Technological Independence in Chinese-Western Philosophies of Technology

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Abstract

This project aims to examine the theory of technological independence in Chinese-Western philosophies of technology. This paper argues for technological independence by debating whether technology and science represent two separate fields. It then proposes a technological independence program. Technological independence manifesto has distinct significance for technological education, research, and policy. Technological independence road mapping provides a means by which future-oriented technology analysis is applied to education, research, and policy. Technological independence road mapping can, and should, dynamically interact with and learn from other areas, including science, to achieve effective integrations in the social market. This process of development is measured by comparative data analysis and managed by a series of strategies in the inputs, outputs, outcomes, and impacts. Technological independence road mapping benefits technological education, research in the philosophy of technology and the history of technology, and technological policy. However, humans are ultimately responsible for the technologies they develop.

Keywords: Technological independence; Philosophy of technology; Science; Technological independence program; Technological independence road mapping

1. Introduction

Technology develops at a rapid rate in the contemporary world, and it plays an increasingly important role in modern-day industrial and information society. Technologies, including nanotechnology, biotechnology, and materials science, have far-reaching implications and have transformed life as we know it in many ways (Linstone, 2011). Technology has also demonstrated creative capabilities that have driven innovation and development in diverse areas, from culture and society to politics and economy (Bast, Carayannis, and Campbell, 2014).

According to the hierarchical and application view, technology was dependent on science, and the dynamic between the two domains was described as a master-servant relationship (Bunge, 1966). Later, several sporadic studies examined technological independence in the scientific-technological era within the context of Chinese-Western philosophies of technology (e.g., Chen and Yuan, 2001; Gardner, 1994; Layton, 1974; Zhang and Zhang, 2001). However, to date, no systematic research in this domain has been conducted.

Therefore, the purpose of this study is to construct a systematic argument in favor of technological independence in Chinese-Western philosophies of technology and propose a technological independence program and a technological independence road mapping. This paper examines technological independence through the lens of many different research perspectives including ontology, epistemology, methodology, axiology, and praxis. A key focus of the discussion is placed on examining how the theory on technological independence is practically implemented in the form of real productive forces. Specifically, is technology independent from science in Chinese-Western philosophies of technology at the theoretical and practical levels? To answer this question, this study uses various methods of research including textual analysis, comparison, and contrast.

The remainder of this article is structured as follows. Section 2 gives a broad overview and compares technology and science in the West and China. Based on the perspective of Chinese-Western philosophies of technology, Section 3 explores technological independenceby discussing the differences between technological and scientific ontology, epistemology, methodology, axiology, and praxis. Section 4 proposes a technological independence program. Section 5 recommends the development of a technological independence road map and examines the implications for technological education, research, and policy. Section 6 presents the conclusions.

2. What are technology and science in the West and China?

2.1. Technology and science in the West

The modern term *technology* evolved from the word *techne*,an expression that is etymologically derived from the Greek word for "craftsmanship," "craft," or "art." In his notable work *Physic*s, Aristotle argued that the essence of techne as one of three forms of knowledge is to create new objects based on the principle of four causes including material, formal, efficient, and final causes. He also distinguished between *poiesis* (making) and *praxis* (doing) (Mitcham, 1980). The central thesis of Ernst Kapp (1877), the founder of the philosophy of technology, was that technique is the projections of human organs. Taking into consideration the three Kantian critiques of scientific knowing, moral doing, and esthetic feeling, Friedrich Dessauer (1956) proposed the notion of the fourth kingdom of technology from a critique of technological making. Jacques Ellul (1964) asserted that technique is "the totality of methods rationally arrived at and having absolute efficiency (for a given stage of development) in every field of human activity" (xxv). Carl Mitcham (1994) defined technology as embodying the concepts of object, knowledge, activity, and volition.

