Texto 1

The Social Roots of Science*

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Fully developed, science is to be found only in modern European-American civilization. As its development began in early capitalism we shall have to study the period from the end of the Middle Ages until 1600. Results obtained by ancient mathematicians, astronomers, and physicists and by medieval Arabic physicians have greatly influenced the beginning of science in modern Europe. We shall not discuss this influence, but the social and economic conditions which made it possible.

Some general characteristics of early capitalistic society which are the necessary conditions for the rise of science are well known. Early capitalistic society is a society of trading and manufacturing townsmen. Therefore theology recedes, worldly and empirical thinking advances. Technology progresses rapidly in this period (period of inventions, machines). This sets tasks to mechanics and chemistry and furthers thinking in general. Economic competition dissolves the collective feudal society and especially the medieval guilds. This destroys the collective-mindedness and traditional thinking of the Middle Ages, furthers individual thinking and is the presupposition of scientific criticism. Early capitalistic economy proceeds rationally, calculates, and measures (bookkeeping, machines). This furthers the rise of rational scientific methods. It can be shown that the mathematical writings from 1300 to 1600 are intimately connected with the needs of tradesmen and bankers on the one hand, of architects, craftsmen, and military engineers, on the other.

In order to understand the rise of science in greater detail we have to distinguish three strata of intellectual activity in the period from 1300 to 1600:

(1) At the *universities* of this period theology and scholasticism still rule. The university scholars were trained to think rationally, they liked rational distinctions, divisions, and disputations, but were scarcely interested in experience. They relied on authorities and, therefore favored quotations and comments. If they were at all concerned with mundane and natural events, they did not search into causes, but endeavoured to explain the aims, purposes, and meanings of the phenomena. The universities were scarcely influenced by humanism in this period.

(2) The first representatives of mundane learning were not scientists but secretaries and officials of municipalities, princes, and the Pope (14^{th} century). They became the fathers of *Humanism*. Their aims were mastery of writing and speech and perfection of style. In the following centuries the humanists lose in large part their official connections and became free *literati* dependent on princes, noblemen, and bankers as patrons. Their aims remain unchanged, their pride of memory and learning, their passion for fame even increase. They acknowledge certain ancient writers as patterns of style and are bound to these mundane authorities almost as strictly as the theologians are to their religions ones. Also humanism proceeds rationally. It develops the methods of scientific philology, but it neglects causal research and is more interested in form than in content, more in words than in things.

Both university-scholars and humanists despise the uneducated lower classes. Both, therefore, wrote and spoke only Latin. Both especially despise manual labor and distinguish between liberal and mechanical arts: only professions which do not require manual work are considered to be worthy of well-bred men. The medical doctors, therefore, content themselves with commenting on the medical writings of antiquity; the surgeons who operate and dissect belong with the barbers and midwives. *Literati* are much more highly esteemed than artists. In the 14th century, the latter are not separated from whitewashers and stonedressers, but very slowly gain social esteem by stressing their relations to learning (perspective needs geometry) and literature. The inventors and discoverers, being craftsmen and mariners, are scarcely mentioned by the humanistic *literati*. Those men to whom, from to-day's point of view, the culture of the Renaissance owes the most important achievements, the artists, the inventors, and the discoveries, entirely recede into the background in contemporary literature.

(3) Beneath both the university-scholars and the humanistic *literati* there were some groups of superior *craftsmen* who needed more knowledge for their work than their colleagues did. The most important of them may be called artist-engineers, for not only did they paint their pictures, cast their statues, and build their cathedrals, but also constructed lifting-gears, earthworks, canals and sluices, guns and fortresses, found new pigments, detected the geometrical laws of perspective, and invented new measuring tools for engineering and gunnery. Many of them wrote diaries and papers in Italian on their achievements; the best known among them is Leonardo da Vinci (1452-1519). Related to them are the surgeons (painting needs knowledge of anatomy) and the constructors of musical instruments (Zarlino). These superior craftsmen invent, experiment, dissect. They already develop considerable theoretical knowledge in the fields of mechanics, chemistry, metallurgy, geometry, anatomy, and acoustics. However, since they had not learned how to proceed systematically their achievements form a collection of isolated discoveries. They are the immediate predecessors of science. The two components of scientific method were still separated: methodical training of intellect was preserved for upper-class learned people, for university-scholars and humanistic *literati*; experiment and observation were left, more or less, to plebeian workers. Real science is born when, with the progress of technology, the experimental method of the craftsmen overcomes the prejudice against manual work and is adopted by rationally trained university-scholars. This is accomplished with Galileo (1564-1642). [...]

Galileo's relations to technology, to military engineering, and the artist-engineers are often underrated. When he studied medicine at the University of Pisa, mathematics was not taught there at all. He learned mathematics privately from Ostilie Ricci who was a teacher of the *Accademia del Disegno*, a school for artists and artist-engineers. As a young professor of mathematics and astronomy at the University of Padua, he lectured privately on mechanics and engineering and established working-rooms in his private house where craftsmen were his assistants – the very first university-laboratory. He started his researches with studies on pumps, on the regulation of rivers, and on the construction of fortresses. His first printed publication describes a new measuring tool for military purposes. His detection of the law of falling bodies is intimately connected with the needs of gunnery. The shape of the curve of projection had often been discussed by the gunners of his time. Galileo was the first one who was able to solve this problem. From 1610 onwards he wrote only in Italian, no longer in Latin. This also shows his relations to the lower ranks of society, his aversion to university-scholars and humanists.

