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What is scientific and technological culture and how is it measured? A multidimensional model

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In the last decade, scientific culture has become a theme much discussed at all levels of public discourse. All scientific and technological policies developed in the last few years in OECD countries have included scientific culture as one of their aims, principles, or objectives. Despite the ubiquity of the term "scientific culture," there is little agreement on its content. Definitions and understandings of what a scientific culture is vary across countries, groups, and individuals. There is also no consensus on how to measure scientific culture. The present paper addresses the question "what is a scientific culture?". It presents a multidimensional model wherein scientific culture is defined as having two dimensions: individual and social. It then discusses how the model can be used to define indicators of scientific culture and to understand recent developments regarding the role of scientists in the diffusion of scientific culture.

" *La culture scientifique nous demande de vivre un effort de la pensée.*"
Gaston Bachelard, *Le rationalisme appliqué* (p. 214).

1. Introduction

In the last decade, scientific culture has become a theme much discussed at all levels of public discourse. Most policy makers now integrate the notion into their statements on economic growth or social progress. All scientific and technological policies developed in the last few years in OECD (Organization for Economic Cooperation and Development) countries have included scientific culture as one of their aims, principles or objectives.

Despite the ubiquity of the term, there is little agreement on its content.[1] The term used to express the notion of scientific culture varies across countries, groups, and individuals. In the United States and the United Kingdom, for example, the usual term is *public understanding of science*, but the term *scientific literacy* is also often used. In Canada, government documents prefer the term *public awareness*. In documents printed by the governments of the European Union, France, and Quebec, the notion has been extended to firms and innovation, such that the term has become *culture scientifique, technologique, et industrielle*.

In addition to the problem of terminology, there is no general agreement on the definitions of the varied terms. As with the notion of "culture,"[2] it is perhaps best to leave the notion of scientific culture to intuition rather than try to circumscribe it within a strict definition. Yet despite the fuzziness of the definitions, there is general agreement that a broad understanding of the methods of science and a general knowledge of some of its specific content is what is indicated by the notion of scientific culture.[3] Accordingly, the chosen means through which people do (or should) become acculturated to science are varied. Whereas some analysts put the school at the center of scientific culture, others see popularization as its core, and thus point to media as its privileged vehicle.[4]

Finally, there are many reasons we should value scientific culture.[5] Some experts emphasize its value in terms of citizens' cultural development; some see scientific culture as a prerequisite for economic development and innovation; while others emphasize the social aspects of scientific culture, which enable people to understand the scientific basis of modern society so they may play an active role in social debates. Thus, acceptable public understanding of scientific culture extends from a minimum amount of scientific knowledge, which any individual should ideally possess, to a more global view of social mastery of scientific and technological developments. In between, we find the more practical view of scientific culture as an asset for economic development.[6]

Besides definition, means, and ends of scientific culture, there is another issue on which there is no consensus: measurement of understanding of scientific culture. Most measures are based on individuals' knowledge of facts.[7] However, as we will see, this is far from being a complete definition of scientific culture.

The present paper addresses the question: what is scientific culture. It presents a multidimensional model that integrates two dimensions of scientific culture: the individual and the social. It then discusses how the model can be used to define indicators of scientific culture. Several indicators are suggested as examples.

2. Dimensions of scientific and technological culture

Despite the varieties of definitions of scientific culture, we can easily notice that what is common to all of them is the idea of appropriation. Whether it is for the development of science, the democratization of the debates around science, or the struggle against public alienation in an increasingly complex society due to scientific development, the stakes involved in the notion of scientific culture turn on the idea of the appropriation of science and technology. This consideration brings us to propose the following definition of scientific and technological (S&T) culture: *scientific and technological culture is the expression of all the modes through which individuals and society appropriate science and technology*.

The value of such a definition lies in its applicability to individuals as well as to institutions and to society as a whole. Thus, the S&T culture of an individual or society expresses the means by which either of them appropriates science and technology. Of course, as we will see, individuals, society, and culture are strongly linked together.

