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Article

Reading Science, Technology and Education: A Tradition Dating back to Science into the History and Historiography

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Abstract:

In this paper, we present an interdisciplinary discussion on the relations between *Science–Technology Education* and *Culture* both historical standpoint and nowadays. The idea that a human mind can produce an intellectual revolution within science and its approaches (methods and methodologies also integrated with contradictions and criticisms) strongly crossed like a *paradigm* both in the history of sciences and disciplines–literatures (reasoning, early enlightenment, positivism, etc.): *but what about its social impact and science mission, as well?* To describe the impact of the *disseminated knowledge* is a consequent aim. A case study on energy conceptualization and its exhibitions in *Society in Context* is discussed; their correlations with education (pedagogical aspects included), science–techniques, industry and social impacts are discussed, as well.

Keywords:

Science in Context; NoS–Science Education; Cultural Mediation; Popularization of Science and Technique; Energy Conceptualization

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An Outline

The science, from ancient times[4] (generally speaking) to nowadays, usually built a perception within society according with the idea that science is synonymous of *progress* and *modernity*;

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[4] We remark that some parts of this paper are a historical–didactic reorganization of a short self–sufficient interlude and spot–ideas presented in previous historical researches. Mainly: *Conceptual and mathematical structures of mechanical science between 18th and 19th centuries* (Pisano and Capecchi 2013), *Lazare and Sadi Carnot: A Scientific and Filial Relationship* (Gillispie and Pisano 2014), *Historical and Philosophical Reflections on the Culture*

especially during period of materializations. We know that anomalies, inversions and controversies also belong to up cited erroneously so-called *progress and modernity*. Then it would be interesting to investigate author per author to understand effectively how science worked and how society worked, i.e., the concept of civilization. For example, Newton's science certainly produced a strong impact on humanity, particularly on the Western civilization both concerning the *scientific* and *supernatural* background of the law of nature, including mathematical interpretations of phenomena like non–physical laws; sometimes outside the context of the theory (i.e. providence, religion etc.). Certainly, by combining scientific traditions and contributions of scholars (i.e., like Copernicus, Kepler, Galileo and Descartes) it provided to create a scientific framework based on an adequate mathematics (and geometry) for interpreting terrestrial and celestial physical phenomena, which, *a priori*, were geometrically idealized to be easily *citizens* in his new revolutionary, *a posteriori* so called, *mathematization of the nature*. On the other hand, a parallel problem related to a dialogue as communication–language between specialists (advanced and applied researches) and non–specialists (versus a scientific civilization) is a trouble matter, i.e. *how is it possible to pass from science to technique and to technologies? In addition, who was really able to be mediator in any other context of society?* Physics, mathematics, chemistry and science education (Pisano 2007) are a social phenomenon because influenced both by the needs of the labour market and by the basic knowledge of sciences necessary for every person to be able to face some operations indispensable in the social and economic daily life. Therefore, the way in which scientific education is framed changes according to modifications of the social environment and know–how. For example, until the end of the 20th century, mathematical analysis was profound in most faculties. With some modifications, the situation is similar for the teaching of other mathematical disciplines: nowadays many operations needing of calculations and mathematical reasoning are developed by the computers or other *intelligent* machines and hence a student needs less theoretical mathematics than in the past (Pisano and Bussotti 2014, 2015d).

Another example: the problem of scientific education in the high school is a huge question and many scholars and equips of scholars have dedicated profound studies to this problem at least from the half of the 19th century. Therefore, it looks legitimate to wonder *why the study of the Euclidean geometry has been progressively reduced in all European countries, despite we are convinced that the Euclidean geometry is one of the most educative disciplines*. Perhaps this is also connected to the fact that in our society, scientific education in the high schools is oriented to the development of the algorithmic abilities of the students (algebra, analytic geometry, calculus, physics, and chemistry) rather than to the development of the demonstrative and rigorous reasoning. This kind of scientific education is considered more useful for the students when they will face the university and the labour market. If the social needs are a consistent part of scientific education, the other aspect is the connection between mathematics education and advanced mathematics research. Namely: *does advanced science influence science education?* The problem is complex. Juts to mention mathematics education, between the end of the 19th and the beginning of the 20th century important mathematicians as Felix Klein (1849–1925) and Federigo Enriques (1871–1946; Bussotti 2012) thought this should be the case (1972; Bussotti and Pisano 2015). Sixty

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of Machines around the Renaissance. How Science and Technique Work? (Pisano and Bussotti 2014), *Tartaglia's science of weights* (Pisano and Capecchi 2015), *Fibonacci and the Reception of the Abacus Schools in Italy. Mathematical Conceptual Streams and their Changing Relationship with Society* (Pisano and Bussotti 2015a), *The Emergencies of Mechanics and Thermodynamics in the Western Society during 18th–19th Centuries* (Pisano and Bussotti 2015b), *Historical and Philosophical Reflections on the Culture of Machines around the Renaissance: Machines, Machineries and Perpetual Motion* (Pisano and Bussotti 2015d). Thus, necessary parts are cited from them as a self–citation to go into the new subject of this paper. We warmly thanks in advance the publishers.

years later, in a different context (in the 60ies and 70ies of the 20th century), an important movement of mathematics education, of which Piaget (1896–1980) himself was a supporter, promoted by outstanding mathematicians belonging to the *Bourbaki movement*, theorized the need to organize mathematics education relying upon to the concepts of abstract algebra. Hence, the relation between didactics and advanced mathematics is anyway dialectic.

A question arises: based on the development of sciences in past, *what kind of scientific education is realizable?*

Science and Education into the History

In the ancient times, *mechanics* refereed to machines (winch, lever, pulley, wedge, screw and inclined plane) devices and motive powers–and–displacements of bodies (Pisano and Bussotti 2015c). Later a science of *movement of weights*, namely *Scientia de ponderibus* advanced. Generally speaking. Sometimes it was related to the craftsmen's activitis, other times to engineers so called *Scientia de ingeniis* (Pisano and Capecchi 2015; Pisano and Bussotti 2015a,b).

