PUS-Based Educational Paradigm From “Mastering Science” to “Understanding Science”

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The publication of the report *The Public Understanding of Science* (PUS) elicited people's thinking on the value of science education and guided reform of science educational reform. With increasingly obvious influences of science to society, understanding science and promoting science progress were of great importance, as well as mastering science and understanding science. Science education shall reflect the education value orientation of PUS and realize transforming from “mastering science” to “understanding science” and from double-base education to science, technology, and society (STS) education, and history, philosophy, and sociology (HPS) of science education, so as to realize the educational value of promoting students' science literacy and PUS. We advocate the educational paradigm from “mastering science” to “understanding science,” but we do not say that “mastering science” is wrong, only because the concept does not adapt to the development of science education, or it is not the ultimate aim of science education, but the periodical target in cognition. “Understanding science” is the ultimate goal adapting to the development of science education, which is the basic science quality possessed by the public.

Keywords: public understanding of science (PUS), mastering science, understanding science, double-base education, science, technology, and society (STS) education, history, philosophy, and sociology (HPS) of science education

Introduction

Sir Baume, fellow of the Royal Society, drafted and the Royal Society published *The Public Understanding of Science* (PUS) officially in 1985. The report highlights the importance of PUS, discussing on how to promote public understanding on science nature and its positive roles to society, and at the same time, it is charismatic to some extent (Royal Society, 1985). The core issues of the PUS report include what do scientists let the public understand? And what are public cognition, understanding, and action of science?

The report elicited people's thinking on the value of science education and guided reform of science education. Science education not only makes students master science knowledge, but also concerns promoting their science literacy. The concept of public science literacy promoted worldwide science educational reforms. In the past 30 years, such concepts as science, technology, and society (STS) education, science, technology, society, and environment (STSE) education, and history, philosophy, and sociology (HPS) of science education have appeared, which have reflected the education value orientation of PUS and guided idea and paradigm of science education to transform from “mastering science” to “understanding science.” Furthermore, “understanding science” has become a basic connotation of public science literacy.

Silent Spring, published in the United States (U.S.) in 1962, marked that people concerned environmental issues for the first time, particularly pesticide using (Carson, 1962). Soon afterwards, breaking out of a series of events, including ozone hole, greenhouse effect, genetically modified food, and nuclear leak, the public were suspicious of science.

In the final analysis, the public were suspicious of science, because they did not understand science.

With increasingly obvious influences of science to society, understanding science and promoting science progress were of great importance, as well as mastering science and understanding science. Nowadays, public participation is necessary to science. To a great extent, the development speed and tendency of science lie in public understanding degree of science. Science undertakings can move forward only when the public understand science.

Traditional Education on “Mastering Science”

Meaning of “Mastering Science”

Traditional science education regards “structuralism” as the basis, “disciplinary structure” as contents, and “mastery learning” as objective, to highlight mastering of disciplinary knowledge. “Mastering” is a word with high frequency of occurrence in the 1980s, including “mastering knowledge,” “mastering method,” “making master of,” “making a good command of,” and so on.

Mastery learning and target classification are cores of Broome’s educational theory. Mastery learning indicates making students master all course contents. Broome classified learning targets into cognitive domain, from simple to complicated: knowledge, comprehension, application, analysis, synthesis, and evaluation (Gao, 1990). In the target classification of Broome, comprehension indicates mastering significances of learned contents; you can express them in your own language, can explain them, and can deduce them simply.

Thus, it can be seen that the “comprehension” is comprehension in cognition, namely, mastering disciplinary knowledge and disciplinary structure in science education.

Educational Paradigm of Mastering Science—Double-Base Target Education

Mastering science is a kind of educational concept. Generally, science curricula require students to master basic knowledge and skills. “Mastering double-base” has become a kind of educational paradigm. Curriculum contents of double-base target education give priority to disciplinary structure. Taking Chinese chemistry curriculum in secondary school in 1978 as an example, curriculum contents include basic knowledge and skills. Basic knowledge includes fundamental concepts and principles of chemistry and the knowledge of chemical elements; basic skills include chemical terms, chemical experiments, and chemical calculation. The curriculum target is “systematically mastering basic knowledge and skills” (Ministry of Education of the People’s Republic of China, 1996) The above is the traditional “double-base” target education in China. Furthermore, the educational paradigm concerns mastering disciplinary knowledge of chemistry.

