CHALLENGES OF TECHNOLOGICAL EDUCATION IN HISTORY

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Abstract. *This paper is concerned with the role of European universities in Scientific Revolution. It is proposed to describe the social and intellectual conditions of some universities as French, British, Scottish, German and Dutch, before the scientific thought made any appreciable impact upon them, as well as the changes which came over due to that Revolution. This discussion is of great importance for the Brazilian University in the framework of new reforms proposed by the government.*

Keywords: Scientific Revolution, Technological Education, European University, History of Technological Education,

1. Introduction

In eighteenth century the new way of thinking the world had root in Europe. As we know it was the age of reason, when men found that they could explain many things in the universe with the aid of a few simple abstractions and what they could not explain they were content to reject. It was also the age of invention, when men found new ways to construct devices, like Newcomen´s steam-pump and Arkwright´s spinning frame.

At this time the scientists began to realize that science could be useful to industry. Euler (1707-1783) published in 1760 a book on the mathematical treatment of gear-wheels and Joseph Black (1728-1799) discovered the latent heat providing an explanation for the steam-engine. At the end of eighteenth century, Lavoisier (1743-1794) began to do for chemistry what Newton (1642-1727) had done for physics in seventeenth century.

As a general rule, the universities shared little of this enthusiasm. Science was taught in the Scottish universities, but much of it was suited only to the level of schoolboys. The British Universities like Oxford and Cambridge, sleeping behind their ancient statues, took even less account of changes in economy and in scientific atmosphere.

2. Science and Industry

Many of the concepts so essential to modern engineering had been germinated a long while before the time of Leonardo da Vinci (1452-1519). It is important to mention, for instance, Jordanus of Nemore and Simon Stevin (1548-1620) as prominent scientists of the Galileo (1564-1642) and Descartes (1596-1650) period.

Using inclined planes, Galileo investigated the laws of falling bodies and reported in his “Dialogues” that irrespective of weight they accelerate uniformly and that their velocity is proportional to the square of time – facts of great importance to engineers. Christian Huygens (1620-1695) later computed the value of the acceleration constant. Galileo investigated also strength of materials, and his were the first crude testing machines made for that purpose. He hung weights on copper rods and on a wooden beam or cantilever putting from a wall. He measured the strength of his “copper”, almost certainly na alloy, with apparently reasonable accuracy. At that time Robert Hooke (1635-1703) had shown that any substance under stress is deformed in some degree.

In studying hydrostatic, Stevin had found that the pressure of water was proportional to its depth. Evangelista Torricelli (1608-1647) now linked hydrostatic and dynamics to show that under hydrostatic pressure a fluid like water passes through na orifice practically as fast as if it were falling from a height equal to the depth of the fluid over the orifice.

Later on, four men born in the second quarter of the seventeenth century made exceptional scientific contributions which proved to be of great value to engineering. Two of them lived on into the eighteenth , but the work of all four belongs to the century of Stevin, Galileo, Torricelli, Pascal (1623-1662) and Descartes. Three were British; one was a Netherlander. Their names were Robert Boyle (1627-1691), Robert Hooke, Christian Huygens and Isaac Newton.

Robert Boyle studied the elasticity of air and formulated in 1661 or 1662 the law which bears his name. It is credited also to the Frenchman Edmé Mariotte (1620-1684) who discovered it independently. Thus Boyle and Mariotte established a fundamental principle for engineers – though engineers never work with “perfect” gases. And with Hooke as his assistant in the laboratory at Oxford, Boyle made the first air pump of modern design.

Robert Hooke experimented on his own account at Gresham College in London with the elasticity of watch hairsprings, in part of his invention, and formulated the physical law which carries his name. In other words, material under tension lengthens in proportion to the pull exerted upon it; under compression, it shortens in the same manner. This relation holds true only up to the elastic limit, which varies with different materials.

