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Technovation 26 (2006) 1294–1301
technovation
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Technological innovation processes revisited

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Abstract

This work is part of an inquiry into the causes of the small occurrence of innovations in the Brazilian society. It was based on a retrospective analysis of cases experienced by the author, as well as on the study of certain industries. The systemic model of the technological innovation process presented here, while revisiting the models in the literature, emphasizes the crucial role of the activity of the conception of new ideas and its interaction with other phases of the process. Conception is critical and was, therefore, separated from other activities mainly because it is subject to the action of innovations inhibiting factors. A model for these factors is also presented. The author expects that an enhanced understanding of the innovation process in its complexity and of the action of inhibiting factors will help R&D managers to achieve better success levels.

Keywords: Technological innovation processes; Conception: a critical activity; Innovations inhibiting factors: managerial; Economical; Psychosocial; Cultural; Pasteur's quadrant; Project management; Matrix structure

1. Introduction

For the benefit of the communication process, that is, trying to avoid communication "noises", let us start from the beginning: "An innovation is an idea, procedure or object perceived as new by an individual or another unit of adoption, e.g., a firm" (Rogers, 1995). And, according to Britannica (2001): "Technology is the application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of human environment".

But, in terms of the processes through which new technologies are created—has that Britannica definition always been valid? The answer is no, because "The history of technology is longer than and distinct from the history of science. Technology is the systematic study of techniques for making and doing things; science is the systematic attempt to understand and interpret the world… Science is devoted to the more conceptual enterprise of understanding the environment and it depends upon the comparatively sophisticated skills of literacy and numeracy. Such skills became available only with the emergence of the great civilizations, so that it is possible to say that science began with those civilizations, some 3000 years BC, whereas technology is as old as manlike life" (Britannica, 2001).

Thus, let us say, from 3,000,000 years BC up to 3000 years BC, technological innovation processes were independent of science and its method. How? It was dependent almost exclusively on the trial and error method to *know how* new ideas functioned, independent of *knowing why* they worked. For example, the hominids artistically shown in the motion picture "2001, a Space Odyssey" hitting their prey with clubs instead of fists, for the first time ever, were discovering how to kill more effectively without knowing why: the momentum acquired by heavier and heavier clubs in their movement and that the action = reaction of Newton's third law applied to the clubs and not directly to their fists.

Although coexisting since 3000 BC up to Britannica's contemporary definition, science and technology followed independent paths most of the time. The crossing of paths

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doi:10.1016/j.technovation.2005.10.003

was theoretically proposed by Bacon (1952): Book II of *Novum Organum*, 1620 and *New Atlantis*, 1617; but only shown as practically advantageous by Justus Von Liebing and Thomas Alva Edison, respectively, in the second half and by the end of the XIX century. "Justus Von Liebing of Germany, one of the fathers of organic chemistry and the first proponent of mineral fertilization, provided the scientific impulse that led to the development of synthetic dyes, high explosives, artificial fibers and plastics; and Michael Faraday, the brilliant British experimental scientist in the field of electromagnetism, prepared the ground that was exploited by Thomas A. Edison and many others" (Britannica, 2001).

Therefore, considering that technology is the set of techniques used to develop products and services and, nowadays, specifically the techniques developed with the employment of scientific knowledge and using the "scientific method", *the technological innovation process is the sequence of activities undertaken to generate new techniques with the help of the sciences and their method.*

2. Innovations inhibiting factors

But one may wonder: why did technologists wait for 49 centuries to systematically use science in their innovation endeavors? That is, why did it take so long to use knowledge related to the "know-why" of things to enhance the search of the know-how? To "enhance" because *knowing why* improves the trial and error method typical of know-how discoveries.

Perhaps a good part of the answer to that question comes from something that can be called *innovations inhibiting factors* that can be classified as *managerial, economical, psychosocial and cultural*. Innovations, plural, because these factors inhibit all kinds of innovations: the contemporary technological innovation process, organizational innovation processes, ethical innovations, etc.

Probably the most ancient documented example of a *cultural inhibition* is the one provided by Archimedes in the third century BC who, according to tradition, after discovering how to move a given weight by a given force (lever principle) boasted to King Hiero of Siracuse: "Give me a place to stand on and I can move the earth". After proving his words to King Hiero, lifting a loaded ship from the dock, he ordered: "Archimedes was to be believed in everything he might say". Or when shouting "eureka" (I have found it) he left the public baths and ran naked home and kept shouting "eureka", after discovering, maybe at the same time, Hydrostatics buoyancy law and a way to solve a problem posed by King Hiero: how to find, without destroying his crown, how much silver had been used in its gold–silver alloy.

Although Archimedes acquired by his inventions "the renown of more than human sagacity", according to Plutarch (Britannica, 1971, vol. 11, pp. 399–400), he "would not deign to leave behind him any commentary or writing on such subjects", since he considered them "sordid and ignoble". Perhaps that attitude could be explained by the meaning of the word ignoble = of low birth or common origin. One should remember that for most of the recorded history, the manual practical arts of the artisans were the labor of slaves or servants and not of those of "high birth". And so, a dignified intellectual activity to nobility would be Geometry, and leaving behind books such as "On the Sphere and Cylinder" (whose main theorem was in Archimedes gravestone), "Measurement of the Circle", "On Conoids and Spheroids", etc.

It is undeniable that as far as intellectual activities are concerned "the systematic study of techniques for making and doing things [for personal profit]" is less noble and altruistic than the "systematic attempt to understand and interpret the world [for the sake of this understanding and the correspondent benefit of mankind in general]". Summing-up, historically, science had more glamour and importance than technology.

3. First- and second-generation innovation theories

Perhaps that is why the "first-generation theory" (Rothwell, 1992, 1994) of technological innovation is the science-push one shown in Fig. 1, together with the second-generation theory: the demand-pull.

In many minds, particularly in those linked to academic research and formulation of public policies for science and technology, the glamour and relative importance of science keeps retaining paradigms, such as the one re-created 50 years ago by Bush (1990): "Basic research is the pacemaker of technological progress", or "a nation that depends on others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade", or "applied research invariably drives out pure".

In other words, in the apparent dichotomy (basic research) versus (applied research) one should, according to Vannevar Bush, choose the first because the second, which traditionally initiates (R&D) the technological innovation process, derives from it.

Stokes (1997) does not agree with that dichotomy and, to argue against it, proposes a second dichotomy shown in Fig. 2.

The main point of Stokes' arguments is that there are basic researches inspired by the future use of the discoveries, for example, Pasteur's work (biochemistry

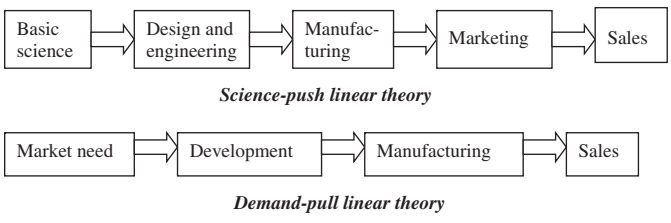

Fig. 1. Science-push and Demand-pull theories of innovation (*Source*: Rothwell, 1994).