Science has a long-held association with philosophy. In antiquity, science (derived from Latin *scientia* and Greek *episteme*) as a form of knowledge was closely related to philosophy, a love of wisdom. Science uses a process of observation and experimentation to describe and explain natural phenomena. In the early modern world, science and philosophy were often treated interchangeably when applied to natural phenomena (Lindberg, 2010). Since its emergence in the Renaissance movement between the 14^{th} and 17^{th} centuries, the term *science* was more commonly used to describe the pursuit of knowledge in the Age of Enlightenment that occurred between the 17^{th} and 18^{th} centuries. After the naturalist-theologian William Whewell coined the term *scientist* in 1833, science progressed into a profession in the first half of the 19^{th} century (Wu, 2011). According to British scientist Bernal (2012), in the modern context, science is understood as a form of knowledge, activity, social institution, research method, accumulation of knowledge, or an influential force that underpins people's beliefs and attitudes about the universe.

Traditional views of science and technology typically treat technology as inferior to science (e.g., Bunge, 1966). Therefore, when studied in the context of social phenomena, science as a pure knowledge is viewed as the basis of technology as a practical instrument and scientists are often perceived to be superior to craftsmen. However, historical evidence reveals that technology emerged with the birth of humanity. Therefore, it has a much longer history than science, which, as previously discussed, did not formally appear until the Renaissance and the Enlightenment. In social productivity, technological invention is more pragmatic than scientific discovery and the Western philosophy of technology results in a pragmatic view in reflections of technological efficiency for human activity (e.g., Ellul, 1964).

2.2. Technology and science in China

In China, the English terms *techne*, *technique,* and *technology* are embraced in the concept of *jishu*in Chinese. However, in ancient Chinese, *ji*and *shu*were used independently. *Ji*mainly refers to the skills and talents of craftsmen (e.g., shooting, curing, and divining in *Liji*, a famous book of Confucian classics); however, sometimes, it is also applied to describe creative arts such as singing and dancing (Chen, 1999). *Shu* has a much broader meaning and is used to describe the methods by which certain goals are achieved. *Shu* not only refers to the skills, methods, and procedures employed in the physical act of producing something, but also is applied in a more abstract sense to refer to thought processes, mental calculation, strategy, deception, Daoist magic, necromancy, and more (Wang, 2013).In modern Chinese, *jishu* has both narrow and broad meanings. According to *Cihai*, a Chinese dictionary, in the narrow connotation, *jishu* typically refers to a variety of operating methods and skills that are developed in accordance with practical production experience and the principles of natural science. It also describes production tools and processes, material equipment, operating procedures, and methods of operation. In the broader sense, *jishu* is an umbrella term that is used to describe all or any means and methods by which human beings reform nature, society, or themselves (Chen, 1999). In history, the Four Great Inventions of ancient China are the compass, gunpowder, papermaking, and printing. Technologists and engineers primarily operate in the technological field.

Traditionally, knowledge was referred as *Xue Wen* (learning, knowledge) in Chinese. However, following the Ming Dynasty (1368-1644), Chinese scholars described the development of knowledge by adopting a new term *GeZhi*; i.e., *Ge Wu ZhiZhi*, which is applied to the study of the phenomena of nature so as to acquire new knowledge, the formal study of the nature of things. Japanese scholars used *kexue* as the translation of science(i.e., classified and studied knowledge) from Europe in the second half of 19th century. Then, in 1890, Chinese scholars began to use the word *kexue* from Japan and pushed the development of Chinese scientific thought. Since then, the word *kexue* has been widely used throughout China (Hui, 2011). In general, scientists study science. As the British scientist Joseph Needham (1964) stated in the Needham Question, "the essential problem [is] why modern science (as we know it since the seventeenth century, the time of Galileo) had not developed in Chinese civilization (or Indian) but only in Europe?" (p. 385). Needham also questioned what led to the Chinese population's evolution of the ability to apply human knowledge in a practical manner: "why, between the first century B.C. and the fifteenth century A.D., Chinese civilization was much more efficient than occidental in applying human natural knowledge to practical human needs?" (p. 385). Needham summarized the wealth of knowledge and learning that the Europeans had acquired in terms of science, medicine, and technology from China. Needham (1980) also split *Science and Civilisation in China* into distinct volumes that corresponded with the pure sciences of mathematics, physics, chemistry, and biology, followed by applied modern sciences or technological fields according to the tradition.