Before presenting the model, we must address the question of how to define science and technology. Although many authors never explicitly state what they mean by "science," we will use a minimal definition. Science is here understood as being characterized by two aspects: (1) as a *corpus* of conceptual and experimental methods that allow the investigation of objects pertaining to the natural or social worlds; and (2) as the *body of knowledge* derived from these investigations. Technology in turn is defined as the set of tools and machinery, in short the artefacts, as well as the knowledge pertaining to their functioning and use.

The first question that naturally comes to mind when reading the above definition of S&T culture is: by what means can S&T be appropriated? Before presenting what we consider to be the three *modes of appropriation* of science and technology, let us look at the two *dimensions* of S&T culture: the individual and the social.

Individual dimension

To appropriate science, a society must first have access to specialists in certain, crucial fields. The society must be able to rely on individuals who, by appropriating science as a means of investigation, become producers of new knowledge. In other words, society must be able to rely on scientists and engineers engaged in research.

In the context of S&T culture, the reference to scientists and engineers as specialists may seem an oddity to some readers. S&T culture is generally more widely associated with promotion and diffusion activities aimed at the general public, outside the realm of specialists. Several researchers share this point of view. For example, Jean-Marc Lévy Leblond categorically states that the specialized knowledge and abilities of scientific experts cannot serve as the basis of an S&T culture, since culture is an act of sharing, a form of communication: "of itself already, science does not function as a culture . . . Today's physicist, biologist or chemist has but a recent past, he only knows the immediate antecedents and the close neighbours of his own work. The urgent continuity of scientific research forbids the attentive patience required by any acculturation."[8] Jacques Ellul goes even further, stating that scientists do not even need to be excluded from S&T culture, since the latter is a nonexistent concept: "Any technological language is, whether we want it or not, algebraic. . . Therefore, if algebra is to become the universal language, the one into which all other languages must be translated, it is easily conceivable that there will no longer be any other form of communication. Therefore destruction of communication between humans makes it impossible to create a culture, which is necessarily founded on the specificity of language."[9] The idea that scientists and engineers are not really part of S&T culture can also be found in the proceedings of a recent international conference on the topic.[10]

In our opinion, such conclusions are hardly acceptable and are of course incompatible with our definition of an S&T culture. For it seems odd to accept the idea that a society could appropriate science and technology without providing itself with scientists. So, far from being outside culture, scientists are a necessary part of it.

Let us therefore go back to our central question: How does a society go about appropriating science and technology? We have just said that an element of this process is the existence of a scientific community. We must now distinguish between the S&T culture of the individuals within this restricted community and the S&T culture of the average citizen, since science and technology reach each individual differently, depending on his or her social role and position, which in turn explains why S&T culture will vary for each individual. The S&T culture of a scientist or engineer is different from that of an adult manual laborer, which is itself different from that of a student. The attempt to evaluate everyone's culture on the basis of a scientist's culture, as is often implicitly done with surveys on known scientific facts, is thus fallacious. Aiming for a high degree of S&T culture throughout the whole population may be desirable. We do not of course wish to limit in any way an individual's knowledge according to his or her particular social status, but we simply stress the fact that it is unrealistic to proceed with such an evaluation without taking social roles into consideration.

Thus for government officials, S&T culture might lie in the ability to design and carry out relevant science policies. For industrial executives and managers, it could be the capacity to invest wisely in research, and to evaluate and select from a group of new technologies, as well as to provide for adequate employee training and proper equipment maintenance. For the worker, it could consist in possessing the skills to understand (at least in part) and use a technology to accomplish a given task. For teachers, it could mean the proper transmission to students of necessary abilities and knowledge; for parents it could mean the capacity to awaken their children's interest in science and technology and to transmit the tacit knowledge of mundane social and technological interactions. For the ordinary citizen, S&T culture could mean keeping abreast of current information in order to participate critically in the social debates involving science and to develop awareness in the everyday use of technologies in matters related to health and nutrition, for example.