During the second half of the 12th century and the first half of the 16th century, Italian cities–states developed mathematics and of science (Pisano and Bussotti 2015c). This kind of education was connected to the economic and social structure, e.g., *scuole d'abaco.* See for example Luca Pacioli (1445–1517) who, in his turn, had a fundamental role in Leonardo's da Vinci (1452–1519) mathematical[5] education (Pisano 2016, 2009). The relations among these mathematicians are significant from a scientific, social and anthropologic point of view.

Between the 15th and 19th centuries so–called *men of war* achieved a consistent efficiency of cannons and guns (e.g., in France and England) even they were out (–lawed) from a scientific theoretical framework. The social milieu of the periods in question, and how that may have impacted on the science that was being carried out has yet to be fully clarified (internal and/or depending conditions in the sciences) "[…] before we appreciate their [the men of war's] hesitations and grasp the nature of their ignorance and their failures." (Gille 1966, 240). For, *where is the science–technique relationship and what is the link with society*? Until 18th century military weapons achieved a consistent efficiency of cannons and guns. Particularly France and England were busy in that. The latter, produced interesting practical and early theoretical studies upon heat engines due to technological and social industrial events. The main interests concentrated on the research of a source of unlimited power, evidently correlated with theoretical studies on the conversion of heat in work: *How?* (Pisano and Bussotti 2015). In effect, a total conversion[6] was, and it is, an ideal idea within the formulation of the first law of thermodynamics and its correlation with conceptualization of the more general energy conservation law[7]. That was mathematically confirmed later, mainly thanks to results of James Prescott Joule (1818–1889) (Fox 1969; Joule 1965, 277–281, 1847,

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[5] On the development of the arithmetic of the *Abacus schools* into the early algebra–mathematics at that time, see Scipione dal Ferro (1465–1526), Niccolò Fontana called Tartaglia (1499–1557) (Pisano and Capecchi 2015) Gerolamo Cardano (1501–1576), Lodovico Ferrari (1522–1565), Rafael Bombelli (1526–1572).

[6] Briefly, the total conversion *work–heat* is only produced within particular ideal conditions (i.e., thermodynamics cyclic process) in which the internal energy can change (ΔU) during the course of a cyclic process; when the cyclic process finishes the system's energy is the same as the energy it had when the process began ($\Delta U=0$). That also means that the ideal equivalence (idealistic total conversion) work–heat ($W=Q$) is obtained. Conventionally, within the loop of the cyclic process, W is positive, then it represents the *heat engine* case study; if W is negative, then it represents a *heat pump* case–study.

[7] We precise that conservation law is a crucial concept in between the history of mechanics and thermodynamics because, i.e., it was a concept faraway from Leibniz (*mv*) Descartes (mv^2) and Newton (*motion lost*) science. On Newton see recently: Pisano and Bussotti 2016, 2017; Bussotti and Pisano 2017

173–176), Rudolf Clausius (1822–1888) and William Thomson (1824–1907) (Clausius 1850, 1865a,b, 1867, 1872); (Thomson 1848, 1851a, b). In spite of that Lazare Nicolas Marguérite Carnot (1753–1823) – already in 1778 (Carnot 1778, 1780, §§ 149–160) – stated this *chimerical dream* within his studies on general mechanical machines[8] (Carnot L 1786). Lazare Nicolas Marguérite Carnot (1753–1823) stated the chimerical dream of an unlimited production of work by means of a *general working substance* (Carnot L 1786; 1778; 1780, §§ 149–160). The source of an unlimited power, evidently correlated with theoretical studies on the conversion of heat–in–work, was analytically formulated by the first law of thermodynamics and its general energy conservation (Joule 1965, 277–281; 1847, 173–176; Clausius 1850, 1865a,b; Thomson 1848, 1851a,b). Finally, Thomson also analytically discussed the second principle of thermodynamics and the necessity of a second thermostat with the aim of executing a passage of heat between a difference of temperature (Thomson 1848–1849, 541–574; 1882–1911, 113–155; 1852, 248–255; Smith and Wise 1989, chaps 9–11).

In the 18th century Lavoisier assumed (1789; 1862–1893) *chaleur, calorique*[9] (et *lumière*). The research carried out by Lavoisier and Pierre Simon de Laplace (1749–1827) (Lavoisier and Laplace 1784) is also of remarkable importance. In 1802 Joseph–Louis Gay–Lussac (1778–1850) formulated a law of gases; then Pierre Louis Dulong (1785–1838) and Alexis Thérèse Petit (1791–1820) showed in 1816–19 that specific heat depended on temperature (in some cases). In particular, the adiabatic law (Poisson 1823, 5–16; Laplace 1822) caused some confusion and various versions of it were formulated; even when Siméon Denis Poisson (1781–1840) formulated the right equation, most scientists did not consider the issue resolved. Scientific knowledge on the matter took two main paths:

1. Kinetic model of gases (on the properties of gases)
2. Efficiency of heat machines (Zeuner 1869), which naturally included the gas theory which would later become thermodynamics.

An important advancement was done by the birth of the periodical tables (Scerri 2013).

Nicolas Léonard Sadi Carnot (1796–1832), son of Lazare and inventor of the thermodynamics (Carnot S 1824, 1978; Taton 1976), already in his unpublished works (Gillispie and Pisano 2014, 176–183, Chap. VI; Gillispie 1971) proposed a new theory referred to a civil heat machines. He is relying on his father Lazare's theory of mechanical machines (Carnot L. 1786, 1803, 1778, 1780; Gillispie 1970–1979). His *Réflexions sur la Puissance Motrice du Feu*[10] (hereafter *Réflexions*) and his last work on the theory on gases, *Recherche d'une formule propre à représenter la puissance motrice de la Vapeur d'Eau*[11] (Carnot S. 1978, 223–225) appeared in quite a short period of time, approximately three years. It was a total overturning of the physics–mathematics relationship (Drago and Pisano 2007, 497–525), a new theory starting from the engineering practices. From strictly physics–mathematic standpoint, Jean Baptiste Joseph Fourier (1768–1830) formulated his differential equation for heat propagation in solids (1807). Fourier (Pisano, and Capecchi, 2009), and some fifty years later, Gabriel Lamé (1795–1870; *Ivi*) wrote *Leçons sur la théorie de la chaleur* (1861). At this point, the theory of heat was a well–defined science and several important conclusions had been

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[8] Carnot L 1786, ix–x, 89–94; Carnot L 1786), vij–ix, 86–87; see also Carnot L 1780, §§ 151–152; Gillispie 1971, Appendix C, §§ 151–152, 328–329.

