Utility Versus Curiosity in Technology and Science

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"Si nous pouvions nous dépouiller de tout orgueil, nous ne dirions peut-être pas *Homo sapiens*, mais *Homo faber*."

—Henri Bergson, *L'évolution créatrice*[1]

Technology and science distinguish humans from other species. Both use similar tools but have different origins and purposes. The first one is as old as humankind, and it is with it that *Homo sapiens* began to build the artificial world [3]. The second of the two appeared about 300 years ago, although primitive vestiges of science had already been detected in the ancient world, mainly in the form of astronomy and geometry. The artificial world is the cumulative result of technological progress throughout human history.

Although technology emerged with hominization, science would not appear until long after. Science was born as a branch of philosophy whose aim was to study natural phenomena by means of rigorous experiments and observational methods, together with a solid mathematical foundation. Philosophers thereby have a greater affinity for scientists than for engineers. Science is a huge human enterprise, a very sophisticated way of looking for the truth.

Technology is formed of mountains erected by all the products that make up the artificial world. Atop this mountain chain, engineering flourishes. As a result, engineering is considered "technology par excellence," as pointed out by the Spanish philosopher Ortega y Gasset [9], a pioneer of the philosophy of technology. Thus, technology comprises engineering. This article will henceforth consider engineering as the highest level form of technology.

Engineering has its own goals and distinctive methods, even if it utilizes the results of science. But while science has undoubtedly contributed to modern engineering, the designs traditionally developed by the latter do not owe their conception to science. Devices such as steam engines, aircraft [10], telegraphs, or computers [7] were all invented in pursuit of valuable artifacts for a useful purpose. It was not the science available when engineers first created these devices that inspired their invention, but intuition [5], which sought a solution to some real-world problems. These devices are the product of engineers' creativity and imagination in solving specific problems of practical use.

Even if science can clarify how a given artifact works, it does not tell us how to make it. Understanding the natural phenomena implicit in artifacts, and proposed by science, can contribute greatly to their design, but not so much to their conception. In conclusion, technology is driven by human inventions that promote the well-being of society.

Science's main objective is knowledge and aims at attaining scientific truths. By contrast, engineering concerns itself with the solution of practical issues (public works, agricultural holdings, communications networks, airplanes, computers, consumer goods, and the like). Accordingly, technology is characterized by a pragmatic attitude that focuses on building useful things [1]. To put it in simple terms, the debate on technology and science could be viewed through the lens of assigning two radically different types of goals to each field: 1) utility for technology and 2) curiosity for science. Even if

[1]If we could throw away all pride, we would not say *Homo sapiens*, but *Homo faber.*

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both share utility and curiosity, the search for utility is the primary objective of engineers, with curiosity remaining secondary. Conversely, scientists are guided mainly by curiosity, and utility follows.

These two goals are the main driving forces for each domain. As such, there are two distinct approaches to knowledge: one relates to the course of action required so as to construct the artificial world; the other, to the satisfaction of the curiosity caused by the never-ending mysteries and beauty of the natural world. Both may overlap because engineers also attempt to grasp the natural phenomena associated with the artifacts they forge, but this is not their priority. For its part, science experiments with the instruments built applying the technology at hand and scientists find numerous research themes in successful artifacts [6].

Modern engineering has resulted in branches such as aerospace, robotics, communications, automatic control, and computer science. All of them are based on devices that have opened up research areas to science. The following well-known quote from Ortega y Gasset [9, p. 116] is relevant here: "In short human life 'is' production. By this I mean to say that fundamentally life is not, as has been believed for so many centuries, contemplation, thinking, theory, but it is action. It is fabrication; it is thinking, theory, science only because these are needed for its fabrication, hence secondarily, not primarily." Many scientific discoveries, including basic sciences, were made subsequent to engineering inventions (for instance, thermodynamics or computer science). Ergo, the expression that states that technology is *ancilla scientiae* should be replaced by science is *ancilla technicae*.