To be able to act in these social contexts, individuals must undergo a period of training, within the family, at school, in college or university, at work, and, less formally, through reading and leisure. This increasingly lifelong process allows an individual to acquire knowledge and abilities, to construct an image of science, technology, and the professions associated with them, and to develop values and attitudes towards them. The degree to which these elements are mastered varies among individuals and groups, and also in relation to the social role these individuals and groups have.

Social dimension

Returning yet again to our initial question, we must acknowledge that S&T culture is much more than all of the above. Our path has led us to consider the process of appropriation of science and technology and its effect on the individuals within a society. However, can the simple reference to the sum of the attributes and practices of individuals adequately describe a society's effort to appropriate science and technology? To answer this in the affirmative would, in our opinion, amount to short-circuiting the specifically collective dimension of S&T culture.

By confronting the various problems associated with the appropriation of science, individuals are led to form groups, to organize around well-defined objectives, and to chart collective actions. Such is, for instance, the purpose of scientific associations and societies and of government legislation aimed at "controlling" science and technology. We shall refer to these groups or social structures as "institutions," whether or not they arise spontaneously from within the community or are institutionalized and have acquired social recognition through their stability over time. Whether they are strong or weak, it is their presence and development in a given society that contribute to culture.

What are the institutions that allow a society to appropriate science and technology? On the social level, the places where S&T manifest themselves most readily are universities and government laboratories, in the case of science; high-tech companies and those that use society's technical infrastructure (transportation systems, communication, energy supply systems, etc.), for technology; and non-university teaching institutions, in general. All the institutions that lend support to the above (such as research funding agencies, risk-capital companies, scientific and engineering associations, consulting firms, technical repair and maintenance shops) must also be taken into consideration. One should also include ministries, consulting organizations, teaching establishments at all levels, the media, museums, public libraries, scientific leisure clubs, and organizations devoted to the promotion and diffusion of science and technology. Finally, recently established institutions mandated to manage society's techno-scientific transformations, such as regulating, norm-setting, and social evaluation agencies, should also be taken into account in the system of social institutions related to science and technology.

Whether directly or indirectly involved in science and technology, each of these institutions contributes to the social appropriation of science and technology through its financial, regulatory, coordinating, educational, or communications mandate. The sum of these activities constitutes the collective part of S&T culture. The presence or absence of these activities illustrates a greater or lesser degree of collective appropriation or a higher or lower degree of investment in S&T culture.

Within a definition of S&T culture, it might be surprising to find institutions (particularly research centers or regulatory agencies) usually found and analyzed in totally different contexts. To those who would be tempted to exclude them, we shall reiterate what has been said earlier about scientists: it is difficult to imagine that a society could effectively appropriate science and technology without having developed, or attempted to develop to some degree, some of the above-mentioned institutions.

It might also appear to some that we are confusing science and S&T culture to such a degree that there is no longer a substantial difference between the two. We did, however, define science as a set of methods of investigation and knowledge and, to that extent, research institutions are already a specific form of social appropriation. Not all societies are endowed with them, or at least not to the same degree. But the social function of these institutions is precisely to appropriate science as practices and knowledge, thus increasing the S&T culture of a society.

To conclude this section, we note that S&T culture is a multidimensional notion. This is precisely what lends it its perceived malleability, since various analysts can, according to their interests and contexts, focus on either of the two fundamental dimensions: individual or collective. In practice, most current conceptions favor either the individual dimension, stressing a single aspect of social appropriation of science and technology (such as popularization), or the collective dimension, concentrating on the role of a single group of actors (such as science and technology communicators). However, a global view of S&T culture must also consider the social dimension of culture.

3. Modes of appropriation of science and technology

Having provided a general idea of what our notion of S&T culture implies, we shall now systematically focus on each of the elements from the perspective of our initial question: what modes of appropriation of science and technology does a society have at its disposal? Three seem most pertinent:

1. **Learning mode**—through which society trains its members and provides them with the means to develop knowledge, abilities, representations, attitudes, and values needed to function in an environment permeated by science and technology.
2. **Implication mode**—through which society draws benefits from the abilities of trained individuals to fulfill certain tasks involving science and technology.
3. **Socio-organizational mode**—through which a society develops institutions dedicated to scientific and technological activities and their reflexive control.