[9] Lavoisier attempted an early distinction between heat and temperature (Lavoisier 1789, 12–17, line 37).

[10] Sadi Carnot wrote a mathematical (only) footnote (Carnot S. 1978, ft. n. 1, 73–79; Pisano 2010, Gillispie and Pisano 2014).

[11] Fox 1971; Reech 1853, 357–378; Lamé 1836.

reached on by mathematicians.[12] Thanks to Sadi Carnot's theorem (Carnot S. 1978, 38) the calculation of the efficiency is independent from whatever *working substance*.

> We draw a distinction here between the vapor [steam] engine and heat ["à feu"] engine in general ["*en général*"]. The latter may be employed with any working substance, steam or anything else, in order to develop the motive power of heat.[13]

He introduced important scientific concepts, i.e. *state of a system, reversible processes*, *cycle*, phases and a by an *ad absurdum* proof (untypically for a physical science at that time). His physical and technological arguments were based on the impossibility of perpetual motion (Pisano and Bussotti 2015d).

Science, Theory and Machines

Sadi Carnot was a pupil of the *École Polytechnique* and invented thermodynamics theory (Pisano 2010; Gillispie and Pisano 2014). He devoted two years to collect information, attend courses in *Conservatoire des Arts et Métiers* and eventually write an early book.[14] In his study of heat machines Sadi Carnot took in account civil engineering only. Sadi Carnot utilized heat at a constant[15] temperature, under certain conditions, *Q/t* (Carnot S 1978, 32). Nevertheless, that assumption was weak. However, presuming that this assumption (or hypothesis) is valid, within analogy, the *falling of water* should be considered analogous to the *falling of the quantity of heat* at constant temperatures. That is to say:

$$Q_1/t_1 - Q_2/t_2 = \Delta S \text{ between the two temperatures} \qquad (1)$$

> [*chute du calorique* is quite similar *chute d'eau*]. But whilst for the water the performance of work is simply proportional to the height of fall, we may not put this performance in the case of heat proportional to the difference of temperature without a closer investigation.[16]

While in the hydraulic wheel W_{max} is proportional only at Δh, in the heat machine W_{max} can depend on unspecified variables. However, as Sadi Carnot remarks (Carnot S 1978, 29) this work is not proportional to Δt since W_{max} seems to have greater experimental values at low temperatures (Carnot S 1978, 72). Sadi Carnot's theoretical effort reaches a standstill at this last difficulty, although he even attempted a calculation in his previously discussed famous footnote (Carnot S 1978, ft. 1, 73–79) to determine the efficiency function. However, let us note that the analogy is more persuasive than it appears in modern times. Moreover, around the XVIII century, it was common to consider machines by performing an abstraction from the masses of bodies (Carnot L 1786, § XXX, 60) and separate the wire of a pendulum from the mass. Therefore, the water that falls on the hydraulic wheel could have been thought of

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[12] Some of them: Liouville 1836; Dirichlet 1837; Reech 1853; Riemann 1861 [1868]; 1892, 391–404. Riemann's lecture (1861) "on the conduction of heat" was not published until 1868 (Spivak 1979, 179–182).

[13] Carnot S, 1978, 8, ft. 1, line 1.

[14] Sadi Carnot's *Recherche d'une formule propre à représenter la puissance motrice de la vapeur d'eau–unpublished manuscript* (Carnot S 1986, 167–180). Generally speaking, the correct date of publication still lacks historical decisive evidence. More or less the most recent Carnot historians agree on a date before 1824 (Gillispie and Pisano 2014, Chap. 3).

[15] Carnot S 1978, 32.

[16] Mach 1986, 201–202.

without mass, that is, as a weightless fluid, as caloric fluid was conceived. This way of envisioning mechanical machines allowed (still within the caloric hypothesis) for the consideration of the analogy as a true connection of heat machines to the theory of mechanical machines which includes the case study of falling water and the hydraulic wheel. Therefore, for Lazare Carnot, this is a fundamental analogy and for Sadi Carnot, who doubts caloric, it is merely striking; for us it plays a central, but not essential role. Young French scientist calculated a cycle between only two isotherms, *t* and *t+dt* can leave us perplexed because the (final) result is still valid from a modern point of view. Sadi Carnot utilized the following adiabatic formula[17]:

$$t(V) = \frac{K + \tau \log[\ln]V}{K^{'} + \tau^{'} \log[\ln]V}, \tag{2}$$

and arrived after some calculations here revised (Carnot S 1978, 73–79, ft. 1; Pisano 2010; Gillispie and Pisano 2014), obtained a dependence (with $Q_2 > Q_1$ and $T_2 > T_1$) from temperature only:

$$\eta_{rev} = \frac{Q_2 - Q_1}{Q_2} = 1 - \frac{Q_1}{Q_2} = 1 - \frac{T_1}{T_2} \tag{3}$$

In 18th century, many amazing and innovative civil machines were constructed (Gillispie 1983). Later new strategist' school advanced and the enormous power delivered by big cannons became the symbol of a new social power capable to mobilise the population oppressed by the *anciens régimes* (Reinhard 1950–1952). Nevertheless, an organized production of civil and gun machines still was weak (Pisano and Bussotti 2015b).

Science, Mathematics and Technology

The development of the relationship between *science maths teaching*, *advanced use of mathematics* and related *technological calculus machines* is one of the most emblematic cases study, i.e., decimal positions, practical problems, *Abacus*, etc. Nevertheless, they cannot be compared with the ease of the calculations in the lines, which is possible by writing the numbers in a positional form and operating directly on the written numbers.

