easy to eliminate false pre-concepts.

2.4 Concealment

The pre-concepts in the student's mind exist in the brain in a very hidden form, usually more implicitly. Therefore, it is difficult for us to discover what kind of pre-concept students have, and only when they encounter specific problems, can we expose false concepts.

2.5 Portability

When teachers give a new science concept, students will first connect with the pre-concept that exists in their minds, compare the relationship between the two, and complete the positive transfer of knowledge.

2.6 Coexistence

After students master science concepts, the previous pre-concepts still exist and do not disappear. Even if science concepts are theoretically perfect and unassailable, there is no substitute for those pre-concepts that are constructed by the learner and reinforced again and again by his or her own accumulated experience.

3. INFLUENCE OF THE PRE-CONCEPT

3.1 Positive influence

Due to the influence of life experience, some obvious concepts and characteristics that exist in some of the more vivid and intuitive things have been more correctly perceived by students, and these concepts are in fact the correct science concepts. As we help students construct science concepts that are completely new to them, these science concepts do not appear to be unfamiliar. Thanks to the accumulation of experience in life, these science concepts are more like the systematic refinements and enhancements of existing pre-concepts. The pre-concept is conducive to the mastery of science concepts, the expansion of pre-concepts into science concepts, and the understanding of the original meaning of concepts and their concrete applications in life. After the student's pre-concept is re-positively reinforced by the teacher, it plays a decisive role in the student's love of life, the observation of things in life, and the accumulation of experience.

3.2 Negative influence

The existence of everything has two sides, so is the pre-concept. As described above, the correct pre-concepts of students are a great wealth accumulated by students and an important material for teachers to teach. However, wrong pre-concepts are deeply buried in students' brains, very hidden and hard to be found. These wrong pre-conceptions are like a ticking time bomb, they can explode at any time, but we don't know when and in what form they will explode, and the danger is unpredictable. Concepts are more like bricks for science, and it is from concepts that the body of scientific knowledge is built. Due to the stubbornness of the pre-concepts, if the connections between the old and new concepts are not guided and integrated, then students may misinterpret the science concepts.

4. CONTENT ANALYSIS OF MATTER STATE CHANGES

4.1 Students' existing pre-concepts

Matter state changes is the content of the fourth chapter, properties of matter, of the seventh grade science textbook of Zhejiang Education Press edition (ZEP edition) [11]. For the changes of state of matter, students know that the three substances will be transformed into each other in real life because of common natural weather phenomena such as clouds and rain. One of the most important prerequisites for a change of the state of matter to occur is a change in the temperature of the substance, and students have learned about temperature measurement before. Students have mastered the pre-concepts: matter consists of three states, and a change in the state of matter is a change in state condition.

4.2 Teaching arrangement

The six state changes corresponding to the three states of matter are ordered as "melting and solidification", "vaporization and liquefaction", and "sublimation and condensation" in junior high school science textbook of the ZEP edition.

Water icing and icy water is the most intuitive and visual set of state changes, and students have the most pre-concepts of this, and it is also relatively the most scientific, so the textbook puts this set of state changes in the first place. The law of transition between solid and liquid states is clearly understood, and the teaching of other state changes can be carried out according to this template.

4.3 Melting and solidification

In the section "melting and solidification", the changes in the two states of solid and liquid of matter are first introduced through common phenomena in life, and the processes of these two states of matter are named. The ice and paraffin wax are used as representatives of common crystalline and amorphous substance, and the difference in the melting process between the two substances is distinguished from the appearance. In order to further accurately describe the process of change during the melting of these two types of substances, experiments on the melting of hypo and rosin are carried out as examples, recording the specific state and temperature at specific moments and plotting them in tables and curves to make the observations and analyses more intuitive and visual. Further, pure solids are divided into two categories, crystalline and amorphous, and the process of solidification is explained in a similar way.

The content of such teaching materials is reasonably designed to meet the cognitive development of students. Ice and paraffin are also substances that are often seen in life, which can help students construct a scientific and complete theoretical system based on their accumulated experience in life.

