Research and Practice of New Engineering Education with History Stories for Scientific Cultivation

Jianguo Ma, Teng Zhang, and Lijun Xu*

School of Instrumentation and Optoelectronic Engineering, Beihang University, Beijing, China
Email: majianguo@buaa.edu.cn (J.M.); lijunxu@buaa.edu.cn (L.X.)
*Corresponding author

***Abstract*—Scientific history is the best textbook for researchers to study, which provides valuable experiences for scientific education. Here we make a conclusive analysis on how the history stories would be used. First, the history of great scientist are examples for cultivation of research attitude. Second, the history are examples for students to practice, which helps improve their research capability. Third, mistakes made by precedent researchers are warning of young researchers, which potentially prevent it for happening again. Furthermore, one history story may provide many points of view, which is demonstrated with the example of Dr. Liande Wu, who led the defense of pneumonic plague. Concluded from general science and specialized lectures, we demonstrate the methods to analyze the stories in detail, and present examples to use them for scientific cultivation. Fusing the stories with scientific education helps the guidance of the students' values and the training of the ability, making them qualified builders and reliable successors.**

***Keywords*—scientific history, research attitude, research capability**

I. Introduction

History is the best textbook and the best sobering agent. As illustrated in Fig. 1, summarizing historical experience, revealing historical laws, grasping historical trends, and drawing historical nutrients are of great significance for scientific research and teaching practice [1]. Moreover, the interpretation and utilization of historical materials are multifaceted. Looking at historical materials from a variety of different perspectives will lead to different conclusions.

Theoretical knowledge in courses and academic research often makes students feel boring, while frustration or uncertainty in the face of choices in research often makes students feel helpless. Historical materials provide vivid examples, which are extremely important for boosting students' enthusiasm for learning and research [2], inspiring them to find ways to overcome difficult problems, and avoiding going down the wrong path of falsification. However, it is difficult for students to read and absorb these historical materials on their own in a timely manner, so it is necessary for teachers to dig deeper and help improve their scientific literacy [3].

This paper summarizes the important role of historical materials in scientific literacy based on the author's experience in teaching the major course and the scientific literacy course "Scientific Writing and Reporting" at Beihang University, and analyzes the principles of telling historical materials and the methods of improving students' scientific literacy through examples.

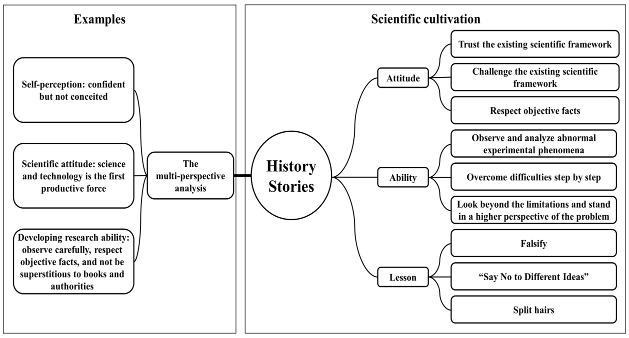

Fig. 1. The value of historical materials in scientific cultivation.

II. History Materials for the Education of Students in Scientific Literacy

A. *Drawing on Historical Experience to Develop Students' Scientific Attitudes*

Attitude determines the motivation to perform, which is more important than technical level [4]. When facing an unknown problem, it makes a big difference whether one is full of confidence and fighting to find a breakthrough, or responding negatively and repeating experiments mechanically, for whether one can overcome a problem. When research cannot get a breakthrough, it is often impossible to know whether one is at a dead end or the darkness before the dawn, so it is impossible to give a unified answer whether to persist or give up at this time [5]. In such cases, historical experience is highly informative and beneficial to help students find a scientific attitude to deal with the current problem [6].