In between, end of 19th and the first decade 20th century, the *Scientific–Technical Culture* (STC) represented one of the foundations of the economic development and the social progress in the Western and Eastern industrial areas. Its contribution stemmed both technical–vocational training, and media insights, i.e., books, libraries, exhibitions, conferences and public courses, the so–called *popularization of science and technique*. From historical standpoints, STC founded its roots in the Enlightenment as well as in the industrial revolution. For, *popularizing science* meant a supplement to the education, or simply compensate for its absence. STC was developed by the public authorities, by the *Chambers of Commerce*, or by some associations with philosophical or religious aims, etc., and it was not free from any ideology. Sciences and techniques were popularized in order to free people, to fight religion or to illustrate the "wonders of the creation", as well as to initiate

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[17] Carnot S 1978, 66, line 10. Since no rooms here, we remind to Gillispie and Pisano's book (Gillispie and Pisano 2014) for the others contributes to complete the history of mechanics and thermodynamics after Sadi Carnot's formulation of the efficiency of a heat machine.

workers with the new techniques. In addition, this popularization aimed to ensure industry the constitution (necessary for its development and its control) of an intermediate category of employees between *blue–collar* workers and engineers, as well as to give the young *bourgeois* the appetite for the industrial professions and for the industrial investments.

Making of a Scientific Education within 19th–20th Centuries

In the second half of the 18th century, Diderot and d'Alembert's pushed sciences and crafts within a common special place: The *Encyclopédie* (Diderot and d'Alembert [1751–1772] 1993). However, we should remark that scientific and technical culture has been holding a very particular importance from the following century; still nowadays, but differently combining. As above discussed on the historical case study about the founder of thermodynamics and heat theory machines, from the 19th to the beginning of the 20th century, in order to maintain its rate of development, a skill as well as educated labour was necessary to the needs of the (applied science to) industrialization. The support of the ruling social class for the advances of the science and its awareness of the utility of science applications were also a necessity. As a result, a strong effort of dissemination of the both scientific and technical knowledge aimed at these audiences was produced. i.e., creation of a technical and vocational training, publication of specialized handbooks, publication of various magazines and books, articles and reports in the daily press, subject or universal exhibitions, conferences, popular libraries, industrial, farm and colonial museums, public courses, and university chairs often encouraged by the town councils. Further, within last decades the novelties of the cinema, collections of didactic images and radio programmes, as combing sciences and technology, were used too[18].

This social phenomenon was identical for all the countries or industrial areas. However, according with institutional and political context as well as to the degree of involvement of the State in its work of education, important differences appeared. For example, taking into account France and Belgium, the dissemination of the knowledge presented different initiatives, i.e.:

- France: the compulsory elementary school by 1870 provided a dissemination.
- Belgium: private foundations by the end of the 19th century carried especially out a dissemination.

Indeed, the nature of the disseminated knowledge could obviously vary according to the thoughts peculiar to the circles, which disseminated it. Therefore, a key–fact at that time is necessary to remark: the scientific and technical culture was one of the foundations of the economic development and the social progress in the industrial areas.

The going through and the study of the documents about the dissemination of the scientific and technical knowledge during the 19th century and the beginning of 20th lead to throw light on a particular literary genre: the genre old works of popularization, often forgotten, sometimes scorned by the historians of science and of the literature because it is neither true scientific work nor fully literary work. However, they make it possible to highlight the differences depending on the concerned audience as for the content of the texts, the style of their writing, their images, while revealing the level of the presented scientific knowledge. The study reveals the interactions between the transmitters and their audiences

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[18] Other kinds of material information reveal this effort of dissemination of the scientific and technical knowledge too: library and publishing catalogues, archives of diverse associations and societies, programmes of entertaining meetings, texts of conferences, visitors' books of exhibitions.

(choice of the vehicles, of the subjects), between real or supposed self–educated and scholarly institutions, but also the links between the science which was produced and the science which was disseminated. In addition through the study of the production of the scientific and technical popularization it is possible to measure the impact of the disseminated knowledge on the target groups and to estimate the speed of the receipt of the innovation, i.e. the time between the production of a scientific or technical innovation and its integration to the popularized speech, the interactions between popularization and social life, in particular as regards hygiene, food, the disease prevention, the diffusion of the medical popularization (fight against the empiricism of the bonesetters, the constitution of leagues of hygiene), and the links between the diffusion of the scientific and technical knowledge and the development of colonized territories by the empires.

Remaking of a Scientific Education in 21st Century

However, the relation between science and society has evolved quite largely since the beginning of the 19th century. Indeed, the model of an ideal relationship between science and society set up during the 19th century in the form of an implicit social contract involving scientists who have the responsibility to propose applications of science for the welfare of a trustful society starts to be criticized since the end of the Second World War (Hiroshima). This will lead to renegotiations of the contract, this time explicitly, between science and society, even between scientists and citizens alone, as from now on it is not so much a question of an official control of the knowledge, as a question of participation of the public in the choice of priorities and of social evaluation of the research results.

The frustration generated by the incapacity of science to solve all the human and social problems, combined with the environmental and sanitary disasters, caused by a certain scientific and technical development, led, on the one hand, to an attitude of suspicion, if not of rejection, towards science, and, on the other hand, to a higher bid in the communication of the scientific authorities and the industrialists. Scientific optimism gives way to the eco–movement and the movement of criticism of science. The scientist is brought to leave his ivory tower in order to justify his social utility or to defend his field of research. Research, paradoxically, becomes more and more narrowly finalized. The whole thing proceeds today within a framework of severe economic crisis and of generalized precariousness in our developed societies, while at the same time our dependence on applications of science generally and on new technologies in particular has never been so strong. In addition, our idea concerning the relationship between science and technique is quite ambivalent: between amazement/hope and fear. Science, which formerly constituted the driving force of the social progress, tends to become a trap for the whole society: pollution, skids of the technique, a tendency, by the democratic States, to intensify the social control over the population, handling of the citizens by various lobbies, injunction to live fully our techno scientific modernity. Yet, the place of the scientific and technical culture within *Culture* in general should be redefined today. After making and unmaking the scientific education of the citizens, it is now time to remake it.

