
Critical Thinking: the Universal Key to Scientific and Technological Innovation

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Abstract: *Science and technology is the full-effect catalyst and high-efficiency prime mover for increasing productivity, and innovation is the important contents and goals pursued by scientists and technicians. Marxist critical philosophy is not only the theoretical basis of critical thinking, but also the necessary seedling nursery of seed-ideas for scientific and technological innovation. The basic instrumental of critical thinking, correlation with innovation ability, and further demonstrating the essential and effectiveness of critical thinking for scientific and technological innovation are discussed.*

Keywords: *Scientific and technological innovation; Philosophy of science and technology; Critical philosophical methodology; Critical thinking*

The Marxist principle points out that the laborer, the instruments of labor and the objects of labor are the three elements of productive forces; science and technology mastered by laborer or materialized into instruments and objects of labor will become the labor productivity and the material productivity. That is to say, science and technology are full-effect catalysts and high-efficiency prime movers for increasing productivity.

1. Innovation is the key factor to promote the transformation of science and technology

Science and technology is not a direct form of productivity and would be transformed to the productivity in two pathways: be mastered by workers, or materialized as instruments and objects of labor. And the two transformation mechanisms must be promoted by innovation. As we all know, the innovation of science and technology is to break through the existing orders of material and spiritual resources and to create a newly born order environment which will creatively establish new knowledge, new theory, new

technology, and new forms, etc, as well to achieve the practical gains of improving the whole people's cognitive ability and social productivity.

The common goal of all scientific research behaviors is to discover the truth and to bring benefit to mankind according to the truth. There are many perplexities and difficulties to be overcome in the pursuit of their goals and ideals. Therefore, the innovation of science and technology in essence is that human beings constantly realize the leap from the kingdom of necessity to the free kingdom. In order to solve practical problems and realize the leap noble values and superior thinking ability would be required. Vincent Ruggiero makes it clear ^[1]: "there is little disagreement that the challenges of the new millennium require thinking beyond the senses and to achieve clear, fair, as well solving problem and making decision critically."

That is to say, to the realm of freedom requires a scientific and effective thinking tool that transcends feelings and enable clear, fair, critical decision-making and problem-solving. Of course, some noble values are also needed. Prof. Qian Sanqiang in the early 1980 s in the first symposium on physical philosophy said, "a good physics workers must grasp philosophical tool, and a successful physicist is bound to be a philosopher."He emphasized the philosophy of higher values will guide the right direction of scientific research and scientific thinking methodology of philosophy is to contribute to the progress of science and technology as a powerful tool and weapon.

2. Critical thinking is the universal key to technological innovation

Why does critical thinking play a critical instrumental role in the innovation process, especially in finding and identifying the critical ideas? It has to do with the

character of critical thinking itself.

First, we need a correct interpretation of the semantics of "critical" thinking. The "criticism" here is the concept in the philosophical context and has the connotation of dialectical unity. Zhao Dunhua pointed out [2]: "In the context of German philosophy, especially in the works of Kant and Hegel, there are always two inseparable aspects of 'criticism': negation and affirmation, abandonment and reservation, exclusion and absorption. Marx's critical philosophy is not a theoretical system, but a method, approach and tool to establish theory...The result of the criticism is the theory and practice unity, the revolutionary and scientific unity. That is to say, critical thinking is a Marx's critical philosophy approach and tool. Its correct performance can make science and technology reach the other shore of unification of theory and practice, revolutionary and scientific unity. Revolutionary, by the way, in this context possess the same meaning as innovation.

Secondly, we should have a grasp of the nature of scientific and technological innovation. The verifiability and repeatability of results are the basic attributes, while the validity, pioneering and extensibility of innovative results are the basis of evaluation. Therefore, the scientific and technical workers must possess the spirit of analysis and criticism, the spirit of creation and the attitude of seeking truth scientifically. They are able to use scientific thinking tools to identify, clarify and find the key to solve problems, to realize fully the complexity, uncertainty and limitations of decision-making. They are good at putting forward valid hypotheses, collecting and evaluating all of information and cited evidences, so as to obtain the optimal solution idea and effect of solving problems, meanwhile timely adjust academic direction or technical details in the practice of testing solutions.

Judgment and synaesthesia are important elements of critical thinking. That is according to the deconstruction and analysis of prototype to be solved, to find the crux of the problem, to screen countermeasures for the problem, to construct new evaluation standards with the help of synaesthesia, to

predict the possible change trend, and to evaluate the effectiveness of the response measures, etc. Finally, practice is used to verify the truth of the judgment and the advantages and disadvantages of the countermeasures, and the new prototype is reconstructed to become the new empirical basis of synesthesia in the future. Dewey, a famous modern American philosopher and educationalist, once said [3], "The most basic requirement for thinking is to maintain a skeptical attitude and conduct systematic and continuous exploration." Richard Paul, a famous scholar of critical thinking, pointed out [4]: "critical thinking is based on good judgment, using appropriate evaluation criteria to judge and think about the real value of things". The statements teaches us when we use critical thinking in the whole process of scientific and technological innovation, everybody ought to maintain a skeptical attitude, to respect the truth and practice, skillfully to deal with all kinds of complexity, uncertainty and limitations, to judge and think about the real value, and to avoid directional and strategic mistakes as much as possible.

