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Study on Cultivation of Primary Students' Ability to Generate Hypotheses in Science Learning

Wang Yiyi[a] and Sun Mingming[b]

Elementary Education College, Capital Normal University, Beijing, 100048, China.
[a]wangyiyi19930920@163.com, [b] sunmm@hotmail.com

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Abstract: Doing scientific inquiry is the main way for primary students to learn science. *Generating hypotheses* is one of the most crucial elements of scientific inquiry. Hypothesis is defined as a speculative explanation for unknown phenomena or objects in the real world which is achieved on the basis of students' prior scientific knowledge and experiences. Hypothesis gives a direction to an inquiry and also plays an important role in connecting students' preconcepts and new concepts. Teachers should help students develop their ability to generate hypotheses through simulating real life situation, making use of materials from daily life suitably and teaching students logical thinking ways.

1. Introduction

In 2017, The Ministry of Education of People's Republic of China has issued new *Full Time Compulsory Education Primary School Science Curriculum Standards*[1], which has clearly pointed out that the objectives of primary school science curriculum should include four aspects, which are Scientific Knowledge, Scientific Attitude, Scientific Inquiry and STSE(Science, Technology, Society and Environment).Also, the *Standards*[2]puts forward eight fundamental elements of Scientific Inquiry. Among them, *generating hypotheses* is one of the most crucial elements for it navigates the whole scientific inquiry. In the practice of science teaching, front-line teachers tend to neglect the significance of *generating hypotheses* while most of their attention focuses on other elements like *posing questions*, *collecting evidences*, *drawing conclusions*, etc. For those teachers, they believe that finishing an experiment and drawing concrete conclusions count most in a science class. In order to trigger teachers' attention to the importance of *generating hypotheses* and improve primary students' skills of doing scientific inquiry, the connotation and values of *Hypothesis* should be clarified first, and the means of developing student's ability to generate reasonable hypotheses should also be proposed.

2. What is Hypothesis?

The definition of *Hypothesis* in *Macmillan English-Chinese Dictionary*[3]is "an idea that is suggested as an explanation for something, but that has not yet been proved to be true".

In *Ci Hai*[4], an authoritative Chinese dictionary, *Hypothesis* is defined as an unsubstantiated argument that is used to illustrate a phenomenon. It is necessary to make a logical argument on the basis of proven scientific theories and scientific facts. A hypothesis must be proved before it becomes a scientific principle.

In *Logic*[5], it is explained that *generating hypotheses* is a mental process, during which people make assumptions about the laws or causality of unknown things and phenomena based on the existing facts and scientific principles, and then prove those assumptions.

Quinn & Mary Ellen(1994)[6]assume that *Hypothesis* is a testable explanation of an empirical relationship among variables in a given problem situation.

In conclusion, four elements are needed in explaining the connotation of Hypothesis*:* the observed unknown things and phenomena; related life experiences and/or proven scientific principles; logical reasoning; a verifiable speculative explanation. The relationship of those four elements can be described in Figure 1. In short, *generating hypothesis* is a logical reasoning process, during which a speculative explanation related to the certain observed unknown will be obtained based on relevant life experiences and/or proven scientific theories. The final speculative explanation may be about the laws of the unknown, the cause for the unknown, or the plausible solution to the unknown problem. As a result, Martin Wenham (1993)[7] has divided *Hypothesis* into *Descriptive Hypothesis*, *Explanatory Hypothesis* and *Procedural Hypothesis*. Those three categories can be illustrated using the following example.

Four identical water cups with different volumes of water are put on the desk, students are asked to speculate which one would be sounded the loudest when knocked with the same force. This speculative explanation is about the description of a possible result before doing a totally unfamiliar experiment, which is *Descriptive Hypothesis*. Asking students to make a descriptive hypothesis can arouse their strong desire to explore, especially when the final experimental results are contrary to their own predictions. At this point, students are eager to find out why they are wrong. The teacher may encourage the students to try again, "Why does higher water level lead to higher sound, and lower water level lead to lower sound?" Students need to think of possible causes to the result, which is *Explanatory Hypothesis*. After that, the explanatory hypothesis needs to be proved, so a detailed and feasible verification scheme is needed. For example, some students think that the volume level links to the length of the air column. "But how do you test your hypothesis?" Teacher continues to question, this requires students to come up with a feasible experimental scheme, the *Procedural Hypothesis*.