Under these conditions, an objective diffusion of the scientific and technical knowledge becomes essential; it becomes even a challenge for the democracy. The key character is in this case the "science critic" – as there are art, cinema and literature critics for these respective fields – but this title still has to be recognized. Besides, the science critic is to be well trained in order to be present in our techno–scientific society and to practice the scientific and technical mediation we need nowadays[19]. Moreover, the *science critics* should be able to:

- Problematize and contextualize scientific discoveries and new technology into society
- Introduce culture into the science and technology and vice–versa
- Discuss the role and the limits of expertise
- Take a stance towards their audience regarding the scientific, technical, political, economic, social, ethical and symbolic challenges
- Stimulate the desire to study sciences
- Provide and communicate science for citizenship (different audiences) through a scientific education.

Science into the Society. Digital Libraries

The previous discussion on the dissemination of the scientific and technical knowledge is partly based on the collections of the digital library on the past of modern sciences of the Lille 1 University called *Iris*[20]. It would be of helpful to provide the role played by Science in Context and discuss between Science, Science education and Science in 19th–21st Context, as well. The digital collections of *Iris* make reappear the science, which seemed to triumph and was honoured in the 19th century and in the first decades of the 20th one, that which literally transformed our world and our opinion on it.[21] Through them, our techno–scientific world is reintegrated into its historical development and can be questioned in this way. In addition, they emphasize the links between science and society, science and arts, science and representations of science, science and applications of science. Iris comes back to a time when the scientific and technical culture was inseparable from the Culture in general, since it is regrettable that today science does not have any more the Culture which it deserves while at the same time science has been for more than two hundred years producing of Culture.

Iris was designed to be used as a tool by researchers in historical studies (History, History of Science and Technique, History of the economic and sociological thought, History of Education); but also as a base for the students regarding their courses and projects, as well as a recourse for the organizations of scientific and technical culture (Natural History Museums, planetariums, technical museums, ecomuseums, thematic establishments, centres for the scientific, technical and industrial culture) for their initiatives in the mediation field towards various audiences. *Iris* became not only a tool for the science of the past and its diffusion, but also a tool for the popularization of the science of today and for reflection concerning its place in our world. This digital library presents modern science through its history and under its multiple facets; it is a modernity constantly in reconstruction but nowadays with a new and strong will to disseminate the scientific and technical knowledge, which should be compared with the will of the past.

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[19] On this crucial matter, Lille 1 University, in partnership with the School of Journalism of Lille, created a Master degree in *Science Journalism* which will be developed into a Master degree in "Information and Scientific and Technical Mediation", with the intersection of the fields of Science–Technology–Health and the Social and Human sciences.

[20] The collections, image bank and virtual exhibitions of the digital library Iris are freely accessible on the website: http://iris.univ–lille1.fr/.

[21] The digital library *Iris* a focus is also be on the north of France and the Walloon area of Belgium, which then formed together the same industrial and linguistic basin with a common history.

Energy, Education and Society

Unmistakeable that discovering of a hands–on way to practice energy made to humanity a huge leap forward, *techniques*, *economy* and *Education*. Nowadays, an *ad hoc mediation-education* represents its instrumentality vehicle to provide the *Science in Context*. Particularly, as technical, one can refers to improvement of the daily–life, manufacturing of machines and correlated jobs and industries (Reuleaux 1786); i.e., see simply power stations of energy's production–distribution played a crucial role in all sectors of human activities. It is not notable that produced consumption and offer–request are constantly and unequally increasing. Economic, social, environmental, political and geopolitical are correlated reasons: Further, the governments are looking for new and/or alternatives solutions: e.g., renewable energies, green energies are on table. In this *Science in Context* panorama, to save energy was evidently the main mediation message, but citizens without an adequate *scientific education* and an *ad hoc* cultural *mediation* have some serious difficulty to be part integrant of the new *scientific–technical knowledge*. The risk is that this crucial generational debate becomes low–dimensioned. A possibility, for example, might be a deep scientific, social, and educational understanding of the energy's concept. If most consider that one can *create* energy as much as it wants, others think it that to eradicate the phenomenon of friction to improve yields machines is enough. Obviously, this is false ideas since they do not take into account the universal first and second principles of thermodynamics. A new adequate education opportunely correlated with technique and technology is necessary. Therefore, *what is everyone talking about energy?* In addition, *what is energy*?

Energy and Educational Misunderstanding Knowledge

As before discussed simple machines (and animals) represented early humans' efforts to obtain some source of energy by means applied forces. Since humankind has mastered fire, the consumption of energy (and its correlated economic, sociological, political, geopolitical, scientific, technological and ecological applications) has only increased for the following main reasons:

- The world's population is steadily increasing and the evolution during the last two centuries shows that it is a very rapid expansion.
- The majority of the inhabitants of the planet are still far from the standard of living in developed countries. However, the only way for this population to increase its standard of living is to develop an economic activity, which requires energy.

But, *what is a reasonable energy and is cultural mediator in the society?*

The energy is mathematically interpreted (commonly appears to us) in different ways and whose common characteristics beyond our immediate understanding, i.e: gravitation, elasticity, nuclear, heat, electricity, magnetism, light, chemical reactions are manifestations of energy. Generally speaking, where a change is shown, an energy is produced or lost.

From education and social standpoint, to say that the energy characterizes the ability to provide work by means an applied force and related movement appears commonly convenient (Cf. Pisano and Bussotti 2017a,b). At this stage, two consequent correlated questions arise: *how can we produce work to obtain energy?* In this sense, the misunderstandings between *force* and *energy*, and *force* and *weights*, *heat* and *temperature* are diffused at school and in society. For sure, the term energy is not always part of a scientific vocabulary! Thus, an adequate social and mathematical interpretation is required. Energy is a crucial concept of physics and its conceptualization, i.e., energy is a scalar physical quantity, extensive, observable and measurable etc., permits both *modelling* and *applications* in other scientific disciplines. A correlated history of science, history of foundation of sciences in context can be of help as above presented.