Nevertheless, mainly since WWII, there has been a tendency to merge engineering and science into a single framework [8]. There is strong intellectual pressure from many scientists, with the endorsement of some philosophers, who support the idea that modern engineering stems from science. In line with that notion, engineering would be run by science. However, this statement is not correct. Science has in fact influenced most contemporary engineering, but the fruits of technology blossom from the creativity and imagination of engineers to solve specific utilitarian problems. It would seem that behind the aforementioned statements of scientists lies they want to share the outstanding position of technology in today's society.

Different goals are pursued even if science and engineering employ similar conceptual and computational tools. These shared tools might be the cause of the popular confusion between science and technology. As early as ancient Greece, Aristotle distinguished between the two forms of human labor in his *Nicomachean ethics:* "For a carpenter and a geometer investigate the right angle in different ways: the former does so in so far as the right angle is useful for his work, while the latter inquires what it is or what sort of thing it is, for he is a spectator of the truth" [4]. This dichotomy holds true 2,500 years later: engineers, even unconsciously, have made common causes with the carpenter; while scientists, as well as philosophers, have agreed with the geometer.

Those who first try to satisfy the curiosity induced by nature's exuberance finish their work by publishing their discoveries. But when the task of solving a practical problem is completed with an adequate artifact of widespread social acceptance, those who design technological objects did not necessarily need to pay special attention to the scientific foundations of their creation, except insomuch as it is needed to improve their design. Moreover, engineers always use reason in applying their methods (reason is not exclusive to science).

Spectrum from engineering to science

As has been mentioned above, engineering and science make use of similar tools, which gives rise to similarities between them. Furthermore, today, many scientists are working on useful applications and appear to be invading areas traditionally dominated by engineers. Figure 1 shows the spectrum of the transition from engineering to science, which can develop our understanding of the connection between the two.

The upper rectangle of Figure 1 extends from the useful activity of the engineer U on the left side, to the right side where the cognitive objectives of scientist C lead. This spectrum was proposed in [2]. The fuzzy relationship between science and technology is illustrated in the lower rectangle of Figure 1, where the sigmoidal functions describe the evolution of utility U and curiosity C along the spectrum. On the horizontal axis, the variable x quantifies the ratio between the theoretical and scientific aspects of the work, and the practical and useful aspects. When there is a change in x, curiosity increases at

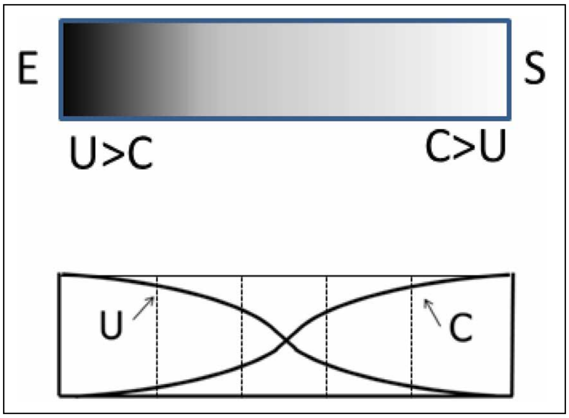

Figure 1. Upper rectangle showing a continuous spectrum that ranges from engineering E (U > C) to science S (C > U). In the lower rectangle, curiosity C and utility U are described by sigmoidal functions along the spectrum. The meaning of the five vertical ranges in the lower rectangle is outlined in the text.

the expense of utility and vice versa, since sigmoidal functions are monotonous.

Five ranges of the spectrum

The spectrum in Figure 1 is divided into five vertical ranges with fuzzy boundaries between them. These ranges show the transitional steps from engineering to science, and vice versa. Traditional engineers are in the first range on the left, where utility prevails. In the next range to the right are research engineers who usually work in higher education institutions or technology research teams, and who are actively looking for new products for the market. The curiosity to explain the phenomena involved in the artifacts they produce always comes second, as already mentioned. Even so, some researchers with engineering degrees dedicate themselves chiefly to publishing papers. They should still be included in this range, even if they are mixed up with applied scientists, and they tend to lean to the right.