As evidenced in the above examples of traditional views, science consists of a combination of pure science and applied science (i.e., technology). The simplified term, Sci-Tech, which is often applied in China, embodies the perception that there is a strong affiliation between science and technology. This kind of expression easily misleads people and creates the false impression that technology is inferior to science, particularly in Sci-Tech education, Sci-Tech research, and Sci-Tech policy. However, in reality, science and technology are the primary productive forces of new China, and technology, in particular, plays a powerful role in supporting the country's economic development. The Chinese national leadership is a type of technocracy. In more recent years, China has progressed from a manufacturing-led economy to one that places a heavier focus on technological innovation and sustainability. The Chinese attitudes toward technology manifest a more positive appreciation of technology in technological practice than those of the West (Wang, 2013).

3. Technological independence from science

This section examines the theory of technological independence, which essentially states that technology is independent of science. This argument will be explored in depth through an analysis of the theoretical research perspectivesof ontology, epistemology, methodology, and axiology, and the process by which these theories are realized in praxis.

3.1. Ontology: technological invention vs. scientific discovery

Technology and science differ in terms of ontology. Technology manifests itself in technological inventions that involve consideration of what to do and how to do. However, science represents a theoretical discovery by which we evolve an understanding of what we should know and why we should know it. Historically, many technological inventions, such as steam engines, mechanical clocks, waterpower devices, and metallurgical techniques, have emerged independently from scientific discovery (Radder, 2009). Technological developments sometimes are evidently sudden and disruptive; for example, the developments of the Internet and unmanned vehicles. In general, scientific developments evolve through a cumulative process, although scientific progresses sometimes have sudden jumps.

In terms of object, technology is artificial and it results in man-made objects, processes, and designs (Hansson, 2007). However, science usually involves nature and natural objects. Observed for the process, technology involves a process by which one progresses from the subjective willing to the outcome of objective objects. However, science is related to a process by which one progresses from the objective phenomena to the subjective observation and utilizes experimentation to describe and explain natural phenomena. From a discipline perspective, technology is related to social science for social phenomena in technology, human, nature, and society, whereas science involves natural science for natural phenomena such as physical science and life science. The attitudes that are typically associated with technology are skepticism, optimism, and uneasiness (Mitcham, 1994). However, scientific attitudes involve curiosity, pursuit of the truth, honesty, objectivity, questioning, critical thinking, and open-mindedness (Kozlow and Nay, 1976).

As held in this study, the difference between the various attitudes that are demonstrated across scientific and technological approaches may be related to the divergence of human capital, educational opportunity, working profession, economic condition, cultural nurture, and social context.

3.2. Epistemology: knowing how and doing what vs. knowing why and knowing what

Many researchers and theorists have debated the epistemology of technology and science, especially in terms of the evolution of knowledge. For example, Ryle (1945) proposed a basic division of knowledge into two factors: knowing how as a practical knowledge and knowing that as an intelligence knowledge. According to Bunge (1966), technology is applied science. Layton (1971) proposed a hybrid model of science and technology that viewed the two subjects as mirror-image twins that heavily interact with one another but are ultimately different. Layton (1974) also claimed that knowledge plays a significant role in defining technology, and that it is possible to differentiate between scientific and technological knowledge through considering intention, or purpose. Wise (1985) argued that treating science and technology as two separate spheres of knowledge, both man-made, seemed to be more reflective of the historical record than viewing science as revealed knowledge and technology as a collection of artifacts that had once been constructed by trial and error but were now constructed by applying science. According to Houkes (2009), scientific knowledge is theoretical and declarative, while technological knowledge is practical, procedural, autonomous, and descriptive, rather than an application of scientific knowledge. In general, technology represents action knowledge, while science represents factual knowledge (Hansson, 2015).