Who is the Mediator into the Society? As before remarked, the industrial revolution is not only limited with a massive use of all kinds of machines and with their technical improvements. Indeed, technological performances were not sufficient to improve the output of these machines. That is why, a scientific study about energy through the universal principles of thermodynamics was necessary. However, these principles introduce the concepts of energy and entropy, which are very difficult to understand, especially the entropy. In Ralph Baierlein's words:

> For the instructor and the student, no single step is terribly difficult to teach or to learn, but in the course of time, students easily lose sight of the big picture, and an intellectually satisfying understanding of what "entropy" represents remains elusive.[22]

Given the public policy–driven nature of the energy transition and the current economic situation, all of us are concerned about energy issues and express opinions, process any decision relating social issues. Nevertheless, in order to take part in this societal debate, an appropriate scientific and social–technical education is required. This requires to scientists and teachers to perform an additional role: *scientific mediator*, as a link between sciences and societies. Of course, re–thinking of alternative teaching methods (NoS approach) is also a necessary condition. It is the single way to establish a lasting relationship between scientists and citizens in a society dependent more and more on science and technological progress.

Energy and Sources

In order to understand the energy in a simple way, let us consider mechanical as a first form of energy. As we above cited energy is related with work, in the following modern general terms:

$$\int Fds = E \tag{4}$$

Some remarks are necessary: a) distinguish the work force, b) work necessarily involves expenditure – a machine that produces the work must be supplied –, c) exert a force requires, on the contrary, no charge, etc. A confusion is usual done by students: if we feel *tired* due, i.e., to an eventual imperfection of our muscles, imply no movement required by no force (F), so (generally speaking) no energy is produced/lost/transformed, or in other words, no variation of work (ΔW) is done. Instead, if we feel tired due to bear a weight from x–position to y–position, this is due to an eventual imperfection of our muscles, but in this case, since a movement is done (an applied force for displacements), then a work is done, and a mechanical energy is possible to calculate.[23] Following previous reasoning, if we consider an ideal physical system by a rolling ball – supposedly free of any friction – a perpetual motion is obtained because no energy to maintain its movement is required. Other examples can be done: when forces acting on a body produce (under no equilibrium conditions) a movement,

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[22] Baierlein 1994, 15. Author's emphasis.

[23] In the unified *International System of Unit* (I. S.), the work W and energy E assume idem unit of measure, Joule (J).

rotation, etc. The physical system performs a work and its correlated mechanical energy is called rotational.[24]

Except nuclear and geothermal energy, and energy from solar radiation as a reasonable source of energy, we can classify sources into two main categories:

1. *Finite energy sources*. These energies consume chemical or nuclear fuels. They exploit deposits nestled in the earth's crust. Fossil fuels (oil, gas and coal) are finite on Earth quantity and nature took millions of years to produce. Uranium is also a finite resource. Fossil fuels are concentrated and inexpensive source of energy that have been and are the wealth of modern civilization. Unfortunately, humanity uses these energy stocks very intensively, which poses the problem of depletion term. World energy consumption is based more than 80% on fossil fuels. These have the disadvantage of emitting CO_2 which gradually increases the concentration of this gas into the atmosphere and increasing the greenhouse effect. This may induce climate change with many negative consequences for humanity. That is why the goal now is to gradually return to renewable energy, cleaner and do not emit greenhouse gas emissions by using advances in science and technology that we provide enough energy to a competitive cost.
2. *Flow energy sources*. These more known as renewable energies are derived from natural phenomena from the sun or the earth, naturally unlimited renewed to human scale. It is the solar energy in all its forms, from biomass, wind, hydro, tidal and geothermal energy.[25]

Energy and Transformations – Conservation – Degradations

Transformations. As before we saw for Sadi Carnot's thermodynamics, in a waterfall, a *potential energy*[26] is available. If this energy left to itself, then it will be transformed (under certain conditions) into heat: water, at the bottom of a waterfall, is heated of all the potential energy unused. We can also force the water to drive a turbine which itself actuate an electrical machine: *potential energy* is transformed (under certain conditions) into *electrical energy*. This latter (under certain conditions) carried by conductor's wires, can also be transformed into *kinetic energy of rotation* and/or *translation* (electric engines) into: heat energy within electric furnaces, light energy in filament lamps, chemical energy (electrolytic cells, batteries charging). If an electrical machine is actuated by means of a steam engine, the primary power source is then the *chemical energy* constituted, for example, by coal–oxygen system. Based on historical accounts provided before, the combination of these two substances transforms *chemical energy* into *heat energy* which is to be transformed into

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[24] To be distinguished from the *translational energy* corresponding to *rectilinear movements*.

[25] They are: 1) Solar energy is that we capture directly under the following forms (converting the radiation into heat at low temperature) under thermodynamic form (conversion into high temperature heat to operate machinery) or as photovoltaic (directly conversion into electricity); 2) Biomass includes all organic materials and energy crops for the production of bio–fuels. However, plant biomass is a renewable energy if we replanted to compensate for what was harvested; 3) Wind energy is the energy captured by a device with blades of wind. It can be used to make machines run (mills, pumps) or converted into electricity by a generator; 4) Hydraulic energy is the mechanical energy associated with the difference in water level, a waterfall or river, transformed swallows into electricity through a turbine generator; 5) Tidal energy is the mechanical energy of the water created by tides and sea currents converted into electricity. Geothermal energy is to exploit the natural reservoirs of steam or hot water or hot rocks present in the deep underground to produce heat. Most of this energy is derived from radioactive nuclei contained (Iacona, Taine and Tamain 2012; Ngô 2009, French Society of Physics 2012).

[26] mgh: m is the mass of the object, g is the acceleration due to gravity, and h is the altitude of the object.

mechanical energy by a steam engine, into *electrical energy* by a dynamo. Consider a motionless body on the ground, to move it at a given altitude we must provide work. Fixed at this altitude, the body has a potential energy, which means that the work is entirely transformed into potential energy. During the fall, this potential energy is converted into kinetic energy and it is completely kinetic at the moment of impact. We have three situations: the first corresponding to a perfectly elastic collision, in this case the object bounces and the kinetic energy is gradually transformed into potential until the object reaches its initial altitude. If the collision is not elastic, the kinetic energy acquired during the fall becomes fully heat. The last situation is an intermediate one, that is to say at the moment of impact only a portion of the kinetic energy is converted into heat and the other part provides the object to achieve an altitude below the initial altitude until the object comes to rest on the ground *Conservation*.