Christian Huygens, a more serene fellow than Robert Hooke and more versatile, was developing the watch spring into spiral, inventing the pendulum clock, and using the pendulum to measure the acceleration of gravity. The pendulum of a given length swings, as Galileo had observed, with a constant period regardless of the weight or of the range of it swing. In addition, Huygens derived the formula for determining the radial or centripetal force necessary to cause a body to move in a curved path, an essential contribution to engineering as well as science.

The last and greatest of those four scientists was Isaac Newton. His "Principia", appeared in 1687 is the first book on theoretical physics, organize in a very concise manner the laws of motion, as well as presents the universal law of the two bodies attraction. His German contemporary Gottfried Wilhelm Leibniz (1646-1716) also deserves great credit for his part in inventing the differential calculus or what Newton called fluxions – the computation of rates or proportions at which variables increases or decreases. The historians of science attributed to both scientists the invention of infinitesimal calculus independently.

3. Science and French Revolution

The political transformations in France, which lead to French Revolution, were large and deep. The intellectual and cultural movement of this period known as Enlightenment, influenced several other countries in Europe and guided the debates in France. As part of these changes a general reform of the French system of education was performed. As result, several new educational institutions were established. The Polytechnics School and the Conservatory of Arts were founded in this period and played an important role for science and engineering in France. In a short period of time Polytechnic School became a center of scientific research and knowledge production. With this new education basis, it was possible for France to reach the top in terms of scientific development in areas like physics, mathematics and natural sciences in general.

The authors that have analyzed this period, the second half of XVIII century, agreed that a remarkable characteristic of it is the presence of "analysis". By "analysis" we mean a method that can be applied to a great number of physical problems, by using algebraic tools, some general principles and a deductive approach. This method enhanced the capacity of scientific research at the same time that also increased the power of generalization and formalization of mechanics and correlated sciences. This agree with the rational spirit of Enlightenment.

As a consequence not only the Rational Mechanics reach a high degree of sophistication with the Lagrangian mechanics in 1788, but also astronomy, acoustics, electricity, optics, the theory of elasticity and probability calculus were substantially modified. During that period a project of a mathematical social science was conceived by Condorcet (1743-1794). The analytical methods initially developed by mathematicians and physicians began to have influence in other branches of knowledge as social sciences.

4. The Polytechnic School in France

In spite of names of Bacon (1561-1626) and Newton ensure to England a high place in the history of the scientific revolution, it was in France which first recognized the great significance of Newton´s work and which first put into practice Bacon´s precepts. One reason is that France had the organization for doing a systematic scientific research. The Paris Academy was, in 1671 endowed for research by Louis XIV and charged with the responsibility for doing experimental work and for disseminating the results of scientific knowledge.

In order to change the engineering teaching a group of scientists and engineers under the leadership of Gaspard Monge (1746-1818) proposed that an engineering school of a new type should be organized to replace all those which had existed under the old regime. The proposition was officially approved in 1794 and at the end of the same year instruction stated in the new school by the revolutionary government. It was allocated to the new school of some 12,000 pounds and it opens with 400 students. In 1795 the school was given its present name, École Polytechnique.

The new engineering school included in his staff the mathematicians Lagrange (1736-1813) and Laplace (1749-1827), the chemist Bertholet (1748-1822). Other famous scientific men took part of teaching mathematics and mechanics, like Monge and Prony (1755-1839). Very soon Fourier (1768-1830) and Poisson (1781-1840) joined them.

In few years Polytechnic School became a great center for generation and irradiation of knowledge around Europe. Paris also became the undisputed capital of scientific thought in Europe and at the begin of XIX century the scientific spirit was finally established in France.

A reform of engineering teaching was necessary because the war with European countries push forward the construction of fortifications, roads and bridges and for the development of artillery. The new situation created led France in the way of application of scientific principles to industry.

5. The Industrial Revolution in Great Britain

Several historians marked Thomas Savery`s engine in 1702 the opening of a historic period that is separate and distinct though it is variously named and its limits are shifted with different views. Historians who stress political phase rather than economic change prefer to concentrate upon the French Revolution at the end of the century. It is the revolution governing all subsequent events; not even the American revolt from British rule takes precedence in the minds of these historians although it antedated the upheaval against the "ancien régime" in France. For those to whom literary and philosophical trends are more important, the period has quality and distinction as the eighteenth century, the century of rational thinking and scientific enlightenment as we have seen above.