In response to the above debates, this article opposes a linear view of technology as applied science on the following grounds. Technology emerged with the birth of humanity earlier than science, which is associated with the periods of the Renaissance and the Enlightenment; therefore, ancient technology is independent of science.

Technology is viewed as a collection of techniques that are employed to create a new object or solve a practical problem for changing the world. It is a creative activity that involves developing to know how by making and doing. Developing the required knowing how involves developing an understanding of the methods and processes required for the phenomena to form. Doing what is an action of doing by using technology (Chen, 1999). Knowing how is generated by a process of learning by doing (Arrow, 1962). For example, knowing how to ride a bike needs understand the skills and procedures of cycling, which is learned by practicing cycling.

The fundamental objective of science is to uncover the reason and truth that underpins a theory for knowing the world. In essence, science represents a process of theoretical discovery that utilizes research and analysis to develop knowing why and knowing what. When an individual understands the principles that accurately describe a given phenomena, he or she has achieved knowing why. To develop knowing what, one evolves a comprehensive understanding of the facts through learning by using. It is through entering into a process of study and discovery that individuals develop knowing why and knowing what (Carud, 1997). For example, one is difficult to develop a full understanding of Newton's laws of motion without first studying the basic physics knowledge that is associated with this theory.

In short, in a given knowledge management system, technology is a kind of practical activity by which one engages in a process of knowing how and doing what by making and doing for creating new objects and solving problems. However, science represents a form of theoretical discovery for knowing why and knowing what for seeking the reason and the truth (Chen, 1999). According to Bohn (1994), knowing how comes before knowing why. This is perhaps because it may be possible to generate a technological system with knowing how alone while the same cannot be said for knowing why. Bohn suggests that knowing why can be created based on knowing how through a learning process that is related to tapping scientific models, running broad experiments across a range of variables to estimate models, and finding interactions among and between input variables. For example, Carud used his engineering knowledge to repair his wife's computer that refused to boot up. However, he could not answer his wife why the problem had developed. This example demonstrates that it is possible to operate based on knowing how alone (Carud, 1997). It is a fact that technology emerged before science. In daily life, technologists and engineers function and behave differently and independently from scientists. Without scientific theory in knowing why and knowing what, technological practice in knowing how and doing what can proceed independently. Therefore, this study argues that technology is independent of science in terms of knowledge.

3.3. Methodology: trial and error vs. verification or falsification

Science and technology also differ in terms of the methodology involved. Technology primarily combines a process of design, invention, creation, and innovations with practical experiences. The effectiveness of technological inventions often increases with trial and error. However, the starting point of science is often a set of hypotheses that are subsequently verified or falsified as a result of a process of experimentation. Scientific development and growth, therefore, evolves through the evolution of conjectures and refutations in theory (Popper, 2014). According to Mitcham (1994), designing, as the essence of engineering technology, is considered to be the salient feature that distinguishes technology from science. Houkes (2008) describes designing as the construction of use plans. Technology and science also differ in terms of innovation. Technological innovation primarily involves the evolution of technological material, methods, and products to develop new combinations of production factors and conditions in which production takes place (Schumpeter, 1942). Scientific innovation, on the other hand, places a distinct emphasis on scientific creativity. Hence, technology exists independently from science in methodology.

In terms of mode, technological invention is usually empirical-inductive and it relies on a series of trial and errors. Scientific discovery is usually logical-deductive and is based on verifications or falsifications (Popper, 1959). For example, not all swans are white. Hence, through a process of falsification, we discover what might not be found by verifications. In terms of the development model, the structure of scientific revolutions represents a paradigm shift that is based on incommensurability in a series of progress (i.e., “paradigm-normal science-anomalies-crisis-scientific revolution-new paradigm-new normal science”) (Kuhn, 1962). However, the pattern of technological development involves an institution shift in a series of procedure (i.e., “the technological institution-the technological innovation-the technological institutionalization-the new technological institution…”) (Han, 2007). In terms of means and ends, science is oriented in unique truth by diverse methods that can be repeated. Technology is orientated toward diversified outcomes by various methods through which human beings perform tasks from physical structure to technical function (Kroes, 2002; Kroes and Meijers, 2002).