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First, one should fully trust the existing scientific framework and be responsible for the rigor of one's experiments. The current scientific edifice is the result of countless extremely intelligent scientists who have gone through numerous rigorous and scientific experiments over thousands of years, so the probability of error is very small, and students should be taught not to easily believe certain exaggerated reports that are eye-catching [7]. For example, in September 2011, the Oscillation Project with Emulsion-tRacking Apparatus (OPERA), a European Organization for Nuclear Research (CERN) group based in Geneva, Switzerland, announced that neutrinos had been detected moving at superluminal speeds and that the group had made 16,000 measurements and reached a statistically significant difference level. However, this conclusion directly contradicts the principles of special relativity, which is a proven theory in many fields. In the end, it was proven that CERN's results were wrong. This error originated from a loose wire. As you can see, even the results of such professional experiments published by professional institutions, which have been repeatedly verified, can contain low-level errors. So students who have subverted results in their experiments should first suspect that the probability is that they have made an error in their experiments. Even if the same result is obtained by repeated measurements several times, it may not be correct. Students should first examine their experiments from all angles under the premise of "they are wrong" and discuss them carefully with their instructors to reach conclusions that do not conflict with the existing theoretical framework. They should not easily publish conclusions that have not been rigorously validated in order to gain attention. In this way, students will develop a rigorous and responsible scientific attitude [8].

Then, students must be willing to challenge the existing scientific framework. This point may seem contradictory to the previous point, but it is actually unified. In order to break the existing scientific framework, one must go through a very rigorous and comprehensive argument. Once one has sufficiently confirmed one's conclusions, one must be brave enough to challenge them. Constantly challenging the existing scientific framework and upgrading the theoretical framework is exactly why the scientific edifice is built higher and higher [9]. Although China was very backward in science and technology a few decades ago, it has developed rapidly in recent years and has some advanced scientific and technological findings. For example, in September 2021, Chinese scientists designed and constructed for the first time an 11-step reaction starch synthesis pathway, overturning the usual pathway of producing food only by plants. This technology is extremely valuable in areas such as solving the food crisis and deep space interstellar travel. Students will be trained to build self-confidence that they are no less intelligent than anyone else and have the ability to challenge the most advanced technologies.

Finally, the above two points boil down to one point, which is the most basic rule of scientific research: respecting objective facts, one must first rigorously argue one's results, and summarize new theories based on objective facts. Due to the rapid development of science and technology, many current scientific and technological conclusions are beyond the intuition and experience of ordinary people. For example, in quantum mechanics light or other particles have both fluctuating and particle properties, but it is impossible to measure both properties at the same time, and delayed choice experiments appear to subvert even the basic laws of cause and effect, as if future events can change history, which is completely against human intuition [10]. The fluctuation theory of light and the particle theory have been debated for 200 years but cannot be justified separately, and now we have to passively "understand" this anomaly. This process is extremely torturous, but it is an example of human scientific research respecting scientific facts.

B. Developing Students' Scientific Research Ability by Drawing on Historical Experience

Although the wheel of history is moving forward and the edifice of science is building higher and higher, scientific judgment and research methods have always been highly similar [11]. If scientific inquiry is compared to going on a march, then using historical facts to develop students' scientific literacy is the practice before going on a march. Analyzing the lessons learned from these historical materials and developing the scientific attitudes as well as the problem-solving ability students need when faced with a variety of difficulties are key to the nourishment we can draw from history [12]. There are so many historical materials and so many aspects that can help students improve their problem-solving ability, so here is a summary of just a few of the typical aspects.

First of all, train students to carefully observe and analyze abnormal experimental phenomena. In the process of scientific research, if the experimental results are consistent with theoretical expectations, then it basically means that the theory and experiment corroborate each other (of course, it does not exclude the possibility of accidental or total error). Then further verification or the next stage of research can be carried out. However, this situation is very rare in the research process, and most of the time in the research process has to face various anomalous results. Careful analysis of anomalous results and the establishment of new theoretical systems based on objective facts are precisely the important factors that drive scientific progress [13]. The discovery of antibiotics, for example, originated when the experimenter forgot to organize the Staphylococcus aureus petri dish before going on vacation and returned to find that there was penicillin growth around which the staphylococcus could not grow, thus discovering that penicillin could inhibit bacterial growth. The key factor in this example is not forgetting to organize the experiment, which often happens in many laboratories, but in being good at observing anomalies and following objective facts to analyze them in depth and summarize the methods and techniques that are beneficial to humans. This ability to detect anomalies and to explore the mechanisms behind them is extremely valuable in scientific research. In fact, the original research goal of the discoverer of penicillin was to find a way to inhibit the growth of staphylococci, so when it was observed that there were no staphylococci around penicillin, it was possible to think of their inhibitory relationship. Therefore, this ability to discover and analyze anomalies is not innate, but requires students to really take their research to heart so that they can achieve scientific results.