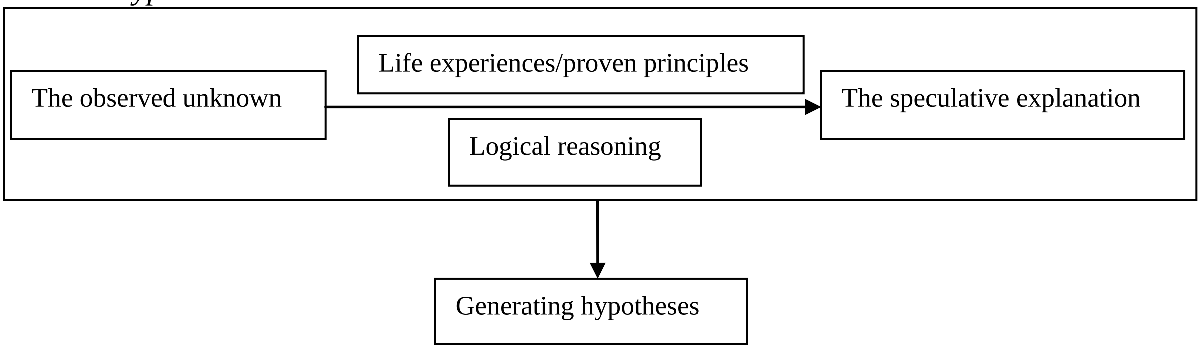

Figure 1: The connotation of Hypothesis.

These three types of hypothesis are advanced step by step and form a progressive system, which is shown in Figure 2.

3. Why is *Generating Hypotheses* important?

As the starting point of a scientific inquiry, there are two main functions of *Hypothesis*.[7][8] Firstly, a hypothesis suggests a specific research direction that guide explorers to investigate specific variables in specific place, the key points of the research have also been explicitly indicated to avoid meaningless investigations. Secondly, as for the students, the process of generating hypotheses is also a bridge which connects students' prior knowledge and new knowledge. It is a key link to realize students' cognitive developments. In order to formulate acceptable explanations, students have to utilize their prior knowledge and experiences to establish the equilibrium between prior knowledge and new knowledge. Taking a fourth-grade science class whose topic is *Where Sound Travels* as an example.

Teacher: Where can sound travel?

Student A: We can hear teacher talking in our classroom, indicating that sound can travel in the air.

Student B: Fish can be shocked by the voices of people on the shore, indicating that sound can travel in water.

Student C: We used to make a phone with two paper cups and a cotton thread that connects the cups. Two men each holds a cup, and they pull the thread straight, one speaks in the cup, the other can hear from the other cup. I guess sound can travel in the thread.

According to their own life experiences, the students conclude that the sound can travel in the air, water and cotton thread. Then they further hypothesize that sound can travel in gases, liquids and solids. The next step is to test their hypotheses in different gases, liquids and solids. In this process, students have perfected their cognitive structure by realizing that sound not only travels in one medium but also in multiple media. Therefore, *generating hypotheses* is a good way to develop students' cognitive ability.

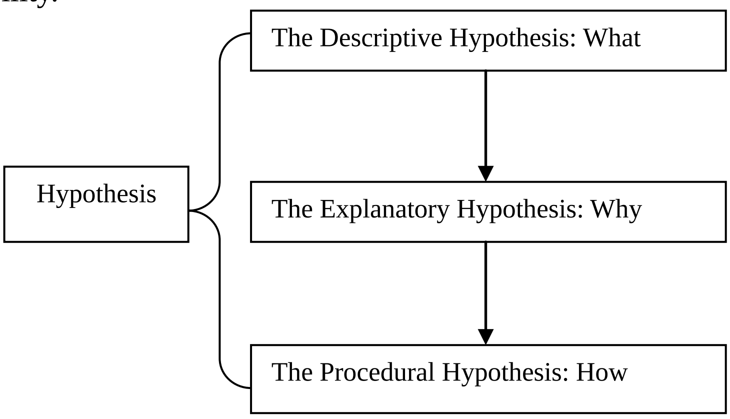

Figure 2: The Categories of Hypothesis.