Each of these modes represents a channel through which a society can master and appropriate science and technology. The first one involves individuals, the third involves groups, while the second is a bridge between them.

Figure 1, below, illustrates the links between the three modes of appropriation. Through various learning modes, individuals acquire abilities and use some of them in their professional activities, thereby contributing to the development and organization of a society (Figure 1, link A). In addition to their professional activities, citizens may, either individually or in groups, have other activities of a social nature (Figure 1, link B). Finally, individuals and groups also interact with social institutions, and vice-versa (Figure 1, link C).

Since modes 1 and 2, listed above, are relatively well known and are at times already integrated into discussions of S&T culture, we will describe them briefly and concentrate more attention on Mode 3, which has received less emphasis in the literature.

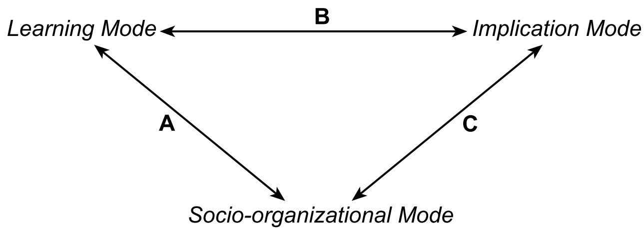

Figure 1. Three modes of appropriation of science and technology.

Learning mode

The learning mode refers first and foremost to the institutional channels through which individuals acquire the attributes necessary to contribute to the S&T system. In contemporary industrialized societies, these institutions include teaching institutions, but also less formal learning modes, such as on-the-job training, leisure activities, self-teaching, and interpersonal relations with family and friends.

The elements that are learned in an S&T culture can be divided into three groups:

1. knowledge (including an understanding of the scientific method);
2. know-how and abilities;
3. values, representations, attitudes, and interests.

Implication mode

The implication mode refers to the actions through which individuals and groups apply the above attributes *outside their primary field of activity*. Thus defined, implication is supplemental to the usual daily professional activities. For instance, a researcher can be said to have a social implication when contributing to the popularization of science and technology or to youth awareness programs; that is, when he or she is engaged in an activity not specifically included in his or her professionally defined task. This action is usually voluntary, although it may also be a response to social or political expectations or be motivated by awards and rewards.

Experts and scientists are not the only ones to exercise implication type activities. Individuals as citizens often intervene in matters of science and technology through public debates and controversies. Implications arising from the general public can be spontaneous and individually motivated or stimulated by formal channels, such as , for example, public hearings or referendums.

Socio-organizational mode

Because individuals are social beings born within a social context that provides them, through training, with an initial structure of socialization,[11] the socio-organizational mode of appropriation is the basis of the scientific acculturation process. To understand the culture of individuals, we must therefore understand the culture of the surrounding society and its various institutions.

The socio-organizational mode of appropriation of science and technology includes two main sets of institutions. The first refers directly to the techno-scientific system, and includes all the institutions involved in scientific and technological activities within a given society. The second has a reflexive function and acts on the first or on some of its components. It includes, for example, institutions such as regulatory and "public audience" agencies.

The first set encompasses institutions devoted to:

1. research, development, and production of technology;
2. diffusion and application of science and technology;
3. communication.

Research, development, and technology production institutions are rather well known and include universities, colleges, research centers, R&D-based industries, public laboratories, etc. Through these, a society carries out scientific and technological research and production activities fundamental to a techno-scientific system.

Institutions devoted to the diffusion and application of science and technology are those that provide scientific and technological services to others, without necessarily producing them themselves.

Institutions involved in communication activities serving either specialists or a general public include: learned societies that promote and diffuse scientific and technological information; technology transfer and technology-watch forums; special-interest associations, whether industrial or professional; and consulting firms. Institutions that exclusively target the general public include the media, museums, and various for-profit and nonprofit organizations dealing with the promotion and diffusion of science. Libraries, document centers, governmental departments, technology shops, and associations are often present at specialist and general levels.