4.4 Vaporization and liquefaction

"Vaporization and liquefaction" is a state change process that revolves around the transformation of the two states of liquid and gas, and the teacher's lesson can also be completed in the same way as that of “melting and solidification”. Water evaporation and boiling, water liquefaction are in fact very common, relying on students' existing experience, the evaporation inquiry experiment can be a large extent to establish reasonable assumptions and help students understand the application of practical problems in life. However, students may be confused about the concepts in the section of “vaporization and liquefaction”. Taking water as an example, water vapor and small droplets are the gaseous and liquid forms of water, and based on students' experience, students will misrepresent the state of "white gas", which appears frequently in the textbook and exercises. They usually think that the name containing gas is gaseous state, water vapor is a gas, then "white gas" should be a gas, and this wrong pe-concept will be deeply imprinted in the brains of students, lingering.

4.5 Sublimation and condensation

The special feature of the section "sublimation and condensation" is that this process of matter state change is not so obvious compared with other state change processes, and it is easier to be ignored by students, so students' knowledge and experience of "Sublimation and Condensation" may be even more deficient. We can use experimental demonstration to make up for some of the lack of the pre-

concepts in life, help students understand the concepts comprehensively, and build up science concepts.

5. PRE-CONCEPTS ANALYSIS OF QUESTIONNAIRES

5.1 Pre-concept analysis of the three states of matter

In order to understand the pre-concepts in students' minds, a questionnaire was administered to the seventh grade of a school. Question 1 of the questionnaire is "In general, how many states does a substance normally have? A.4, B.3, C.2, D.1".

The learners who participated in the survey were aware of the existence of the three basic states of matter and knew about the three forms of matter through their experiences in elementary school as well as in their daily lives. The second volume of the third grade of elementary school science has covered the chapter "temperature and water changes", liquid water begins to solidify into ice when the temperature drops to 0 °C, and solid ice can also melt into liquid water at room temperature. The experience of water droplets on the outer wall of the water cup containing ice cubes and water droplets on the outer packaging of popsicles consumed in the summer also made students more aware of the liquefaction process of gaseous state to liquid state. The gradual decrease of the stagnant water in the puddle can also make students to intuitively feel the process of water changing from liquid to gaseous state. For the conversion of solid and gaseous state, the elementary school science textbooks are not directly involved, but students have accumulated some experience material for this case in life.

5.2 Pre-concept analysis of the state of "white gas"

Question 2 of the questionnaire is "What is the state of ‘white gas’? A. solid, B. liquid, C. gas, D. other states". The data showed that 38.1% of the students thought that "white gas" was in B. liquid state, 61.9% thought that it was in C. gas state, and no students thought that it was in A. solid state or D. other states. Most students took white gas literally and assumed that it was actually a gaseous substance. Some of the smarter students got away with picking the right answer by assuming that because the word white gas is in quotes, it is not the same as the usual gaseous state, and therefore white gas cannot be a gas.

The process of vaporization is described in the section "water and water vapor" at the primary school level, where water "disappears" from a puddle in the rain. This example is not unfamiliar to us, we only know that the liquid water in the puddle has not solidified into a solid state and continues to remain in the puddle, so vaporization into a gaseous state is the most reasonable explanation, but the details of the specific transformation in this process are not clear to the students themselves. For students, what is more familiar is the term we popularize in life, "white gas", and of course, the conclusion that "white gas" is gaseous germinated in his young mind. With the accumulation of experience in life, every time they see the substance "white gas", they will strengthen their own cognition, and over time, "white gas" is a gaseous state will be deeply rooted in their hearts. As a result of students' unscientific perception of the state of "white gas" in their lives, they make intellectual errors and form the erroneous pre-conception that "white gas" is a gaseous state.

5.3 Pre-concept analysis of crystal and amorphous substance

Question 3 of the questionnaire is "What is the difference between a crystal and an amorphous substance? A. whether it is a solid, B. whether it is pure, C. whether it is endothermic during melting, D. whether the temperature changes during melting". This question was answered with a variety of options, with 11.9% choosing A, 23.8% choosing B, 28.6% choosing C, and 35.7% choosing D. Students were unfamiliar with the concepts of crystals and amorphous substances.

The concepts of crystal and amorphous substance are not addressed in primary school science textbooks, and it is not clear to students whether they belonged to the category of solids. The students who judged this question correctly in the questionnaire may have some knowledge base or some teachers in primary school explain deeply, which provides a certain knowledge foundation for students' learning in junior high school. Compared with other concepts, students do not have much knowledge about crystals and amorphous substance, which is a good thing for our systematic teaching.

5.4 Pre-concept analysis of endothermic and exothermic

Question 4 of the questionnaire is "Which of the following state changes is endothermic?" (multiple choices) A. water → ice, B. ice → water, C. water → water vapor, D. water vapor → water, E. ice → water vapor, F. water vapor → ice". All students chose A. water → ice, no students chose B. ice → water, and for several other state changes, students had a variety of choices.