4. How to cultivate Primary school students' ability to generate hypotheses?

The connotation of *Hypothesis* shows that two main stages are involved for students to generate a hypothesis: making use of what they know and logical reasoning. As for primary students, especially those younger grades, they may not master so many scientific principles, most of their hypotheses are proposed on the basis of their life experiences. So a large portion of science teachers' job in primary school is to help students make full use of their life experiences and teach them how to think logically.

Firstly, teachers need to create real life situation in science class that are familiar to students.[9] It will be easier for students to recall what they have experienced in the similar situation in real life. For instance, in the lesson of *Motion and Friction*, a fifth-grade science class, factors that influence the magnitude of sliding friction are to be explored.

Teacher shows the students a picture of an icy road and asks, "Can you drive a car on such a road?" Teacher asks students to make a descriptive hypothesis.

Students shake their heads and reply “no”.

The teacher questions, “Why?” Students are led to make an explanatory hypothesis.

Student A: The icy road is too slippery, and cars are prone to skidding and cause accidents.

The teacher nods.

Again, teacher asks, “What can we do to prevent the car from skidding in slippery road?” It is about a procedural hypothesis.

Student B: What we use is anti-skid tire. There are many tread patterns on it.

The teacher agrees and raises another question, “Why does a normal car skid on the ice, but with the tread on the tires, the car doesn’t skid?” Another explanatory hypothesis is needed.

Student C: Because the surface of the tire that has tread patterns becomes rough.

After teacher’s introduction of the definition of *Sliding Friction*, students hypothesize that the weight of an object and the roughness of the surface where object moves determine the magnitude of sliding friction according to their life experiences. Some students even notice that the streamline body of a car can reduce friction when compared with the big bus whose body is rectangular. That means students have noticed fluid friction in real life, which is an amazing discovery.

“How do you testify your hypothesis?” Teacher guides students to give a procedural hypothesis.

“We can use spring thermometer to measure the magnitude of friction just like what we have learned in last lesson and change the roughness of surface or weight of objects to testify our hypothesis.” One student answers.

“Right.” Teacher finally concludes, “After posing a hypothesis, finding a way to test it is of great importance.”

Generally, simulating real-life situation in science class is an effective way for students to recall their own life experiences when making a hypothesis.

Secondly, in a science class, taking good advantage of objects that students always see or use in their daily life is also of great use. In the lesson *Making an Eco-bottle*, students are demanded to design a micro-ecosystem. Teacher takes the students to observe a fish tank in the hall on the first floor of the school.

The teacher stands beside the tank and says, “We see the fish tank every day, can you tell us about the food web/chain that exists in the fish tank according to your prior knowledge?” The teacher’s question aims at a descriptive hypothesis. The knowledge of food web/chain is what students have mastered before. The teacher uses the material from daily life to help them review the scientific knowledge at first, and then instructs them to analyze the composition of the fish tank carefully, which is a descriptive hypothesis. Finally, students are requested to design a micro-ecosystem by themselves, a procedural hypothesis is needed. Since fish tank originates from their daily life, each student gets chances to observe it carefully, and thus they will understand science is everywhere.

After class every day, students cluster in front of the fish tank, and then discuss with each other what they have discovered. Then, they report to teachers their discoveries.

Student A: There are fishes, stones, water plants, soil and water in the tank.

Teacher: What are plants, animals and non-living things? What are their roles in the tank?

Student A: Fishes are animals. Water plants are plants. Soil, water and stones are non-living things.

Student B: Fishes eat fish food and plants.

Student C: Water plants produce oxygen and food for fishes through photosynthesis.

Student D: Soil, stones are used for fixing and nurturing water plants.