Secondly, develop the ability of students to overcome difficulties step by step. Nowadays, the systems involved in scientific research are generally complex, containing many modules or steps, and the probability of making the whole system work properly is extremely small. Therefore, students need to learn to overcome difficulties step by step: when doing each module or each step, they must first try to do each module or step well; if the whole system goes wrong, they have to disassemble the system into independent submodules or steps, and check whether each part works properly separately [14]. Finding the point of error in the whole system is like deciphering a code, for example, an 8-digit code, which requires finding a correct combination among 100 million combinations, which is very time-consuming and laborious; however, if we can disassemble each bit, there are only 10 possibilities for each bit, and we only need to try 80 times in total to succeed, which reduces the workload dramatically. Fortunately, complex systems in scientific research are often disassembled, and this time, patient disassembly and step-by-step approach is needed, which helps to identify and solve problems as soon as possible. Take the launch of a satellite as an example, which requires the rocket and the entire system of the satellite to all work properly in order to be successful, and a small error in one small part can lead to the failure of the entire launch. Therefore, during the development process before the launch, a large number of scientific teams are needed, each team is responsible for a small part of it to ensure that each small part works properly and is combined into a whole stage by stage. Even so, China's current most advanced Long March 5 launch vehicle failed at the launch of the Yao-2 satellite on July 2, 2017. After that, it went through 908 days of "zeroing in" and "carpet search" on every detail, with many twists and turns in the process, and the date of relaunch was delayed again and again. Under the painstaking efforts of space workers, Long5 was finally successfully launched on December 7, 2019, putting the remote third satellite into orbit with precision. Nowadays, scientific research is basically complex, and letting students master this step-by-step ability is an important guarantee for them to overcome difficulties in the process of scientific research.

Eventually, to cultivate the ability of students to look beyond the limitations and stand in a higher perspective of the problem. In October 2020, a student from a major Chinese university ended his life in a laboratory after leaving a very light-hearted and witty suicide note. The suicide note showed that the student had a good heart and a relatively cheerful personality. The reason why such a good student committed suicide was because of the unrepeatable nature of the experiment. He tried to control the experimental parameters to get reproducible results. But the exact same conditions actually yielded different results each time. This phenomenon was similarly described in Cixin Liu's The Three-Body Problem, where physicists used the same conditions to get random results, and felt that the world of physics collapsed and a large number of physicists committed suicide. If confined to one's own experiments, this phenomenon of controlling for consistent parameters but getting inconsistent results is actually not uncommon and has been encountered by many researchers. The reason is just like the one described in "The Three-Body Problem", where scientists controlled only those parameters they thought of, but not all of them. Since there are also variables that they are not aware of, it is the differences in those variables that lead to inconsistent results. Therefore, at this time, one should not deny oneself, but should promptly go beyond the immediate experiment and take a higher perspective to examine what else is beyond one's cognitive scope to consider. In this regard, the history of the discovery of artemisinin is exemplary. To develop a new drug to fight malaria, Youyou Tu led a team in 1969 to sift through more than 2,000 herbs from folklore, and further extracted more than 380 extracts from more than 200 herbs (including Artemisia annua/artemisia extract) for testing. Most of the results were unsatisfactory, and artemisinin was effective but consistently unstable. Faced with this instability, instead of mechanically repeating the tests, Youyou Tu stepped out of the original experimental process and came up with the idea of extracting the active ingredients under low temperature conditions in order to preserve the active ingredients while reducing the toxicity of the original extracts. The improved experiments resulted in the successful extraction of artemisinin, which has achieved an amazing 100% efficacy against murine malaria, making it the first-line antimalarial drug that has saved millions of lives. It is clear that looking beyond the limitations of the immediate experiment and taking a higher perspective on the problem is extremely important for overcoming difficulties and obtaining breakthroughs.