The above are features of “double-base” educational paradigm. Knowledge and skills learned by students are integrated, systematic, and rigorous, which are in favor of mastering solid basic knowledge and forming integrated disciplinary knowledge structure. “Double-base” is the leading content of middle school chemistry teaching and it shall reflect its fundamentality. However, the teaching program requires them still highly. It requires “mastering systematically,” which highlights the educational concept of “mastering disciplinary knowledge and disciplinary structure” (Ministry of Education of the People’s Republic of China, 1996).

Chinese “double-base” teaching is also reflected in relatively low requirements to application of basic knowledge, namely, “primarily understanding their application in practice” (Ministry of Education of the People’s Republic of China, 1996).

With such education, students do not understand science. Once, there was a situation question: Coal contains sulfur and sulfur dioxide will be generated during burning and enter into atmosphere to pollute environment, how can we solve such environmental issue? Many students answered as follows: $S + O_2 = SO_2$. Students mastered knowledge in the sense of disciplinary structure, but they do not understand science really from the aspect of science understanding.

Under educational thought of PUS, limitations of double-base educational paradigm become more and more prominent.

Curricula of “double-base” educational paradigm excessively stress logical order and systematicness of disciplinary knowledge. Therefore, teachers always emphasize mastering of basis knowledge and skills and ignore students’ physical and mental development and social development demands. Curriculum contents of the “double-base” educational paradigm always break away from students’ life realities, ignoring extensive connections of chemistry and society, life, production, science, and technology; concern plenty of declarative knowledge but ignore thoughts, viewpoints, methods, and processes in chemical knowledge, and ignore students’ learning interests and their dynamic role in learning.

The double-base educational paradigm of mastering science has not adapted to educational thought of PUS, which cannot become the ultimate goal and value orientation of science education. People start to seek the educational paradigm adapting PUS, to realize the target of understanding science.

PUS-Based Education of “Understanding Science”

Meaning of “Understanding Science”

Doctor John Durante, professor in PUS in the United Kingdom (U.K.), reported that PUS is at least made up of the following three aspects: (a) understanding of science knowledge; (b) understanding of science research method; and (c) understanding on how science to drive social development. It inosculates with basic requirements of public science literary (Li, 2005).

Thus, it can be seen that science education shall not rest on the cognitive stage of mastering science or cognitive domain.

With science education, students shall understand science nature and influences from science to society. If we conduct science education with science spirit, attitude, and method, students can have a perfect command of learned knowledge after understanding science and handle the relationship among STS correctly. “Understanding science” is an inevitable choice of science education.

Two Educational Paradigms of Understanding Science—STS Education and HPS Education

Knowledge-based viewpoint of traditional science education thinks that science knowledge does not involve in value or transfer with scientists’ personal quality and social attribute, without “value” or “context property.” Science knowledge is not “contextual” knowledge, which keeps away from subjective emotion, or we can say that science knowledge excludes all subjective factors. Therefore, there is a traditional “double-base education” paradigm.

With the appearance of PUS, Edinburgh School, advocating sociology of science knowledge, spared no effort to advocate that science knowledge is the product of social construction.

Definition of science education from baike.haosou.com reflects the value orientation of modern science education:

Science education in the science education research field regards all adolescents as the main body, school education as the main position, and natural science education as main contents, involving total education of such disciplines as technology, history of science, philosophy of science, science of science culture, and science sociology, so that adolescents can master basic knowledge and skills of natural science, learn science methods, experience science inquiry, understand the relationship among STS, grasp science nature, cultivate science spirit, and comprehensively foster and improve science quality, develop social productivity, improve social culture, and let science spirit and humanistic spirit mix in modern civilization through cultivating qualified citizens with science quality. (Science Education, n.d.)

The definition can be interpreted as the PUS-based definition of science education, so that PUS-based educational paradigm appeared, giving priority to STS education and HPS education.