The second set of institutions interacts with and provides a structure for the first in the appropriation of science and technology. This set includes institutions devoted to:

1. training, research, and information in science and technology;
2. support for science and technology;
3. regulation and coordination of science and technology.

Several institutions, some of them well known, belong to this set. The training, research, and information functions are often carried out by educational institutions when they create new, specific training programs (such as programs in Science-Technology-Society or Management of Technology) and new research centers or groups devoted to thinking explicitly about science and technology. Diffusion of information concerning the techno-scientific system is also largely ensured by information-gathering government departments.

Many institutions involved in supporting the techno-scientific system are in fact relatively new: technology agencies devoted to economic development; agencies specializing in the transfer and commercialization of research results; consulting services for technology-based industries, and various financing institutions, such as funding agencies, risk capital and investment firms, private foundations, and private investors dealing in technology.

Regulatory activities are carried out by a set of very recently formed or emerging institutions. Their presence or absence within a society is an indicator of that society's degree of science and technology appropriation, and they thereby constitute an aspect of its science and technology culture. Among these are governmental agencies involved in: regulation and standardization (patent offices, product homologation, vehicle testing, etc.); scientific and technological impact evaluation (former American OTA); and public consulting forums on health, environment, and safety. Coordination of the techno-scientific system also involves consulting agencies, sectorial or horizontal ministries, and other agencies, like Science Councils, mandated to draw up or implement policies and strategies.

Figure 2 provides a synthetic view of the three modes of social appropriation of science and technology discussed so far.

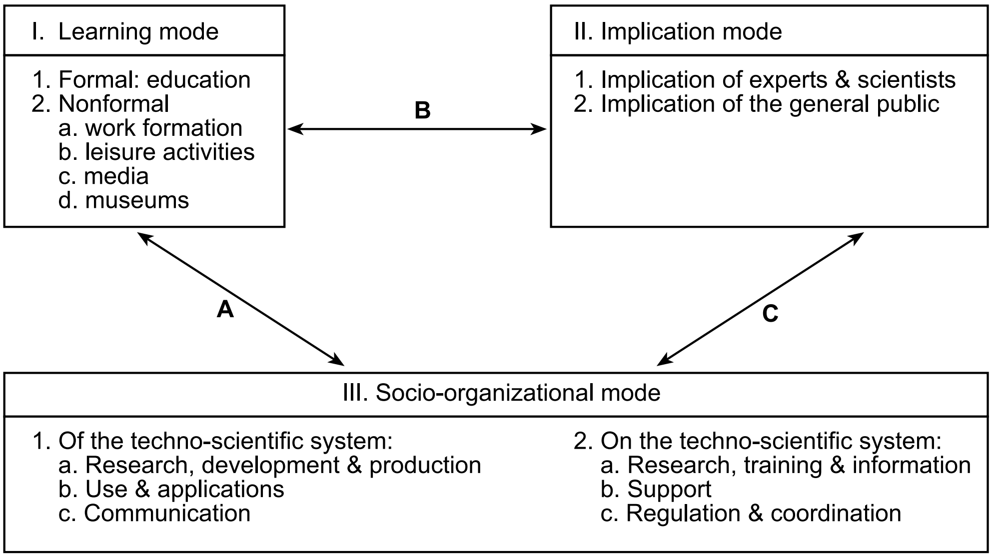

Figure 2. Social appropriation modes for science.

4. Indicators of S&T culture

Having defined S&T culture and specified the various modes of its appropriation, we are now in a position to try to identify indicators of S&T culture.

Following the works of J. D. Miller in the 1970s and 1980s,[12] indicators of S&T culture have recently begun to be included among the more usual science and technology indicators. Both the National Science Foundation and the European Union now publish such indicators on a regular basis.[13] Two series of indicators usually serve to measure S&T culture in these documents. First is the knowledge of science by people and second is their attitudes toward science and technology.