We can assume:

- *External Energy*: potential (E_P), kinetic (E_k), and mechanical energies (E_M). So have the following relationships: $E_M = E_P + E_k$.
- *Changed Energy*: it is the work W and heat Q, which reflect respectively macroscopic and microscopic energy transferred to a system.
- *Internal Energy* (U) is associated to motions and interactions between the particles of the system and historically it is mathematically assumed for justifying the impossibility to equal experimentally *heat* and *work*.
- *Mechanical Total Energy*: $E_{TM} = U + E_P + E_C$ that reflects all contributions and it is therefore characteristic of the energy stored by the system.

According to the *First Law of Thermodynamics* (as an extension of the *Mechanical Total Energy* which include heat phenomena, too) deal with *Variation of the Total Energy* of a physical system in interaction with its external environment. It is given by his general form (under thermodynamics equilibrium) as in the following[27]:

$$dE = \delta W \pm \delta Q \tag{5}$$

Because *heat* and *work* are both means of changing the value of total energy, they do not maintain separate identities after the transfer of energy is finished. For an isolated and adiabatic physical system the variations of volume is zero ($W = 0$ and $Q = 0$) so the total energy remains constant. This ideal assumption is also known as the *principle of equivalence work–heat*, insofar as it expresses the equivalence between the different forms of energy (under not experimental conditions). As we showed before, Sadi Carnot proposed what nowadays is called second principle of thermodynamics where idealist equivalence is not permitted. In other words, it is an overall assessment in which it cannot be created or lost of energy, but simply a converting one form of energy into another form or its transferring of one system

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[27] dE (also written as dU, exact differential) is the exchanges in internal energy of a system for *quasistatic process*. E is an abstraction to justify mathematically the process. δQ (also expressed as TdS, where S is the entropy and T is the temperature) is the infinitesimal quantity of heat supplied/lacking and δW (also expressed as pdV) is the mechanical work on/from the system/surroundings. The signs convention *plus* and *minus* remind this aspect of the Equation (5); i.e., the heat supplied to the system as opposed to by the system (see also Clausius 1850, or later on, Planck [1897] 1903). The latter two quantities, δQ and δW, are not exact differentials and for, they do not describe the state of the system. The Equation (5), for non-cyclic processes, is written as $\Delta E = W \pm Q$, from heat machines researches for producing the maximum of efficiency (Pisano and Gillispie 2014; Pisano 2010).

to another. It is therefore educationally and pedagogically inappropriate to speak of *energy production* and impossible to have a perpetual motion machine of the first kind (a machine that will allegedly produce more energy than it will takes in). Finally, it is worth noting that the real rationale of this law is the constant checking its consequences.

Degradation. Let us consider a physical system as a seat of transformations that take him back to the same initial state. In this case we have: $W + Q = 0$. This reflects, on the one hand, the quantitative equivalence between work and heat, on the other hand this means that if the system receives the work, it provides the heat, and if it receives heat, it provides work (Brunhes 1991). More, equality indicates that the energy of the system is conserved during its evolution. However, it does not provide the sense of this development. Furthermore, real's transformations can always be spontaneously one way transformed into heat. Thus, in this case the transformation of work into heat may be idealistically total. On the other hand, the transformation of heat into work can be achieved but only under some physical conditions. Therefore, the first principle mathematically expresses the equivalence of the quantity of heat *Q* and work *W*, while the second – by Sadi Carnot and then performed by Clausius and Kelvin – reflects their experimental non–equivalence (Pisano 2010; Gillispie and Pisano 2014).

In modern terms:

$$W \underset{\rightarrow}{=} Q \qquad \text{and} \qquad Q \underset{\rightarrow}{>} W \tag{6}$$

The arrow indicates the direction of change of the transformation. It usually follows that these two forms of energy transfer are not equivalent:

> *While the work W can be used to increase the energy of any form, the heat Q leads directly, if it is not converted first of all into work, to increase only the internal energy of the system.*

Therefore, the *heat* is classified as *degraded energy* and various forms of work not degraded forms. Such non–equivalence between the two transformations, the transformation of heat into work and that of work into heat, leads to those natural transformations do occur in only one direction: the reduction and the complete disappearance of a potentially possible work. We can say that in all transformations, the energy fall in quality, and that, without ceasing to be constant, it deteriorates and degrades. According with this form *degradation of energy*, the basic idea that the second law of thermodynamics involved will be very easy to explain and to understand quite simply. Indeed, it seems that conservation and degradation appear as two aspects of the general law of energy transformations: keeping the amount (first principle), loss of quality (second principle). It is clear that maintaining the quantity is expressed by equality; on the contrary, the loss of quality is reflected in the general case by an inequality. However, this inequality has as limiting case equality. One can find circumstances where equality is almost reached. The only thing that is quite impossible is to change the direction of the inequality. Exceptional cases where there is equality have a considerable theoretical importance in thermodynamics, as we will see in the next section on heat machines; they correspond to reversible transformations. It is important to note that the second principle was formulated in many different ways (Capek and Sheehan 2005) usually equivalent to each other and all describe what the irreversibility through entropy is. This principle has no theoretical evidence, except in cases of particular models as ideal gas.

This is just an empirical principle. Fermi pointed out that the best proof of this principle is the failure despite all the efforts put in default by constructing an apparatus having a perpetual motion of the second kind (a device that would transform periodically work in the entire heat exchanged by anybody).

Heat Engines and Efficiency

Even the so–called renewable energies have their negative effects. Therefore, one solution is to improve the efficiency of the used machines. In other words, increase the efficiency of the engine. It is true that technological improvements obtained by empirical trial and error, had increased engine performance. However, from a theoretical point of view, it was important to know whether these technical improvements could increase indefinitely the performance or if there was a limited theoretical forever impassable. The analysis on a Carnot's cycle leads to $Q + W = 0$ and therefore the conservation of energy principle sets this limit to 100 %. Nevertheless, the real changes are irreversible and according the two propositions of the second principle no real machine cannot reach this limit. As previously shown, Sadi Carnot determined a theoretical limit of much stricter performance obtained for reversible cylinders cyclically working. In French society, at the Parisian Polytechnic school, civil engineer Clapeyron, who was also a friend of Sadi's, mathematically exposed the *Réflexions in Mémoire sur la puissance motrice de la chaleur*, adding (Clapeyron 1834, 153–190) what nowadays we wrongly – both historical and didactic standpoints –read as "Carnot's cycle" (*Ivi*, 190; see also Clausius 1850, 368–397; 500–524; 379). This analytical reinterpretation of the so–called PV diagram (*loop*, or *Clapeyron diagram*) of the cycle did not have a metric (i.e. with respect to Descartes' diagram). Later Kelvin, Planck's statement and so called Kelvin–Planck relationships:

> [Kelvin] It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects.[28]
> [Planck] It is impossible to construct an engine which will work in a complete cycle, and produce no effect except the raising of a weight and cooling of a heat reservoir.[29]
> Every process occurring in nature proceeds in the sense in which the sum of the entropies of all bodies taking part in the process is increased. In the limit, i.e. for reversible processes, the sum of the entropies remains unchanged.[30]

Another usual manner to display the principles in the textbooks is:

> [Kelvin–Planck relationships] It is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce a net amount of work.