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Texto 2

Mathematics as a Bridge between Linguistic Descriptions and Perceptual Reality

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Various forms of mathematical symbolism evolved from natural language and, in some instances, visual representations, to fulfill particular functions and, as Joseph (1991) makes clear, historically these developments were not confined to the Western world. However, in the efforts to solve practical problems arising from the political and economic interests of seventeenth- century Europe, modern mathematical symbolism evolved to bridge the gap between perceptual reality and linguistic descriptions. That is, mathematicians such as Descartes (1596-1650) and Fermat (1601-1665) became concerned with investigating curves like ellipses, parabolas, and hyperbolas which described phenomena of the physical world such as the paths of planets, comets, and projectiles. These curves were important for solving immediate practical problems such as those associated with warfare, navigation, and trade. In investigating these curves, the idea was developed that 'to each curve there belongs an equation that uniquely describes the points of that curve and no other points' (Kline 1972: 198). Before this time, it is reported that algebraic symbolic notation was in some state of disarray, fulfilling no obvious purposeful activity. For example, Kline (1972) reports Descartes as explicitly criticizing algebra 'because it was so completely subject to rules and formulas "that there results an art full of confusion and obscurity calculated to embarrass, instead of science fitted to cultivate the mind" (1972: 193). From Descartes's links of the equation to curve, the study of motion and change was independently developed by Newton and Leibniz. This represented a major extension in mathematical activity since 'previous mathematics had been largely restricted to the static issues of counting, measuring and describing shape' (Devlin 1994: 2). That is, the link from text to visual was achieved with the development of Cartesian geometry and calculus where the 'grammatical metaphor' in the form of symbolism was linked to the 'visual metaphor' of the abstract diagrams and graphs.

Galileo's (1564-1642) plan for studying nature through quantitative mathematical description (Kline 1972) had directed Descartes's explorations in mathematics and science. A scientific revolution (Kühn 1970) followed in which quantitative mathematical descriptions of the material world replaced physical explanations of phenomena (Kline 1972, 1980; Wilder 1981). Science was no longer to be based on metaphysical, theological, and mechanical explanations of the causes and reasons for events in the material world. The new goal of science was to seek mathematical formulas to describe phenomena independently of explanations. However, the path to the 'unified' discipline of modern mathematics reveals the discontinuous nature of mathematical knowledge (Foucault 1970, 1972) with shifts in theoretical paradigms (Azzouni 1994; Grabiner 1986; Kline 1980; Tiles 1991; Wilder 1981) and intense rivalry over forms of mathematical notation as documented by Cajori (1927,1952, 1974, 1991).

From a contemporary viewpoint, following Lemke (1998), natural language primarily realizes typographical modalities or categorical descriptions, while mathematics realizes topological modalities or descriptions of continuous variation. Thus the descriptive power of mathematics outstrips the potential of language in the field of continuous covariation and descriptions of relations of parts to a whole. However, although the symbolism allows for complete descriptions of these relations, trends and patterns which are present in these formulations are often difficult to discern. The visual display of symbolic notation in the form of graphs and diagrams allows these trends and patterns to be revealed perceptually (Lemke 1998). However, these visual patterns are only partial descriptions which are further limited in terms of manipulative and calculatory power. As Lemke (1998) explains, the symbolism is thus more powerful but less intuitive than the visual displays.

Modern mathematics evolved as a written semiotic and so may be contextualized with respect to the semantic space occupied by written and spoken language. Halliday makes the point that speech and writing differentially represent reality. 'Written language represents phenomena as products. Spoken language represents phenomena as processes' (Halliday 1985: 81). Mathematical symbolic descriptions may be related to the costs involved in which written texts construct a synoptic world of things and their relations while oral texts construct a dynamic world of happenings and processes. Halliday formalizes the cost of written language as 'some simplifying of the relationship among its parts, and a lesser interest in how it got the way it is, or in where it may be going next' (Halliday 1985: 97). On the other hand, the cost of the dynamic view is 'less awareness of how things actually are, at a real or imaginary point of time; and a lessened sense of how they stay that way' (Halliday 1985: 97). Mathematical symbolic descriptions are concerned with dimensions of meaning which occur in the disjunction between these forms of language. That is, mathematics is concerned with capturing continuous patterns of variation and relations of parts to the whole which reveal the status quo at all points of time. Mathematics captures exact dynamic descriptions of relations as things frozen in time through the lexicogrammar of mathematical symbolism.

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Responda às questões 1 a 4 a seguir, com base no texto 1 dado.

Questão 1. O texto descreve as origens da ciência na civilização europeia-americana moderna. Que características gerais da sociedade capitalista são citadas pelo autor como condições necessárias para o surgimento da ciência?

Questão 2. A fim de compreender o surgimento da ciência em maior detalhe, o autor distingue três estratos de atividade intelectual no período de 1300 a 1600. Descreva, de acordo com o texto, cada um deles.

Questão 3. Na visão do autor do texto, quando é que a verdadeira ciência nasce?

Questão 4. Elabore uma versão em português do último parágrafo do texto (trecho entre "*Galileo's relations*" e "*university-scholars and humanists*").

Responda às questões 5 e 6 a seguir, com base no texto 2 dado.

Questão 5. De acordo com o texto, houve um período no desenvolvimento da matemática em que a utilização da notação simbólica algébrica, desordenada, não cumpria uma atividade intencional clara. Apresente os comentários da autora a este respeito, e os aspectos históricos citados que contribuem para que esta situação se modifique.

Questão 6. Descreva as distinções trazidas no texto referente aos papéis das linguagens natural, simbólica e visual