It is not generally accepted that the invention of the steam engine and industrial machinery alone made possible for the small insular kingdom a revolution of that magnitude and to defeat again and again a continental nation of more than twice its population. It is more accepted a combination of several causes of different natures as political, social and economics. In addition the doctrines of economic liberalism had influenced strongly this period. Adam Smith (1723-1790), published in 1776 the " Wealth of Nations", stating that the real wealth of a nation lay not in exploiting colonial areas in a fixed trade but in a free and expanding commerce with all parts of the world.

This change of view in Great Britain may have come from the overexpansion of its domestic industry and the need of foreign markets to trade off the surplus goods.

The steam engine, as first developed by Thomas Newcomen (1663-1729), freed thousands of men and horses from the hard physical labor of keeping mines clear of water. The steam engine also made possible reopening many mines which could not be kept clear of water without it and soon increased the demand for labor in the pits. The society as a whole gained a greater profusion of goods and services. Over a period of time, despite the increase of population which accompanied the mechanization of industry and the development of medical science, particularly preventive medicine, there was an even greater demand for labor and marked rise in the general standard living. In general, the immediate profits from the Industrial Revolution accrued, however, not to the workers but to the relatively few who, by accumulating and risking capital, owned the tools which the workers used.

In relation to the steam engine, we can say that it emerged from the experiments of Otto von Guerike carried out in 1654. Nonetheless, its origin are related to the works of scientists and machine operators in the seventeenth century, such as Huygens, Papin, Leibniz, and others who systematically worked with the problem of atmospheric pressure and the use of heat as a form of energy. Papin tried to construct na atmospheric machine in 1707, for the purpose of pumping water into a reservoir. Savery built a machine with the same purpose in 1698.

6. The British Universities

In the accomplishment of the scientific revolution British scientists played a notable and distinguished part but British universities except fortuitously and incidentally played practically no part. A kind of isolationism of the universities is attributed to causes that differ from one university to another. To appreciate each separately we must study the universities of Oxford, Cambridge and the Scottish universities.

The political atmosphere in Oxford University was characterized by no democratic rules. Dissenters, who were the greatest enthusiasts for science and technology, were not admitted to the university. Political power lay with the Colleges, which were obliged by their statutes to elect fellows on all sorts of criteria other than that of intellectual distinction.

The teaching staff was composed of celibates in holy orders, members of the Church, committed to a curriculum of the time of Charles I. The circumstances alone would have been enough to prevent Oxford from adapting itself to the new scientific age.

Oxford in some aspects looks like a mediaeval university. It was composed by a group of Colleges where young men could study the trivium and quadrivium as a preliminary condition to their professional training. On the other hand, Oxford can be seen as a group of professional schools providing advanced study in technology, medicine and law.

In Cambridge the barriers to the introduction of science were less formidable, but it could not be said, even as late as 1852, that scientific work had taken root there. However, Cambridge had produced Newton and before the beginning of nineteenth century, mathematics and mechanics were essential ingredients for a degree. From the political point of view, Cambridge also excluded dissenters as Oxford did and was not so prejudiced toward thinking. On the other hand, Cambridge was not so helplessly bound by the authoritarian teaching of the Anglican Church. Probably it was by this reason that this university was able to abandon the Aristotelian tradition in science teaching, while Oxford still retained it.

Finally, it is possible to say that in Oxford and Cambridge universities the scientific thought, which by 1800 was already consolidated in the foundations of modern physics and chemistry and which had caught the imagination of the general public, had scarcely influenced the universities of England. Some authors even said that the Scientific Revolution had occurred not through, but in spite of the English universities.