3.4. Axiology: practical value vs. theoretical value

In terms of axiology, technology changes the world in a practical manner. It uses and controls nature, creates artificial environments that are designed to mimic nature and coordinates the relation between the human race and the natural environment within which we exist. Technology is also heavily focused on enhancing effectiveness and efficiency, resolving the problems we encounter in our everyday lives, and advancing the solutions that we have developed to these problems. Technological practice is closely related to economic development, human welfare, and social benefit. Science differs in this regard, because it is primarily concerned with reflecting on the world, developing an understanding, discovering the truth behind our existence and the natural environment and the pursuit of knowledge and understanding. The effectiveness of a technological development is judged by the extent to which it is effective, efficient, practical, rational, and novel, whereas the standards by which scientific developments are judged is truth, as measured by practice (Chen, 1999). In value assessment, scientific norms have four fundamental principles: communism, universalism, disinterestedness, and organized skepticism (Merton, 1942/1973). However, these scientific principles do not fit technology. Hence, the practical value of technology is viewed independently of the theoretical value of science.

Science and technology also differ in terms of the following axiological aspects. In terms of space, technology has the border, and technological invention has the patent and intellectual property. However, science has neither the border nor confidentiality, but priority in the discovery order. With respect to time, technological invention has timeliness, and technological innovation is the measure of technological progress. On the contrary, scientific discovery is timeless and scientific theory does not become out of date. In terms of openness, technological invention is protected by patents. However, scientific discovery is treated as open and accessible to all; it is not deemed to be ethical to protect scientific discoveries. With respect to productivity, technology is material, direct, realistic, and original, whereas science is mental, indirect, potent, and involves extensive productivity (Liu and Ye, 1995). In terms of social function, technological developments drive social change and human progress. However, the relationship between science and society depends on the welfare of them both (Bernal, 1939). With respect to ethics, the ethics that underpin technological and engineering progress and development are very different from those exhibited in the scientific field. Technologists and engineers materialize morality and ethics, which is a fundamental aspect of design practices (Steen, 2014; Verbeek, 2006).

The philosophy of technology helps to improve ethical behaviors in technological innovation and in the ethics that underpin engineering education (Cao, 2014). Scientists ensure that scientific ethics is reflected in their research conducts and behaviors. In terms of opposition, technology counters false technology, whereas science reverses pseudoscience.

3.5. Praxis: technological experience vs. scientific experiment

In terms of praxis, the fundamental difference between technology and science is that technology is predominantly practical while science is mainly theoretical. In technics and praxis, experience is deemed to be of immense value (Ihde, 2012). Aspects of the methodological approach to modern experimental science that are observed in use today can be traced back to pre-scientific, technological tradition, and scientific experimentation involves acting and observing (Hansson, 2015). As described in Section 2.1 of this paper, in terms of historical evolution, technological experience preceded scientific experiment and, therefore, scientific experiments were constructed on pre-scientific, technological experience. Hence, technology sits independently of science in the praxis.

In terms of performance, technology is embodied in technological and engineering cases by focusing on experience and is related to technological education, research, and policy. However, science is embodied in scientific cases and is involved in scientific education, research, and policy.

4. A Technology Independence Program

As the above discussion reveals the independence mechanism, technology and science are two different fields of interest that differ from one another in terms of many theoretical factors, including ontology, epistemology, methodology and axiology, and in praxis from a perspective of philosophy.