These indicators are of limited value and have often been criticized. The first major problem is that they measure (and implicitly define) S&T culture mainly through the knowledge of facts. This conception is based on an encyclopedic definition of culture inherited from the eighteenth-century model of the *érudit*. When S&T culture is measured in this way it implicitly values the idea that the more scientific facts an individual knows, the more he or she is said to be scientifically literate.

Another important criticism that is often made is that these measures take into account neither scientific and technological know-how (includes skill and understanding, as opposed to mere knowledge of facts) nor the capacity to deal autonomously with the technological artefacts of everyday life.

A third problem with these indicators, and one which is less often raised in the literature, is their exclusive focus on the individual: S&T culture is seen as an individual performance—the knowledge of facts and attitudes toward science and technology. However, individuals are not, so to speak, the only literate members of a society. Societies as a whole are also more or less scientifically or technologically literate. Societies and social institutions can also learn, for example, to control science and technology or to intervene to diminish the perverse effects of technologies. This dimension of S&T culture—the social dimension—is not measured with existing indicators.

A model for designing indicators of S&T culture

General science and technology indicators are based on a simple theoretical model used in OECD countries since the sixties. It is the so-called input/output model (Figure 3): investments (inputs) are made in various types of scientific activities (research) and they translate into knowledge and applications (outputs), which in turn can feed back into inputs.

Inputs ⇒ Research ⇒ Outputs

Figure 3. Input–output model of scientific research.

Input indicators for R&D are most often *monetary investments* and *manpower* appointed to those activities, as well as related *equipment* and *instrumentation*. Output indicators include *diplomas*, *articles*, and *patents*. Indicators of research activity are in fact indirectly derived either from inputs or outputs. For instance, fundamental or applied research activities are either measured through the monetary or manpower resources that are invested in each of them, or assessed through the number of articles published in a given discipline or speciality.

We can easily adapt this model to the measure of S&T culture by replacing «research» with «practices». Investments are thus perceived as inputs that lead to cultural activities, which produce cultural outputs (Figure 4), which in turn can become inputs for more practices.

Inputs ⇒ Practices ⇒ Outputs

Figure 4. Input–output model for S&T culture.

Various types of possible indicators for each dimension are discussed below. They can be expressed in absolute or relative values. As shown in Table 1, several indicators, inputs for instance, are exactly those currently used to measure science and technology by governments and the OECD. Other indicators are more specific, however, for instance practices (or activities), which often remain black boxed in the R&D model and are never directly measured.

Table 1. Types of indicators of S&T culture.

Input Indicators

- number of agencies or institutions
- monetary investments
- manpower
- equipment

Practice Indicators

- number of individuals involved in a given practice (reading, visiting a museum, etc.)
- duration and frequency of practice

Output Indicators

- number of products: goods, services, activities, or diplomas
- monetary value of products
- number of individuals possessing given attributes:
    - ∗ knowledge of facts
    - ∗ know-how
    - ∗ values, representations, and attitudes
- quality and degree of mastery of these attributes

Table 2. Examples of S&T culture indicators.

	Input indicators	Activity indicators	Output indicators
Learning mode	• Number of qualified high-school science teachers • Number of hours of science taught (high-school level) • Monetary investments in popularization activities • Number of science and technology fairs	• Rate of technology diffusion & household use • Number of workers on job training • Number of students in science and engineering courses in universities • Number of firms using information technologies • Number of readers of scientific and technological magazines, of watchers of TV programs devoted to S&T, and of visitors to museums	• Number of university S&T graduates in science • School results in S&T (high-school level) • Knowledge of S&T facts • percentage of individuals interested in S&T careers • percentage of individuals who value S&T, and scientists and engineers
Implication mode		• Number of scientists and engineers involved in popularization	• Number of governmental reports written by university scientists
Socio-organizational mode	• Monetary investments in R&D • Number of engineers in SME firms† • Monetary investments in all forms of government support to science		• Coverage (number of hours) of S&T programs on TV, radio, and in film • Space devoted to S&T in newspapers & public affairs magazines • Technological trade balance • Laws concerning ethics of S&T

† Small and medium sized enterprises.