7.The Scottish Universities

In Scotland the universities were more sensitive to the scientific spirit of the age. Once, in 1827, the father of geology Charles Lyell compared the Scottish and British universities. He said that "natural philosophy form an indispensable part of the preliminary education in Scotland". Both Edinburg and Glasgow developed medical schools and had in his courses large audiences. There was a rigorous examination system and scientific subjects formed an integral part of the academic curriculum.

One fundamental reason for the vitality of Scottish universities was that they remained throughout the eighteenth century strongly related with scientific thought on the continent. At a time when English universities were closed shops for the Church of England and were insulated against influences from abroad the Scottish universities maintained a dynamic interchange of ideas, especially with the universities of Holland. In the early eighteenth century the university of Leyden became an important center for the propagation of Newtonian physics through Europe. Scottish students were welcomed in Holland to study medicine and mathematics.

Another important difference between the pattern of teaching in Scottish universities and in Oxford and Cambridge at the beginning of nineteenth century was that in Scotland they used professional lecturers, the subjects was taught by a specialist while in England teaching was undifferentiable in the hands of colleges tutors. In other words, Scottish universities were both colleges and professional schools.

In brief, the Scottish universities had really absorbed the new philosophy of the Scientific Revolution and transmitted it while the British universities were submitted to a strange isolationism.

8. The German Universities

If the scientific spirit was unable to cross the channel it did cross the Rhine and found in Germany an appropriate and intellectual climate. The basic conditions are the social favorable context for the survival of science as financial support and freedom to pursue research, associated with opportunities for scholars to work together and to transmit ideas and techniques to their successors. All these conditions were present in German in the early nineteenth century.

The German universities were founded and maintained by independent states and constituted a very interesting case without parallel in Europe. Teachers and students were permanently migrating from one university to another and continually interchanging ideas. In addition a kind of healthy rivalry had established between one university to another.
In German, a unique network of institutions devoted to higher education was developed after the turn of the nineteenth century such that it became one of the major intellectual forces in Europe. Until the beginning of the eighteenth century the German universities had not emerged from the shadows of mediaeval scholasticism. But during this century the situation changed. We should remember some important facts related to this change. From the intellectual point of view, Kant worked in Koenigsberg and the university of Gottingen was founded in 1737. This university and the university of Halle changed the pattern of teaching in German. The mediaeval universities, that means the conventional faculties of philosophy, theology, law and medicine were obliged by the circumstances to change.

Another important characteristic of German universities is that the research is essential for teaching. The scholar’s dream was symbolized by a magic word: Wissenschaft. It is important to emphasize that that word in German is not the pure translation of the english word science. It means more precisely an objective and critical approach to all knowledge. In fact Wissenschaft became the guiding star of some German universities before the arriving of Scientific Revolution.

We must also remind that most great German scientists of eighteenth century worked outside the universities and that wissenschaft flourish inside them.

The new way to look the knowledge contributed to develop methods of objective analysis for questioning, for comparing, for searching and solve problems. Therefore, the German university was a fertile soil for the transplantation of the scientific spirit from France. In this process there was a time when it became obvious that all science had meant to French thought it was now going to mean also to German thought, and that the universities were to be it headquarters.

9.The Dutch Universities

As we said before, the development of the scientific knowledge in the universities depends upon certain favorable conditions. These conditions were present in Holland under different context from other countries. The interest of the rich merchants, of the Lord Regents in science and technology had a material foundation. As tolerant in matters of the spirit as intolerant in matters of commercial competition, they did not only have the money to entertain themselves with the arts and science, but also to invest in them.

Other conditions for the development of a good teaching were created by the population growing, pushing the scientists and engineers to solve problems of drainage of lakes and estuaries. The military engineering also had a big progress because the interest of Orange princes in their sieges and fortifications as similarly happened for the development of French engineering.

The economic context was also favorable. In Holland a diversified industry soon appeared. As example the textile industry of Leiden, already known in the middle ages, tapestry weavers, sugar refiners, glass blowers, lace workers, porcelain makers, potters and brewers lent, all of them composed the dutch manufacture in the market. Many of these industries introduced new inventions.