Paul Gardner (1994) described four views of the nature of the relationship between science and technology:

1. The application view, which holds that science precedes technology, such as technology as applied science;
2. The demarcation view, which holds that science is independent of technology and has different goals, methods, and outcomes;
3. The materialist view, which holds that technology precedes science in the historical and ontological priority and that technological experience is necessary for scientific development;
4. The interactional view, which holds that science interacts with technology and each, learns from each other in mutually beneficial ways.

Science as technology was illustrated in the early works of Martin Heidegger, Jürgen Habermas, Peter Janich, and SrdanLelas, and was developed into technoscience by Donna Haraway, Bruno Latour, Don Ihde, Karl Rogers (Radder, 2009), and also Sven Ove Hansson (2007). According to JuNaiqi (2007), technology is superior to science when viewed through the lens of historical materialism, effects of technology, and science-technology relation. This current study holds the following three views that technology is independent of science, technology precedes science, and scientific development learns from technological experience. Therefore, this article opposes the applicational view, supports the demarcation view, and also agrees with materialist and interactional views.

In terms of the philosophy of technology, some notable Chinese scholars have disputed a research program based on the demarcation between technology and science. From the perspective of the demarcation between science and technology, Zhang Huaxia and Zhang Zhilin (2001**)** argued that any research program that is related to the philosophy of technology should focus on technological epistemology, holding technological knowledge theory and technological logic at its core. This research programs in this domain should incorporate six distinct areas: **(**a) technological definition and ontological status, (b)technological epistemological procedure, (c)technological knowledge structure, (d) regular technology and technological revolution, (e) technology and culture, and (f) technological value and technological ethics.However, treating science and technology as two different systems of knowledge are not the essential discrimination between the two domains. Chen Changshu and Yuan Deyu (2001) argued that the main way in which science differs from technology is that technology involves practical activity in the economic domain while science involves theoretical exploration. They claimed that technological value should be at the heart of the research program into the philosophy of technology, and added alternative six demarcations that facilitate openness.

These six demarcations are as follows: (i) the demarcation and connection between technology and science; (ii) the demarcation and connection between philosophical turn of technological study and technological turn of philosophical research; (iii) the demarcation and connection between the philosophy of technology and philosophy of science; (iv) the demarcation and connection between the philosophy of technology and other integrated disciplines related to technical issues (e.g., economic philosophy, technological economy, historical philosophy, sociology of technology, cultural philosophy, technological psychology, and technological esthetics); (v) the demarcation and connection between the engineering philosophy of technology and the humanities philosophy of technology; (vi) the demarcation and connection between basic research and applied research of the philosophy of technology. In comparison to the research objectives of this paper, the former focuses on technological epistemology as the beginning of the research program of the philosophy of technology, while the latter places an emphasis on the practical value of technological developments as its ultimate goal. Both have the potential to guide a research program that is focused on the philosophy of technology; however, they are at different developmental stages of beginning and maturity. This current study assesses that both research programs are termed as a science-technology demarcation program. Philosophical disputations on ascience-technology demarcation program for the philosophy of technology improve the depth of the Chinese philosophy of technology and make a significant contribution to existing philosophies on technology in the diverse vitality.

Further, this current study proposes a research program that is designed and developed based on that technological independence exists from a philosophical perspective. This technological independence program including the following five areas is centered with technology in a developmental independence view, rather than the demarcation between science and technology. As time has progressed, technology has continued to evolve in terms of both its connotation and denotation. Hence, views of technological ontology, epistemology, methodology, axiology, and praxis are of relevance and needs to be updated.

(a) Technological ontology includes the definition, classification, nature, characteristics, structure, and key factors relating to technology.
(b)Technological epistemology studies consider the relationships between science, technology, and engineering; the relationships among techne, technique, skill, and technology; the relationships among humans, nature, society, and technology; technological optimism, pessimism, and neutralism; and the epistemology on specific technologies such as information technology and biotechnology.
(c)Technological methodology studies involve technological design, innovation, transfer, diffusion, application, rule, and system.
(d) Technological axiology studies are theory-based pieces of research that include consideration of technological assessment, forecast, rationality, responsibility, ethics, risk, safety; and application value studies that consider technology and culture, technology and economy, technology and politics, technological advancement and human welfare, and technology and society.
(e) Technological praxis studies are mainly concerned with the examination of real-life technological and engineering cases and are related to technological education, research, and policy.