In primary school, students learn at a shallow level, and the change of energy in the process of state change is not directly involved in the teaching, but the students know that the thermometer is decreasing in the process of melting ice into liquid water. Students can infer that this process should be accompanied by a shift in heat. Conversely, the energy change of the solidification process is also relatively clear. However, for other matter state changes, students do not have an intuitive perception of the energy changes, resulting in students' confusing choices for the other options.

5.5 Pre-concept analysis of factors affecting the speed of liquid evaporation

Question 5 of the questionnaire is "Which of the following is the factor affecting the speed of liquid evaporation? (multiple choices) A. liquid type, B. liquid temperature, C. wind speed on the surface of the liquid, D. liquid mass, E. surface area of liquid". 57.1% of students chose all of the choices, 14.3% chose all of the choices except D. liquid mass, and all other students omitted the choices and selected only some of the choices.

This is the key content of the evaporation lesson in the teaching of "vaporization and liquefaction" in junior high school, and students have their own concept of the exploratory experiment of "investigation of factors affecting the speed of the liquid vaporization" in their lives in fact. In primary school, students have also learned the exploratory experiment of "Can heating speed up water evaporation?", in the process of this experiment, students have some conjectures about the factors of water evaporation, and teachers have verified these conjectures in an experimental way, and students should have a deeper understanding of this.

5.6 Pre-concept analysis of the substances inside the bubble and the condition of bubble motion when water boils

Question 6 of the questionnaire is "What is the substance inside the bubbles formed when water boils? A. water vapor, B. water, C. air, D. a mixture of air and water vapor". As for the composition of the substance inside the bubble, 54.8% of the students thought that it was D. a mixture of air and water vapor, 33.3% thought that it was A. water vapor, another 4.8% thought that it was C. air, and the remaining 7.1% thought that it was B. water.

In primary school, in the "Can heating speed up water evaporation?" experiment, by heating the water in a stainless steel long-handled spoon, students can see that when the temperature reaches the boiling point, bubbles are constantly emerging from the water, and this process is accompanied by the formation of "white gas". However, students are not clear about the specific composition of the bubble, and students who can realize that water is transformed into a gaseous state through the process of vaporization, so the inside of the bubble is water vapor, and the learning stage of the change of matter state in primary school has reached a high degree of mastery.

5.7 Pre-concept analysis of water mist formation

Question 7 of the questionnaire is "How does the water mist form on the glass window in the cold winter morning? A. water vapor liquefaction in the room formed on the indoor side, B. water vapor liquefaction outside formed on the outdoor side, C. indoor water vapor, D. outdoor water vapor". 71.4% of students believed that this water mist is A. water vapor liquefaction in the room formed on the indoor side, 16.7% of students thought that water mist is B. water vapor liquefaction outside formed on the outdoor side, 7.14% of students thought it is C. indoor water vapor, and 4.76% of students thought it is D. outdoor water vapor.

Question 8 of the questionnaire is "How does the water mist form on the ice cream bag taken out of the refrigerator in summer? A. small water droplets formed by liquefaction of water vapor in the room, B. water vapor in the room, C. seeping out from the inside of the ice cream". 76.2% of the students thought that the water mist on the ice cream packaging bag was A. small water droplets formed by the liquefaction of water vapor in the room, 23.8% of the students thought that it was B. water vapor in the room, and no students thought that it seeped out from the inside of the ice cream.

In the primary school teaching, the process of water liquefaction is systematically explained, and the experiments that most represented the nature of the liquefaction process are also demonstrated. Secondly, students are not unfamiliar with the phenomenon itself, such as the water mist on the glass windows in cold winter mornings, and the ice creams that students like to eat in summer. Students have their own perceptions and feelings when they are exposed to these examples, so their rich pre-conceptions can help them to discern that the formation of water mist is formed by the liquefaction of water vapor. As for which side of the glass the water mist exists on, the careful students in their daily lives will be able to see it at a glance when they look closely at the window.

5.8 Pre-concept analysis of dry ice stage effects

Question 9 on the questionnaire is "What is the stage effect created by dry ice? A. carbon dioxide gas formed by sublimation of dry ice, B. dry ice itself - a carbon dioxide solid, C. water vapor in the air, D. water droplets formed by liquefaction of water vapor in the air when cooled". 61.9% of the students thought it was A. carbon dioxide gas, 23.8% of the students thought it was C. water vapor, and only 14.3% thought it was D. small water droplets.