The universities in Holland were primarily schools for the training of reformed ministers, but they did not neglect the secular sciences. This was a much better situation than existed at many a university in other countries. Yet, it remained a fact that the really great ideas of the natural sciences and philosophy were generated in the world outside the universities. It is the case of Stevin, Descartes and van Leeuwenhoek (1632-1723).

In the sixteenth and seventeenth centuries we found physicians engaged in various sciences different from medicine. It should be remained that at many universities the medical faculty was the only place where lectures were held on the natural sciences, so that men interested in mathematics, physics or natural history first to complete their medical studies. Descartes had also studied medicine and his philosophy was very attractive to people of medical profession.

10. The Expansion of Technological Courses in Europe

In the country of empiricism paradoxically the British Universities adapted themselves to teaching experimental sciences under the influence of German Wissenschaft. It is a question that remains to discuss how higher technology found a place in British Universities. It is known that the first chair of engineering in a British university was as long ago 1796 by the Jacksonian professor of natural philosophy in Cambridge. University College in London has had a chair of engineering since 1841.

The Glasgow chair of engineering was set up by royal warrant and was evidently not welcomed by the academics in the University. The senate refused to supply the first professor with a classroom until the Lord Advocate intervened on his behalf. Even as late as 1861 engineering was not considered a proper department in which a degree should be conferred. The University of Edinburgh in 1855 created a part-time chair of technology, which was occupied by George Wilson, regius director of the Industrial Museum of Scotland.

Before 1870, there was neither an adequate supply of pupils trained in science from schools nor na adequate demand from industries for graduates in engineering. Training in technology was through apprenticeship, on the job and any formal training in colleges was regarded with suspicion, as likely to lead to the disclosure of "know how" and trade secrets. Gradually, and with reluctant and inadequate support, technology took its place in the curricula of the colleges and universities of Britain.

It was to the continent that Britain turned for models of how technology should be taught. But these models were not simply copied. They were profoundly modified and adapted for British conditions. On the other hand on the continent higher technological education is not primarily a responsibility of universities. It is conducted in institutions called Polytechnic Schools or Techische Hochschulen. In German, for instance higher technological education is concentrated in eight Technische Hochschulen which have the status of universities. In Holland a Polytechnic School was opened in Delft in 1864, to train works managers, civil engineers, naval architects, and science teachers for schools. Even the United States followed the same rule. The Massachusetts Institute of Technology was founded in 1856, to become a place where a systematic study of political and social relations with scientific methods and processes are alike essential.

The prime purpose of this widespread system of technological education was not humanitarian. It was to enable continental countries to catch up and to overtake British industry.

11. Final Remarks

Throughout this work, we have tried to show the different contexts, conditions and situations that are favorable or that created obstacles for the development of scientific knowledge inside or outside the universities. France was the first country to develop a high level of technological education in his famous École Polytechnique created by French Revolution. This school influenced the majority of engineering schools created in Europe and in Brazil.

The change in the teaching patterns around the world is a direct consequence of the Scientific Revolution that means a deep change of seeing the world and solve their problems. Therefore, political conditions should be satisfied to accomplish a Scientific Revolution. This paper is also an attempt to show how the differences among several European countries determines the rhythm and the intensity of the impact on the universities.

12. References

Ashby, E., London, 1966, "Technology and the Academics" , Macmillan.

Struik, D. J., Holland, 1981, "The Land of Stevin and Huygens" , D. Reidel Publishing Company.

Oliveira, A. R. E., "The Contribution of Leibniz to the Engineering Sciences" , COBEM 2003, S. Paulo.

Oliveira, A. R. E., " The Contribution of Coulomb to Applied Mechanics" , HMM04 International Symposium on History of Machines and Mechanisms, Cassino 12-15 2004, Italy.

Dugas, R., 1988, "A History of Mechanics" , Dover Publication, N. York.

Rashed, R., 1988, " Science a l´époque de la Revolution Française" , Librairie Scientifique et Technique, Paris.

Daumas, M., 1996, " Histoire Géneral des Techniques" , Presses Universitaires de France.

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