5. Technological Independence Road Mapping

This study takes the approach of the technological independence manifesto, which declares that technology is an independent power from science in both historical and social contexts. The technological independence manifesto, as a philosophical theory, has significant implications for technological education, research, and policy. This study argues in favor of the development of a technological independence road map as the agenda that guides the future work of academic circles, education and policy departments. In essence, technological independence road mapping represents a framework for the development of technological independence, by which future-oriented technology analysis is systematically applied to education, research, and policy. The development of a technological independence road map can, and should, involve dynamical interactions and exchanges with other areas, including science, to achieve effective integrations in the social market. Hybrid careers have created a network of interaction between scientific and technological communities, and these relationships have played an important role in spreading scientific knowledge and technological practice (Krankis, 1992). Many challenges and opportunities exist within the dynamic and complex systems of science and technology. These include discontinuous innovation.

Evolutionary, neo-Schumpeterian, and complex system dynamics approaches are conceptually attractive and can be potentially utilized to practical policy-making initiatives by applied systems-relevant research (Aghion, David, and Foray, 2009). The extent to which the application of technological independence road mapping achieves its objectives is measured by comparative data analysis in the inputs and outputs. The implementation of the tasks themselves is suggested to be managed by a series of strategies for exogenous and endogenous developments in the outcomes and impacts. Effectiveness and efficiency are two useful factors that are employed to qualitatively and quantitatively assess the power and impact that technology has on the ability of policy makers and practitioners to avoid market failures in different areas of the world. Through the use of carefully designed assessments and strategies, technological independence road mapping also provides a means by which the future developments of different technological areas, including information technology, nanotechnology, biotechnology, and materials science, are forecasted and anticipated.

This study recommends that technological independence road mapping use a model of education-research-policy that is developed in combination with education-oriented, research-led, and policy-guided approaches, for the purpose of technological developments in terms of philosophy and management. Technological independence road mapping incorporates guidelines and instructions that involve many important aspects including technological education, research into the philosophy of technology and the history of technology, and the development and application of technological policy.

5.1. An education-oriented approach

Education represents the central vehicle through which intelligent talents are trained and developed so as to foster endogenous development. According to the endogenous growth theory, increasing research and development expenditures alone are not enough to accelerate growth. Rather, it is necessary to improve the total quality and quantity of inputs related to the research and development process (Romer, 2000).

It is technological independence that sets technological education apart from scientific education. For instance, education in the philosophy of technology is very different and independent from education in the philosophy of science. Education in the philosophy of technology includes teaching various aspects relating to technological ontology, epistemology, methodology, axiology, and praxis. However, education in the philosophy of science departs information on scientific ontology, epistemology, methodology, axiology, and praxis. Similarly, education in the history of technology is different and independent from education in the history of science. In order to develop an adequate understanding of the technological frontiers that exist in society, it is necessary to study different technologies across different disciplines in depth. Measurements of inputs and outputs that are employed to monitor the success of technological education include the amount of money invested, the number of educators who specialize in technological education, the number of students who are enrolled in technological education, and the number of graduates who successfully complete programs of technology and engineering. Measurements of inputs and outputs that are used to monitor the success of scientific education include the amount of money invested, the number of educators who specialize in scientific education, the number of graduates who successfully complete programs of science.

5.2. A research-led approach

Research represents the core process by which the human being generates new knowledge and increases capacity for social development. During the research process, success may be awarded and celebrated, while failure may be recognized as a critical aspect of the process of growth and development, especially in new areas. Future-oriented research is crucial for the development of new technological research that will benefit future generations.