Pure scientists are on the far right. These scientists want to know by nature. Applied scientists, for whom utility plays an increasing role, are in the next range to the left. They move to the left and away from the far right, yet retain specific values that define scientists, as is the pride in publishing their results.

The second and fourth ranges (research engineers and applied scientists) meet in the central range, probably the most remarkable of the five ones. In this range, engineers and scientists work together, and everyone brings their characteristic procedures. They collaborate without renouncing their respective canons: each contributes by sharing the knowledge, methods, and abilities that define them.

In today's world, most high-quality technology research is done in the middle range. It produces zigzag patterns, characterized by the fluidity of exchanges between engineers and scientists, which is one of the main features of the effective research currently being conducted.

Applied goals are the main drive behind research in the middle range. In this range, engineers have the opportunity to better understand the phenomena associated with the design of artificial objects, and this knowledge is the contribution of scientists. This insight can be of immense value in solving problems in engineering practice. Therefore, those who work in the middle range are divided into those who are primarily interested in procuring practical objects and those who offer scientific knowledge, the treasure of scientists.

Science can provide inspiring ideas on how technology products work. Thus, knowledge on the right side can be crucial to solving problems on the left side, even when scientists might not have sought it with a specific purpose in mind. Conversely, some engineers are clever enough to realize the practical utility of knowledge on the right side, which is far from trivial. The use of abstract properties of prime numbers in modern cryptography is a good example.

Even though they are engaged in pure science, scientists sometimes try to derive applicability from their discoveries, looking out of the corner of their eyes. Hence, the tiny utility area that appears at the top of the fifth range in Figure 1. Furthermore, this practical knowledge may also be of theoretical interest and lead to scientific developments closer to the domain of pure science. Applied researchers can also go beyond the technology products that motivated their research. In this light, engineering research also fosters basic research in adjacent fields. Additionally, some applied scientists say that their true goal is conventional science and that their involvement in practicality is merely circumstantial.

The foregoing engenders fertile interactions that take place in the middle range of Figure 1. Thanks to their contributions, both engineers and applied scientists partake in the savoir-faire and the skills applicable to the development of new products, perhaps unknown at the beginning of the research process. In any case, it is the left side that propels the entire process of searching for new practical products. Engineers pull scientific knowledge toward the left side.

The applied products obtained in the middle range are implanted in the social body by those on the left side: engineers or those performing a similar function (the same happens with clinical medicine). Engineers (or clinicians) put the major achievements reached in the middle range into practice.

Unequal priorities of engineering and science

As for Figure 2, which is also introduced in [2] and complements Figure 1, there are two triangles: the one on the left stands for the engineer (black arrows), while the one on the right corresponds to the scientist (white arrows). Each upper vertex is marked with the letter *L*, representing the work carried out by the scientists on the right or the engineers on the left. There is also *A* for artifacts or applications of *L*; and *P* for publications that report *L*.

The triangle on the left illustrates how the work *L* of engineers or technologists first leads to artifacts *A*, and only later can it be published in *P*. The opposite is true in the right triangle; the knowledge acquired by scientists first leads to *P*; and then, if appropriate, it leads to an application *A* linked to *P*. These two triangles clearly show the different courses of action of engineers and scientists. All the same, they work together in the middle of Figure 1.

Letter *A* plays a different role in each of the two domains. For engineers, it consists mainly of artifacts, devices born of their creative imagination, supported by the state of the art of the many branches of engineering. By contrast, for scientists, *A* is the result of previous scientific knowledge applied to practical problems. Scientists speak about the applications of their scientific discoveries, rather than about artifacts, as engineers usually do. Hence, the different values that *A* has in each case.