The model (Table 2) includes some 23 indicators related to the three modes of appropriation of science and technology. We have tried to maintain a balance between the three types of indicators, according to whether they measure inputs, practices, or outputs. It must be remembered that indicators can change categories according to the standpoint from which they are used. Thus, an output indicator, such as the number of hours of scientific programming on television (media coverage) a society produces, could also be considered as an input for the individual.

Few of the indicators are new, and for that reason they should not be too costly to produce. What is new is that we consider them here under the rubric of S&T culture. Some of the indicators already exist either in government surveys and OECD repertories, in national statistics on education, or in specific studies. Concerning the surveys and national statistics, the data should not be difficult to collect. The most difficult problem is with specific studies: these are generally nonrecurrent and *ad hoc*. To give an idea of what the model looks like in practice, we have reproduced in the appendix the indicators we used to assess the S&T culture of Quebec. It is apparent that about half of the indicators can be adequately measured, and the other half does not yet have systematic data available.

We believe that the proposed model can be used to provide a preliminary sketch of the level of S&T culture of a given society. It is preliminary because we could have retained 25, 30, or 40 indicators (each indicator has its own justification in line with the three appropriation modes[14]). It is preliminary also because most of the indicators retained are quantitative in nature, which of course is basically the nature of an indicator. People would, however, like to be able to use indicators to evaluate qualities such as the mastery of an object by an individual or the efficiency with which an institution fills its mandate, etc. Although such indicators, when they do exist, are only numerical translations of qualitative situations, they remain harder to develop and standardize and are more costly to produce. The only such indicator that we have retained is the one dealing with high school results in science.

5. Conclusion

The model proposes a reversal of the perspectives on the links between science, technology, and culture. One can group the different perspectives developed so far in the literature around three basic models (Figure 5). The first, analyzed and criticized 30 years ago by C. P. Snow, presents science as a distinctive sphere, often in opposition to culture.[15] As we have seen, this is also the point of view of Lévy-Leblond. The second model, now the most common, also separates science from culture, but allows some links between the two through a diffusion from science to culture via mediators (like scientific communicators). This model is known today as the two-stage model.[16]

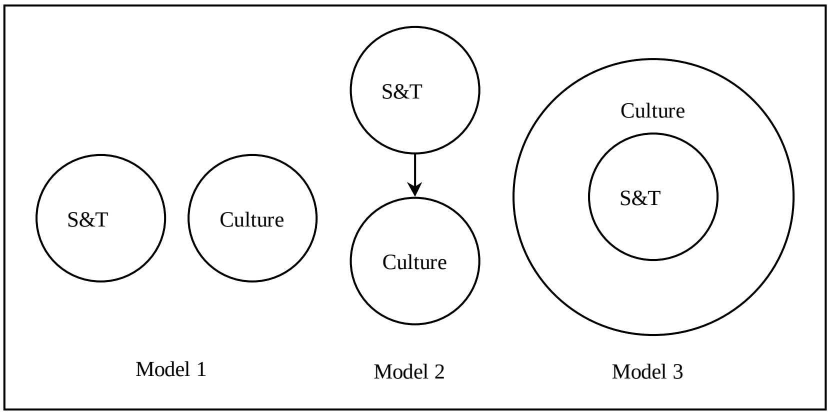

Figure 5. Three models of science and culture.

We propose a third model, in which science and technology are from the start defined as being part of culture. The model assumes that S&T culture comes first. Science and technology, together being a social phenomenon based on collective effort, must necessarily be included as forms of the social organization of culture.

The systematic and multidimensional concept of S&T culture that we propose can be used for purposes other than measuring. It provides a theoretical framework that integrates all historical modes of science and technology appropriation, as well as all the actors involved in the process. The order of appearance of these various modes can be shown schematically as follows:

- systematic production of scientific knowledge (seventeenth century)
- diffusion of knowledge by scientists and engineers:
  - * orally (demonstrations) (eighteenth–nineteenth century)
  - * by writing (popularization) (nineteenth–twentieth century)
  - * through teaching (nineteenth—twentieth century)
  - * through the media and audio-visually (twentieth century)
- development of the role of the scientific communicator (twentieth century)
- governmental funding and social control of science (post-1945)
- daily contact of individuals with technology in the work and home settings (mostly post-1945).