With their careful observations, students get to know what and why they should do to design a new micro-ecosystem.

Both of the methods mentioned above depend on external surroundings or materials to arouse students' prior knowledge and experiences to put forward hypotheses. But what is more important is to teach students how to formulate reasonable hypotheses through logical reasoning.

The logical reasoning methods of science learning mainly include: inductive reasoning, deductive reasoning and analogical reasoning.[10]Inductive reasoning is the derivation of general principles from specific observations, that is, from “individual” to “general”.[10]For example, in *Solar System*, a chapter for sixth-graders, students have already learned about the Earth, Mercury, Venus and other heavenly bodies. The teacher points out that these heavenly bodies are planets. Then students are asked to summarize what the common characteristics of planets are. Under teacher’s guidance, students induce that planets all go around the Sun, they don’t give their light and their rotation direction are in line with the direction of revolution. Induction reasoning enables students to come up with descriptive hypotheses about the laws of planets.

The second reasoning way is deductive reasoning. It is a top-down logical method. Some general principles have been given to students, when it comes to specific situation, specific statements and conclusions have been deduced. That is from “general” to “individual”.[10]Also in *Making an Eco-bottle*, the teacher presents a pond.

Teacher: What is the energy provider in this system?

Students: Waterweeds and duckweeds.

Teacher: Why do waterweeds and duckweeds provide energy?

Student: Because they are plants that can conduct photosynthesis.

Since students have gotten the idea that plants are the major energy producers in the ecosystem. So students deduce this explanatory hypothesis.

The third is analogical reasoning. This method is based on the fact that two related objects have certain attributes that are the same or similar, thus deducing that they are the same or similar in other attributes.[10]In the lesson *How Sound Travels*, one aim of the class is to learn how sound travels. The teacher gives a hint by reviewing a previous experiment: Touching still water with vibrating tuning fork and then observe the water surface.

Teacher: What did you see in this experiment?

Students: There were several circles of water wave on the surface.

Teacher: The vibration of the tuning fork creates ripples in the water. What will it create in the air?

Student: It creates ripples in the air, too.

Both air and water are fluid, and vibration can create ripples in water, so students can naturally put forward the descriptive hypothesis that vibration also generates waves in air through analogical reasoning. By going over the previous experiment, the teacher gets students’ attention to the water surface, and then leads students to propose the hypothesis that sound travels in the form of waves in air by analogy.

To sum up, simulating real life situation and using materials from daily life plays a part to inspire students to utilize prior knowledge and life experiences to generate hypothesis. It is also indispensable for teachers to teach students using deductive reasoning, inductive reasoning and analogical reasoning suitably when a reasonable hypothesis should be made.

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References

[1] People's Republic of China Ministry of Education.(2017) Full time Compulsory Education Primary School Science

Curriculum Standards. 6-7.
[2] People's Republic of China Ministry of Education(2017). Full time Compulsory Education Primary School Science Curriculum Standards. 9-11.
[3] Wang Ying.(2005) Macmillan English-Chinese Dictionary for Advanced Learners. Beijing: Foreign Language Teaching and Research Press. 493.
[4] Ci Hai Editorial Board.(1999) Ci Hai.Shanghai: Shanghai Lexicographical Publishing House.173.
[5] Wang Haichuan.(2012) Common Logic.Beijing: Science Press.
[6] Quinn, Mary Ellen.(1994) Teaching Hypothesis Formation.Science Education.59(3):289-296.
[7] Martin Wenham.(1993) The Nature and Role of Hypotheses in School Science Investigation. International Journal of Science Education.15(03):231-240.
[8] Lu Jiang, Lu Min.(2016) Hypothesis and Scientific Discovery. Hefei: Hefei University of Technology Press. 15.
[9] Ye Feng.(2010) Cultivating Children's Ability of Supposition and Assumption in Primary School Science Teaching. Journal of Ningbo Institute of Education. 12(4):133-134
[10] Liu Benju.(2006) Attempts to Cultivate Students' Ability of Guessing and Assuming in Classroom Teaching. Biology Teaching.31(05):14-16.