Some scientists argue that they can deal with curiosity and utility at the same time. A well-known Latin aphorism says that two hares (metaphorically, utility and curiosity) cannot be pursued

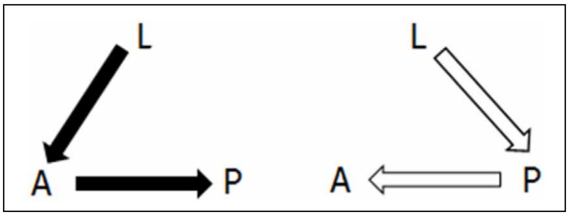

Figure 2. Mirror triangles representing the work of the engineer on the left and the work of the scientist on the right.

simultaneously at the risk of not capturing either.[2] The only way to catch both is to first catch one and then catch the other. This aphorism applies here: first attain either *P* or *A*, and then the other. The priority is determined by whether the work is carried out as a scientist or as an engineer. Specific features of unequal engineering and science methodologies bring about this priority. As happens with utility and curiosity, order matters.

A third triangle can be inserted between those in Figure 2, resulting in Figure 3. Now, research teams are being taken into consideration. The new triangle is a combination of its two adjacent triangles, representing multiple triangles that can be imagined between the two ends. If Figure 3 is placed at the bottom of Figure 1, its relationship to the spectrum is verified. In the middle triangle, each arrow is divided into two parts: black and white, for engineering and scientific work, respectively. In this case, *L* is accomplished in multidisciplinary teams that involve technologists and scientists and directly influence both products *A* and publications *P*. In the previous analogy of the two hares, two different coordinated teams would be required if the hares are pursued simultaneously, whereas a single hunter would need two successive steps.

By virtue of their fruitful collaboration, there are persistent attempts to fuse technology and science. This fusion would result in both unions under the joint labels of “science and technology” or “technoscience.” Anyhow, the fusion must be rejected as it negates each field’s specificity. Could it be argued that an engineer and a scientist need the same training? Do they not have different deep goals which define each? To make matters worse, there exists also the concern that science would

[2] *Qui duos lepores sequitur neutrum capit.* The author thanks Enrique Cerdá-Olmedo for letting him know about this aphorism.

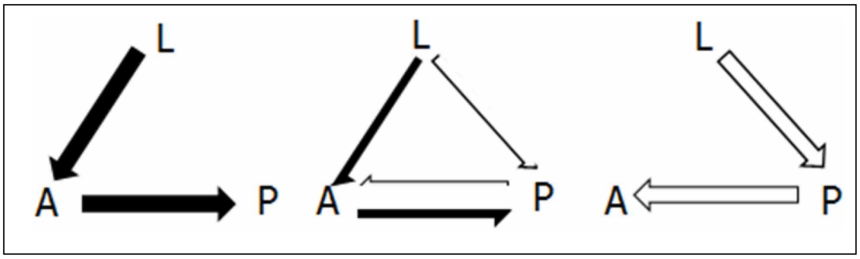

Figure 3. Insertion of a triangle in Figure 2 representing the middle range in Figure 1.

prevail over technology in the case of fusion, so the latter would end up subsumed by science (the fearsome "bear hug").

Engineers and pure scientists are located each at one end of the spectrum. To provide them with adequate training, the corresponding higher education institutions must keep their necessary and substantial differences. Still, a common language allows for fruitful cooperation in the middle range, as mentioned above.

The topics discussed in this article go beyond the relative priority of technology and science. They refer to what our primary relationship with things is: their use or their knowledge. From a historical point of view, technology precedes science. Consequently, use has opened the way to knowledge since the dawn of mankind. The issues addressed in the current paper could counter the policies that have led to the controversial "European paradox" (many scientific publications, yet few technology achievements). If such a paradox is to be overcome, then the dogma questioned by it—that basic science is the best way to promote technology—is also to be overcome. ■

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