Therefore, as Sadi Carnot suggested (Carnot S 1824, 10–11) two sources of heat are required to produce work.

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[28] The content of the second principle of thermodynamics and the necessity of a second thermostat with the aim of executing a passage of heat between a difference in temperature is largely discussed (Thomson 1848–1849, 541–574; *Id*., 1882–1911, 113–155; Id., 1852, 248–255; Thomson 1851b, I, 175–183; Clausius 1850, 155, 368–397, 500–524; 1854, 481–506; see also *Id*., 1865a,b, 1868–1869).

[29] Planck [1897] 1903, 86–89.

[30] Planck [1897] 1903, 100.

Concluding Remarks

In the nineteenth century, in Europe the figure of the scientific engineer is emerging. In Paris the *Grandes Écoles* were founded, where the most distinguished mathematicians worked, writing treatises and teaching to the students. In 1794 the *École polytechnique de Paris*, a military school for the training of engineers, was founded. Joseph–Louis Lagrange (1736–1813) and Gaspard Monge (1746–1818) were among the first professors of mathematics. On 30 October 1794 (9 *brumaire*, a. III) the *École normale supérieure de Paris*[31] was also born (Dhombres 1992). The school aimed to train scholars and teachers of both science and humanities. The attention of the French mathematicians toward applications was therefore, at least in part, due to the need that educational institutions train technicians for the new state; the situation was different in other European countries. Particularly the core material in the scientific engineers' curricula was mainly mathematics and physics. This means analysis (*calculus*) in the first half of the 18th century up to include geometry (*projective geometry*) in the second half. Great importance was also attributed to purely theoretical disciplines, such as *number theory* and *abstract algebra*. Mechanics was developed within other disciplines becoming, i.e., *Mécanique céleste* (stars, comets, planets satellites, stability of planetarium system), *planet* (geodesy, cartography), *mathematical physics applied to Engineering* (mechanics, instruments, frictions, structures, analytical theory of heat), *corporeal mechanics* (statics, dynamics, hydrodynamics, crystallography), *Molecular mechanics* (*Elasticity*). On the other hand, the interaction between scientists, engineers and society crossed the new abilities of machines and prototypes of civil engines. In this sense a *scientific mediator*, as a link between sciences and societies is required for re–thinking of alternative teaching methods to establish a lasting relationship between scientists and citizens in a society so much depending on technological progresses as well. For, the previous historical discussion on dissemination science and technology in the past, reveals the interactions between the transmitters and their audiences (choice of the vehicles, of the subjects), between real or supposed self–educated and scholarly institutions, but also the links between the science which was produced and the science which was disseminated. In addition, through the study of the production of the scientific and technical popularization it is possible to measure the impact of the disseminated knowledge on the target groups and to estimate the speed of the receipt of the innovation, i.e. the time between the production of a scientific or technical innovation and its integration to the popularized speech, the interactions between popularization and social life, in particular as regards hygiene, food, the disease prevention, the diffusion of the medical popularization (fight against the empiricism of the bonesetters, the constitution of leagues of hygiene), and the links between the diffusion of the scientific and technical knowledge and the development of colonized territories by the empires.

With regards thermodynamics theory, energy and its application are evident that, relative to the amount of heat received, the lower the heat returned portion, the greater portion of heat converted into work. The ideal would be to minimize the returned portion to best use all the heat received; but we cannot cancel it, otherwise there would no longer need cold reservoir and we know that is impossible. Finally, as we already saw in the first section, Sadi Carnot showed that the efficiency η (see Eqs. 2, 3) of a reversible heat engine is higher than any other engine operating under the same conditions. Therefore, whatever the expected progress of science, technology enhancements and technical improvements that

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[31] The school was closed on 1795. Thus, it was re–founded on 1808, 17th March. On this model, the *Scuola Normale Superiore in Pisa* (Italy) was founded (1810) as a branch of the *École normale supérieure* and later gained independence.

could be achieved in order to reduce the influence of dissipative phenomena, friction, etc., so heat engine cannot exceed this theoretical limit, impassable as the laws of physics still apply.

The idea of a *science critics* (scientific disciplines, history, education studies, information and communication, epistemology, sociology of science) for to knowing the sciences news, the history of scientific and technical culture, as well as and the science–society debates of the past, to inquire, decipher and present current science–society debates. Consequently, in order to evaluate on various levels the challenges of the introduction of "new technologies" into society, and search and put in account the scientific and technical news (introducing Culture in sciences and technology and vice–versa), problematize and to contextualize scientific discoveries and technology innovations is nowadays necessary. More, in order to be able to discuss the role played by limits of expertise, to take a stance towards their audience regarding the scientific, technical, political, economic, social, ethical and symbolic challenges, to communicate to different audiences through various vehicles, to stimulate the desire to study sciences, an adequate scientific school and university Education firstly, and for scientific–technology citizenship education later, is desirable.

Finally, the Society, since the end of the Renaissance (generally speaking) to nowadays, usually built a perception within society according with the idea that science is synonymous of *progress* and *modernity*; especially during period of materializations. We know that anomalies, inversions and controversies also belong up cited erroneously so-called *progress and modernity.* In this sense the science in general, in all its contradictions, anomalies and developments certainly also represent a cultural phenomenon. Therefore and integrated science, history and education objectives are required in the teaching Science–NoS and curricula.

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