The above three points are just examples of how historical experiences can be used to develop students' scientific research ability. Teachers need to explore more historical materials and draw on more historical experiences according to the characteristics of their courses in order to improve students' scientific research ability in related fields.

C. Summarize the Lessons of History and Prevent Repeating the Same Mistakes

Historical facts not only provide us with valuable experience, but also provide us with painful lessons in one accident after another. In this regard, we should take this as a warning to avoid repeating the same mistakes. There are also many painful lessons in research, so here are just three typical lessons about falsification, "Saying No to Different Ideas", and splitting hairs.

Firstly, the most unacceptable thing in the field of scientific research is falsification. Scientific research is to discover the laws of nature or to invent new instruments, etc. Only real laws of nature can be used and only real instruments can be our tools. By falsifying, we will waste our own time, lose our reputation, and even cause the whole scientific edifice based on it to collapse, wasting the time of countless people and leaving ourselves in disrepute [15]. In January 2014, Haruko Obokata claimed that weak acid stimulation could transform differentiated mammalian cells into stem cells. Yet others were unable to replicate this experiment. Therefore, it was questioned that the data in her paper was obtained by falsification. She was then given the opportunity to confirm her results, but she was unable to reproduce the original results. As a result, she was found to have falsified the data and her supervisor committed suicide. Haruko Obokata's falsification was more fortunate for human beings, as it was discovered earlier and only hurt her and her supervisor, and did not cause the accident to expand. A more serious example was the falsification of experimental data by Piero Anversa at Harvard University, who falsely claimed the existence of cardiac stem cells to repair damaged heart muscle. The lie was not promptly debunked, and many researchers worked for more than a decade afterwards to develop the false theory, wasting a great deal of researchers' time and money. But a fake is always a fake, and the laws of nature do not change because of what people think. This kind of falsification will not bring any practical value, but only great loss and damage to one's reputation [16].

Next, scientific research should not "Say No to Different Ideas", but should seek common ground while reserving differences and respect the opinions of other researchers. Scientific research itself is a process of exploration. Everyone's perception has some limitations. No one can absolutely guarantee that he or she is right, so we should not suppress others' views because of disagreement. Before heliocentrism, the theory of geocentrism met all experimental observations and could be used as orthodox theory. But the Roman religion fought against heliocentrism because it supported geocentrism. This would ultimately only prove its own brutal despotism, and the views it so vigorously defended would be proven wrong by objective measurements. Even religious forces with great power cannot fight objective facts, much less individuals. Edison, the founder of General Electric and the king of inventions, once had a lot of power, but he used his power to discredit AC power and deliberately used it to kill elephants and prisoners in order to implement his DC power. However, before the advent of DC boost technology, AC was indeed superior to DC, and Edison's smear could not blind people. In the end, people chose AC, and Edison's actions became the downfall of his life.

At last, research should not split hairs, and splitting hairs should not be confused with perseverance. Although both are striving relentlessly to achieve their goals, perseverance is characterized by either steady progress on a set course or a flexible and patient approach to finding solutions to problems, like Youyou Tu. In contrast, splitting hairs is merely mechanical repetition, lacking a comprehensive review and objective analysis of the problem. Moissan, a Nobel Prize winner in chemistry, split hairs in order to turn graphite into diamond. Since diamond and graphite are isomers, and it had been previously proven that diamond could be turned into graphite, many people believed that graphite could be turned into diamond by adding heat and pressure. Moissan believed that the sharp contraction of molten iron during its sudden condensation could press the graphite contained in it into diamond. So he asked his assistant to try again and again with this method. After failing over and over again, the assistant could not stand the pressure and bought a diamond out of his own pocket and put it in the molten iron, and then told Moissan that the experiment was successful, thus ending the experiment. Objectively speaking, Moissan was not to be blamed for using this method of experimentation at that time when his knowledge was limited, but he was forced to try it again and again by using only this method, which eventually led to the assistant being forced to falsify. Therefore, even if he really did not know about the matter of falsification, he still has to bear part of the responsibility.