In addition, we should pay attention to the severe fact suggested by Murphy's Law, that is, there is a greater probability of technical risk from possibility to sudden fact. It is not only a critical thinking focus on content, but also inspires us from the reverse to give it new connotation: the success of science and technology innovation from possibility to sudden facts can be a bigger probability event. The key is whether you find the key to success. In the development history of science and technology, there are full of such empirical examples and stories.

In a word, critical philosophy and critical thinking is really a thinking tool that fit your needs perfectly, no matter from the need of scientific and technological innovation itself, or sticking to the skeptical mentality and true value judgment, avoiding the obstacles of scientific and technological innovation such as Murphy's curse.

3. Critical thinking is a breeding garden for seed ideas

From the perspective of methodology, the basic

methods of scientific and technological innovation include transplantation, grafting and breeding. The establishment of seed idea is the core of originality and innovation, and critical thinking is the breeding garden of seed ideas.

As we all know, the problem about interfaces is a basic problem in the study of natural science and philosophy. The function of boundary setting between various fields of science and technology is to reflect the homogeneity and synaesthesia within each discipline and technology, as well as the distinguishable idiosyncrasies and correlations among different disciplines and technology groups. But which of the practical problems we face in the field of science, technology and production activities is to being according to these artificial boundaries? As Harlow Shapley ^[5], a prominent astronomer at Harvard, put it, "It is indeed a grand time to be alive and asking questions." Therefore, scientific and technological innovation often involves the need for boundary crossing and interface integration of the original discipline knowledge system. This leads to the creation of seeds of innovative genes, inherited with mutated, and most of them are with new, strong and superior genes. Obviously, it is necessary to apply the methods, approaches and tools of critical philosophy and critical thinking that can achieve the unity of theory and practice, revolutionary and scientific unity.

Actually, shackle on men's innovation minds is the main ideological shackles of superstition authority and conformist, as the American famous contemporary critical philosophy scholar Martha Nussbaum described in ^[6]: "If the argument is not the focus of attention, it's easy to be affected by the speaker's reputation and cultural authority, or by his companion's common view. On the contrary, Socratic critical questioning is completely anti-authority. The position of the speaker is not important; the important one is the nature of the argument that counts." This emphasizes that the weapon to break through authority and stereotypes, to focus on facts and truth is critical questioning. Rabindranath Tagore, an Indian philosopher and poet, also highly advocated Socrates' self-critical thinking mode and argument-style teaching thought. He believes

that critical thinking, which advocates full freedom of exploration and experience, is the only correct way to get the new idea from the kingdom of necessity to the kingdom of freedom. He stated that ^[7] "By fully free exploration and experience, while stimulating the mind to think independently...the mind obtains its own impression. ...The true freedom of the mind is to be achieved not by acquiring the materials of knowledge and possessing the thoughts of others, but by making the mind to form its own standards of judgment and producing its own thoughts."The history of science and technology shows that it is the free exploration and experience of the pioneers and the independent thinking of the mind that produce their own ideas that become the most valuable seed ideas. For example, Newton's absolute space-time frame, Einstein's relativity of time and space, Planck's quantization of motion state and energy, Prigogine's dissipative structure theory, that a nonlinear system far from equilibrium may evolve into a stabilized self-organizing structures, Lobachevskian hyperbolic geometry as the mathematic foundation for the Relativity and so on are known famous seed ideas. It is the seed ideas that germinate and gradually grow into towering trees, and that verify constantly the great power of scientific spirit and the thinking methods.

4. Critical philosophy is Muse of the science and technology in future

Early in this century, the NBIC research program sponsored by the national science foundation (NSF) planned the science and technology development goals: artificial neural networks and artificial intelligence technologies to uncover the mysteries of the human mind. The research program report predicted^[8]"These breakthroughs are being used to speed up the pace of technological progress and might change our species once again in a way that is as profound as the first acquisition of spoken language hundreds of thousands of generations ago.". Less than 20 years on, we have felt the challenge of science and technology to the human beings who drive it. Mankind asks: can artificial intelligence have the innovation ability? The answer is: no! Because AI can only serve as a new tool with super functions, accelerating the pace of scientific and

technological progress, and it is impossible for any original scientific and technological innovation newly born without mankind guidance. The key to start innovation is always in the hands of human beings. As D. Hofstadter wrote [9]: "In the thinking process, there are intricate layers and self-entangling each others. They might play a key role in the process." Human has synaesthesia (in explicit or implicit forms, such as association, intuition, rejecting, illusion, etc.), which the machine never have, to master and develop critical philosophy and critical thinking method in cracking barriers between complex layers and clarifying the self-entangling context. And finally, the seeds of innovation are cultivated through practice and scientific experiments. Quantum entanglement, for example, can be used innovatively to develop quantum communication. Can AI do it well? AI can only be used for quantum communication after all.

5. Conclusion

It is a new time when science and technology rapid develop and a new industrial revolution ride on the momentum. At the same time, human beings, who promote the continuous development of science and technology, also face challenges and worries about the achievements created by human beings, such as artificial intelligence. However, we firmly believe that the ability to innovate is unique to humans and cannot be replaced by any form of machine such as AI. Because we can not only create any advanced form of intelligent machine entity, we also have our own intellectual and perfect spiritual weapons and ability to promote philosophy and are capable of controlling and guiding all forms of scientific and technological products such as AI to improve social productivity for the well-being of mankind.

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