STS Education

One of the PUS cores lies in correctly understanding the influences of science and technology on society, so that students can understand the relationship among STS.

Does science education cultivate science elites or improve citizens' science quality comprehensively? "Science for All," as a new slogan for challenging science education, was responded around the world in the early 1980s. Therefore, common citizens can face future STS and participate in decisions of society, politics, and individuals. So far, STS education has begun.

STS is the abbreviation of science, technology, and society, which is a wide educational field. STS education concept thinks that science education shall not only cultivate scientists and technical personnel understanding and devoting to society, but also citizens understanding science, technology, and their results, and participating in decisions involving in science technology. The most important feature of STS education is bringing social factors into science education as an indivisible part. In science education, STS are a correlative entirety. The educational pattern aims to cultivate the public's science and technology quality, to cultivate and train individuals' participation sense and decision-making ability, and to emphasize orientation of social value in decision practice.

STS education has become a kind of educational paradigm. STS emphasizes imparting knowledge in view of science and technology, sustainable development concept, environmental protection, science method, science spirit, and science morality at the time of spreading knowledge, so as to expand their knowledge scope. Therefore, STS education includes not only science knowledge and nature conception, but also life outlook, value outlook, world outlook, etc..

The STS educational paradigm is relatively mature. STS education has infiltrated into all disciplines of science education.

The *National Science Education Standards* (National Research Council, 1996) of the U.S. focus on the relationship among STS. In these standards, keywords, such as science, technology, society, environment and sustainable development, etc., are frequently mentioned. Science education should pay more attention to students' learning from the perspectives of personal and society. Science education should make students really understand science, and science education should be the understanding of science and technology's impact on individuals and society too.

In April 2013, the U.S. *The Next Generation of Science Standards* (NGSS) (National Research Council, 2013) was published. Once again, science education emphasizes the interaction of STS. In NGSS Appendix

J—Science, Technology, Society, and the Environment, the goal that all students should learn about the relationship among STS (known by the acronym STS) came to prominence in the U.K. and the U.S. in the early 1980s.

To improve the science literacy of students as the core goal, science curriculum reform in China in 1999 paid close attention to the relationship among STS (Huo & Ni, 2004). *Chemistry Curriculum Standards of the Junior High School* (Ministry of Education of the People's Republic of China, 2011) continue to focus on the interaction of science, technology, society, and environment, to help students understand the nature of science and improve their science literacy.

The STS educational paradigm is in keeping with PUS thought. At present, subject curricula of Chinese science education aim to promote students' science quality and permeate STS concept, so that students can concern and comprehend relations among STS.

Therefore, STS education will be the primary education paradigm for the development of science education and for understanding of science in the future.

HPS Education

Another core of PUS lies in correctly understanding science nature, which raises certain requirements towards the public's science quality. Based on this concept, America-led Western countries carried out, in succession, promotion of PUS-based educational paradigm through HPS education in the 1980s.

HPS education mixes relevant contents of history of science, philosophy of science, and sociology of science into science curricula in middle and primary schools, so as to help students understand science nature. With HPS education, we can understand science nature and social functions of science correctly.

Analyzing science undertakings in historical view, the public can understand science according to real occurrence mode of science or the public can understand science as a whole. Philosophy of science tells us that science knowledge is a kind of factual description and certain cognition of people to the development law and nature of objective world, but understanding science knowledge is a kind of value judgment, carrying value factors of the subject. The relation among STS becomes more and more close. Science education shall not only explain science, but also point to the society. As for science education, the public shall understand basic knowledge of science and social value of science knowledge (Zhang, 2008; 2011).

The value orientation of HPS education lies in improving people's science quality really, effectively, and roundly.

Views of science nature contained in HPS education are very important to middle school students, mainly including:

1. Science knowledge is not long-term but short-term;
2. Theories hook on to science knowledge;
3. Experiences are bases of science knowledge;
4. To a certain extent, science knowledge is a product imagined, inferred, and created by people;
5. Science knowledge hooks on to social and cultural background;
6. Science theories, laws, observations, and inferences are different;
7. Science methods are not generally applicable.

Thus, it can be seen that HPS education is a kind of brand-new science education concept and efficient path improving the public's science quality comprehensively, based on the PUS educational paradigm.