III. Examples of Multi-perspective Analysis of Historical Materials

A historical material, viewed from different sides, can have multiple different educational implications [17], requiring each course instructor to parse out content appropriate to his or her own curricular needs. In this paper, we use the example of Liande Wu leading the fight against the plague in China at the end of the Qing Dynasty to show multiple perspectives of a historical material [18]. Against the pressure of traditional Chinese custom (leaving the body whole), Liande Wu risked being infected by dissecting the body. He discovered that the cause of the plague was the plague bacterium that had swept through Europe for centuries and killed hundreds of millions of people, the famous "Black Death", or the "No. 1 Disease" in China. To make matters worse, Liande Wu observed that the plague was not spread by contact only like the Black Death, but also by droplets, so he named it pneumonic plague and invented a double gauze mask to stop the spread. This idea was considered a pipe dream by Western experts. French infectious disease expert Mesny did not believe in the idea proposed by Liande Wu and insisted on not wearing a mask. As a result, he soon became ill and died of the infection. Liande Wu used train cars as isolation sites to house patients and contacts, depending on the condition. By relying on the two main tools of masks and quarantine, the plague, which was more contagious than the Black Death, was finally cleared in 67 days. This remarkable experience in fighting the epidemic provides valuable material for our education in many ways.

In terms of self-perception, we should be confident but not conceited. Instead of living in the illusion of a "heavenly country", Liande Wu recognized the advancement of Western science and learned the advanced technology of the West. If Liande Wu had not studied at Cambridge, he might not have been able to lead the people in the fight against the epidemic. Therefore, it is every student's endeavor to recognize their own shortcomings, learn various scientific knowledge with an open mind, and become stronger. As an old Chinese saying goes, "When three people walk together, there must be my teacher".

In terms of scientific attitude, it is important to recognize that science and technology is the first productive force. Good research is able to promote the progress and development of human society. Using scientific knowledge to save people's lives like Liande Wu and Youyou Tu, or enhancing the progress of space science and technology research like the Long March 5 team, or opening up a new chapter of human development like the artificial starch team, all prove that science and technology is the first productive force. It is the historical responsibility of researchers to develop truly useful science and technology to enhance the development of human society.

In terms of developing research ability, we need to observe carefully, respect objective facts, and not be superstitious to books and authorities. Pneumonic plague has not been found in authoritative studies in the West, much less in books. If one is bound by authorities or books, one will be detached from objective facts, thus making it difficult to draw correct conclusions, much less make breakthroughs. Liande Wu's discovery of the droplet transmission characteristics of the plague and his targeted design of masks and increased isolation were the keys to success in the fight against the epidemic.

IV. Conclusion

Historical materials are of great value in developing scientific literacy. Through rational analysis and refinement, they can provide a multi-perspective educational role. In terms of improving scientific literacy from the perspective of science and technology, the three main aspects of analysis include developing scientific attitudes, learning from experience to develop scientific research ability, and learning from lessons to prevent repeating the same mistakes. In terms of scientific attitude, it is necessary to be rigorous and cautious and trust the existing scientific system; at the same time, it is necessary to maintain the courage to challenge. There are many materials and educational perspectives on learning from historical experience to improve research ability, and this paper gives examples and analysis in terms of observing and analyzing anomalous phenomena, taking a step-by-step approach, and looking beyond limitations. In terms of learning lessons to prevent repeating the same mistakes, the paper analyzes and demonstrates the dangers of falsification, "Saying No to Different Ideas", and splitting hairs. Finally, for the educational significance of mining historical materials from multiple perspectives, this paper takes the example of Liande Wu's leadership in the fight against the plague, and shows its educational significance in terms of self-perception, scientific attitude and developing research ability. In conclusion, in-depth analysis and rational use of historical materials are of great significance to improve students' scientific literacy.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Lijun Xu conducted the research. Jianguo Ma wrote the paper. Teng Zhang provided an internal review and comments to the primary author. All authors had approved the final version.

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