Finally, the model can be used to understand and analyze the discourses and actions of different actors. For instance, the recent trend on the part of funding agencies to encourage scientists to be more active in the diffusion of their work, rather than leave this task to professional science communicators (as was the case before), fits quite well in our model, which does not exclude the researcher from the system of S&T culture. Such a reversal toward an active role for the producers of science and technology would be far more difficult to conceive within a more restrictive definition of S&T culture. The model also helps to make sense of the opposition to these trends mounted by professional associations of science communicators that defend the specificity of their actions.

We believe that most controversies concerning S&T culture—namely, its definition and its measure—can be explained by the fact that authors have generally focused on only one of its multifaceted dimensions. The present model has tried to incorporate several dimensions of S&T culture toward a better understanding of its dynamics.

Appendix. Indicators of S&T Culture

Inputs, practices, and output are given in Tables A1–A3 on the next three pages.

Table A1. Inputs.

GERD as a percentage of GDP†			
	1985	1990	1994
Quebec	1.47	1.54	1.87
Canada	1.44	1.46	1.61
OECD	2.30	2.38	2.14
Investments in related scientific activities (RSA) ($ millions)			
	1985	1990	1994
Quebec		344.6	
Canada		2303.4	2112.7
OECD			
University research financed by industry ($ millions)			
	1985	1990	1995
Quebec	29.5	56.5	93.3
Canada			296.0
United States			1500
Number of hours of science taught (high school 1–3)			
	1985	1990	1994
Quebec	300	600	550
Canada			
OECD			665

† GERD = Gross domestic expenditures on research and development.

Table A2. Practices.

Diffusion of computers in household (percentage of households)			
	1986	1991	1996
Quebec	8.7	12.4	24.0
Canada	10.3	18.5	31.6
OECD			
Diffusion of numerically controlled machines in firms (percentage of firms)			
	1986	1989	1996
Quebec			
Canada		27	34
OECD		45	51
Number of workers involved in ongoing education and training (percentage)			
	1985	1990	1994
Quebec			17.2
Canada			22.8
OECD			
Researchers involved in popularization (percentage)			
	1985	1989	1995
Quebec			47
Canada			
OECD (France)		22	
University students enrolled full-time in science (percentage)			
	1985–1986	1990–1991	1993–1994
Quebec	33.6	32.4	32.0
Canada	31.7	25.1	26.7
OECD			
Number of people who read popular science books and magazines (percentage)			
	1985	1990	1994
Quebec			44.7
Canada			
OECD			

Table A3. Output.

University diplomas in science (percentage)			
	1985	1990	1993
Quebec	28.9	30.9	28.9
Canada	28.2	27.0	25.9
OECD			39.3
High-school results in science (TEIMS survey) (percentage of good responses in exam)			
	1985	1990	1994–1995 (Grade 8)
Quebec			59.0
Canada			58.7
OECD			55.5
Coverage of science on TV (number of hours)			
	1985	1990	1996
Quebec (SRC)	0.5	0.75	3.5
Canada			
OECD (UK.)		2.45	
Value-added in high-technology-based firms (percentage)			
	1985	1990	1994
Quebec			
Canada	7.8	9.8	9.2
OECD	12.4	13.0	12.6
Knowledge of scientific facts (percentage of good answers in survey)			
	1985	1991	1995
Quebec			
Canada		66.4	64.0
OECD		63.6	52.0
Number of people who believe science benefits society (percentage)			
	1985	1990	1995
Quebec			
– quality of life	79.0	83.3	
– health	82.7	82.9	
– material comfort	87.7	87.6	
Canada			
– in general		80.0	79.0
Unites States			
– in general	86.0	84.0	86.0

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