In 1996, the U.S. *The National Science Education Standards* clearly put forward the relationship between science and history of science, and Chapter 6 “History and Nature of Science in Five to Eight Grade” mentions that all the students should be gradually understand the goal of human science, the nature of science, and the history of science (National Research Council, 1996).

In 1999, the reform of science curriculum in China begun to pay close attention to the nature of science. For example, chemistry curriculum standards explicitly put forward “to understand the nature of science” and “to deepen the understanding of the nature of science” in junior high school chemistry curriculum and the high school chemistry curriculum. Although chemistry curriculum standards do not specially point out that chemistry education must carry on the HPS education, but compiler of the chemical teaching material compiled a lot of history, philosophy, and sociology of chemistry, in order to realize the HPS education.

So, HPS paradigm of science education is the development trend of international science education to cultivate students’ concept of the nature of science. HPS paradigm can make the students understand science.

Conclusion

We advocate the educational paradigm from “mastering science” to “understanding science,” but we do not say that “mastering science” is wrong, only because the concept does not adapt to the development of science education, or it is not the ultimate aim of science education but the periodical target in cognition. “Understanding science” is the ultimate aim adapting to the development of science education, which is the basic science quality possessed by the public.

STS education pays much more attention to the influences of science and technology to society, while HPS education concerns science nature and social functions of science more, but they understand values of science education from the angle of PUS.

PUS educational thought requires changing science education concept from elite education to mass education, from scientist education to public science quality education, from mastering science to understanding science, and from double-base education to STS education and HPS education. Such changes are not only in form, but also in concept of science education value, which is a kind of realization of PUS-based concept of educational value.

References

- Bradford, C., Ruba, P. A., & Harkness, W. L. (1995). View about science-technology-society interaction held by college students in general education physics and STS course. *Science Education*, 79(4), 355-373.
- Carson, R. (1962). *Silent Spring*. Boston, M.A.: Houghton Mifflin Company.
- Friedrich, S. (2012). History and philosophy of science: Between description and construction. *Berich Zur Wissenschaftsgeschichte*, 35(2), 217-238.
- Gao, Y. M. (1990). Bloom’s taxonomy of education objectives: Evaluation of cognitive domain. *Theory and Practice of Education*, 10(5), 58-62.
- Huo, A. X., & Ni, J. X. (2004). Appraising the new chemical course by “a pair of basis” and “STS”. *Journal of Tianjin Normal University (Elementary Education Edition)*, 5(4), 11-13.
- Li, G. D. (2005). Public understanding of science. *China Reading Weekly*.
- McGinnis, J. R., & Simmons, P. (1999). Teacher’s perspectives of teaching science-technology-society in local culture: A sociocultural analysis. *Science Education*, 83(2), 179-211.
- Ministry of Education of the People’s Republic of China. (1996). *Full-time ordinary senior middle school chemistry teaching outline*. Beijing: Ministry of Education of the People’s Republic of China.

- Ministry of Education of the People's Republic of China. (2011). *Chemistry curriculum standards of the junior high school*. Beijing: Ministry of Education of the People's Republic of China.
- National Research Council. (1996). *National science education standards*. Washington, D.C.: National Academy Press.
- National Research Council. (2013). *Next generation science standards*. Retrieved from <http://www.nextgenscience.org/next-generation-science-standards>
- Royal Society. (1985). *The public understanding of science*. Retrieved from https://royalsociety.org/~media/Royal_Society_Content/policy/publications/1985/10700.pdf
- Science Education. (n.d.). In *Haosou baike*. Retrieved from <http://baike.haosou.com/doc/5978206-6191167.html>
- Yuan, W. X. (2009). Study on the teaching of the nature science abroad. *Comparative Education Review*, 288(1), 7-12.
- Zhang, J. (2008). HPS (history, philosophy & sociology of science): A new paradigm of science education. *Studies in Dialectics of Nature*, 24(9), 83-87.
- Zhang, J. (2011). To analyse the two paradigm of international science education reform on the basis of the sociology of science knowledge viewpoint. *Inner Mongolia Social Science*, 32(6), 160-163.