Although students often see this phenomenon in their lives, some of them do not think about what causes it. In primary school, the conversion between solid and gaseous states is not directly explained in teaching, so when some students are involved in the new concepts of sublimation and condensation, they will immediately apply their newly acquired knowledge, mistakenly believing that the conversion of solid dry ice into gaseous carbon dioxide is the most reasonable.

6. REASONS FOR THE FORMATION OF PRE-CONCEPT

The reasons for the formation of the pre-concept can be divided into internal factors and external factors, internal factors are mainly caused by the learner himself, and external factors are mainly caused by the objectively existing external environment. The formation of these pre-concepts has had a positive or negative impact on the later construction of science concepts.

6.1 One-sided understanding of life experience

Based on the curiosity of children for novelty, children have a sharper observation ability than adults for the objectively existing world. Therefore, for the nuanced observation of many things, students will form their own cognition of things, which may be wrong or with a certain degree of one-sidedness. When similar phenomena appear later in life, this previously formed misperception will continue to be strengthened.

6.2 Thinking stereotypes

Before each individual begins formal, scientific, and systematic concept learning, they have already built their own cognitive system with their own thinking patterns for problems arising in the external environment. According to the principle of first-come-first-served principle or the study of formal science concept learning by learners, it has been shown that when learners come into contact with science concepts, they will compare science concepts with the original concepts in their minds to enrich their old knowledge when there is no qualitative difference between the new knowledge and the old knowledge. In this process, it is actually the old knowledge or some old experiences and concepts that dominate. And when the new knowledge conflicts with the old experience, the learner will only carry out the new construction of the new knowledge system, and the stereotypes of thinking will produce obstacles to the development of creative thinking mode and the construction of the correct science knowledge system.

6.3 Negative transfer of knowledge

For students who have not yet understood the essence of the concept and fully mastered, when they learn the concepts with some similar characteristics previously exposed before, the new concepts will be equated with the previous concepts or classified into the previous concepts, and the learning of the relevant knowledge of the new concepts will only play a negative transfer role, hindering students from constructing a scientific and complete new conceptual knowledge system.

6.4 Image thinking

The cognitive characteristics of junior high school students at this stage is that image thinking far exceeds abstract thinking, so image thinking is the main thinking of junior high school students to recognize new things. Image thinking is characterized by intuition, simplicity and directness, which can lead to biased perception and understanding. Science is originally a very rigorous discipline, sometimes the cognition and understanding we see with the naked eye led by image thinking are not necessarily correct, and when there is no rigorous abstract thinking formation, some wrong pre-concepts will be produced to block the formation of science concepts.

6.5 Online media

The Internet provides access to all kinds of fragmented knowledge. However, much of the knowledge itself is not correct, and may be just a fragment of some media workers through more entertaining and unscientific means. When such words are learned by learners whose thinking ability and rational analysis ability are not rigorous enough, it will be very unfavorable to the subsequent learning of science concepts.

6.6 Differences between "everyday language" and "scientific language"

We often hear some expressions in life that do not exactly match with scientific terms, and these expressions are constantly repeated and used in life, resulting in most people's wrong understanding of the nature of things. For example, "white gas", in fact, we often see this phenomenon in life, next to the boiling kettle and next to the ice cream bag just taken out of the refrigerator. But due to the habit of daily language, we will mistakenly classify this "white gas" as a gaseous substance.

7. CONCLUSION

The part of change of state is a part of junior high school science teaching that is more closely related to students' daily experience. In order to dig out the possible pre-concepts of students in learning about state change, we designed relevant questionnaires and conducted questionnaires.

Through further analysis of the content of the questionnaire feedback, we found that junior high school students have formed rich pre-concepts before learning science. And there are some core concepts that most of the students think correctly, while there are some concepts that very few students have a correct understanding of them.

On the whole, the formation of students' pre-concepts comes firstly from their own life experience and intuition, and is preceded by common sense of life. Secondly, through reasoning based on their own intuition alone, they make wrong speculations about nouns. By identifying the correct and incorrect pre-conceptions of the students, we can provide a basis for the teaching design of the difficult and important segments of the subsequent part of the change of state of matter as well as the correction of the false pre-conceptions of the students.

CONSENT

All the interviewees consent the use of their views for analysis and publication purpose of the study.

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