Technological independence sets technological research apart from scientific research. For example, research in the philosophy of technology is very different from research in the philosophy of science. In the past, the philosophy of technology was somewhat underdeveloped in comparison to the philosophy of science; however, research into the philosophy of technology kept on the increase (Ihde, 2004). In contrast to the philosophy of science, like the technology itself, the philosophy of technology is more practical, innovative, experimental, adaptable, and open to change (Garcia and Jerónimo, 2014; Ihde, 2014). The philosophy of technology embraces both a reflection philosophy and a practical philosophy, while the philosophy of science is usually a reflection philosophy.

Research in the philosophy of technology includes consideration of technological ontology, epistemology, methodology, axiology, and praxis, while research in the philosophy of science includes consideration of scientific ontology, epistemology, methodology, axiology, and praxis. Also, research in the history of technology is different and independent from research in the history of science. Although historically they have been viewed and treated in much the mixed manner, basic research, applied research, experimental development, technological progress, and industrial applications are in very different areas that can exist independently of each other. Different technological areas can, and should, be studied in depth so as to develop future technology that is aligned with social and cultural developments. Input and output measurements that are employed to assess the effectiveness and efficiency of technological research include invested capital, number of researchers engaged in technological research, technological export, patents, and technology advantage. The measurements of the inputs and outputs of scientific research include invested capital, number of researchers engaged in scientific research, and number of scientific publications.

5.3. A policy-guided approach

It is important that valid policies are designed and developed to direct the development of technological society in social practice. The implementation of well thought out and considered policies macroscopically manage and influence the direction of social development.

Technological independence separates technology policy from science policy. Technology policy is technology-oriented. It involves the assessment and forecasting of technical offerings and the means by which developments are anticipated, and appropriate decisions relating to future technologies are made. Technological assessment plays a significant role in technology management and public decision-making (Tran and Daim, 2008). Technological forecasting acts as a valuable support network that strengthens the national innovation system within the context of the global society (Martin and Johnston, 1999). Technological foresight is currently in the process of catching-up vis-à-vis innovation studies. Science policy is focused on science and involves scientific evaluation, prediction, and decision-making (Andersen and Andersen, 2014).

Studies that aim to anticipate the future of science and technology have both significant potential and fundamental limitations (Meissner, Gokhberg, and Sokolov, 2013). In order to optimize the opportunities and effectively manage the challenges, it is important that science and technology policies, science policies, and technology policies are handled and managed in their respective right in accordance with appropriate institutional policies. Science policy and technology policy can be implemented separately in the relative organizations, value systems, and reward institutions. The measurements of the inputs and outputs of technology policy include capital and labor investments in technology, technologic innovation rank, and technologic competitiveness index. The measurements of the inputs and outputs of science policy contain capital and labor investments in science, scientific innovation rank, and scientific competitiveness indexes.

6. Conclusion

This study argued in favor of the theory of technological independence that technology is, and should, be treated as independent from science in terms of ontology, epistemology, methodology, axiology, and praxis. Based on technological independence, this study further proposed the development of a technological independence program that is accompanied by technological independence road mapping. Based on the perspective of philosophy, the proposed technological independence program includes technological ontology, technological epistemology, technological methodology, technological axiology, and technological praxis. Technological independence manifesto, as a philosophical theory, has significance for technological education, research, and policy. However, technological independence does not mean the absolute isolation of technology from science and similar disciplines. On the contrary, it is important to take into consideration the fact that technology has many important connections with science and society. Technological independence road mapping defines a process by which technological research is approached and technological education that takes into consideration the philosophy of technology and the history of technology, as well as technological policy is developed. However, technology can be a source of great success and dismal failure in modern-day society (Ihde, 2006). In terms of treating the possible technological trap, technological developments need to be carefully managed in an efficient and secure manner and responsible innovation should be promoted in a cautionary principle (Editorial, 2007).

Therefore, it is important that the significant role that humans play in the development and management of technologies is not overlooked. It is critical for humans to develop technology in a responsible and ethical manner through the adoption of appropriate technological education, research, and policy.

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