Revista Electrónica de Metodología Aplicada
2003, Vol. 8 nº 1, pp. 1-23

Historical origins of statistics applied to pedagogy

Antonio Matas Terrón[1]
e-mail: amatas@us.es
[1] Facultad de Ciencias de la Educación
Universidad de Sevilla

RESUMEN
En el presente trabajo se ofrece una revisión histórica de la relación que han mantenido entre sí las Ciencias de la Educación (en espacial la Pedagogía) y el conocimiento estadístico. Se analiza el contexto general hasta la década de los años treinta del pasado siglo, momento en el cual puede entenderse que existe una consolidación de la Estadística como recurso en investigación en Pedagogía. Se revisa la influencia determinante del positivismo, como marco de pensamiento general en el siglo XIX. A partir de este contexto filosófico y científico, se proyectaron distintas vías, dentro de la ciencia, que suelen coincidir en una preocupación por la "objetividad". Se analizan la tradición de disciplinas como la psicofísica, la psicología o la medición, que influyeron decisivamente en la incorporación y consolidación del conocimiento estadístico, en la Pedagogía Experimental, y con ello, en las Ciencias de la Educación.

Palabras clave: Historia de la Pedagogía, Historia de la Estadística, Pedagogía Experimental.

ABSTRACT
This paper offers a historic revision of the relation kept between Sciences of Education and the knowledge statistician. It's analyzed the general context up to the decade of the thirty of the past century, moment when the statistical knowledge can be considered a being consolidated within the Science of Education. Influence determinant of the positive, as framework of nineteenth century is exposed. Since this philosophic and scientist context, some ways are studied, inside of the science, all they preoccupied by the "objectivity". The tradition of disciplines as the psychophisic, the psychology and measure, is analyzed. These sciences influenced decisively to incorporate and to consolidate the knowledge statistician in Experimental Pedagogy, and so, in Sciences of Education.

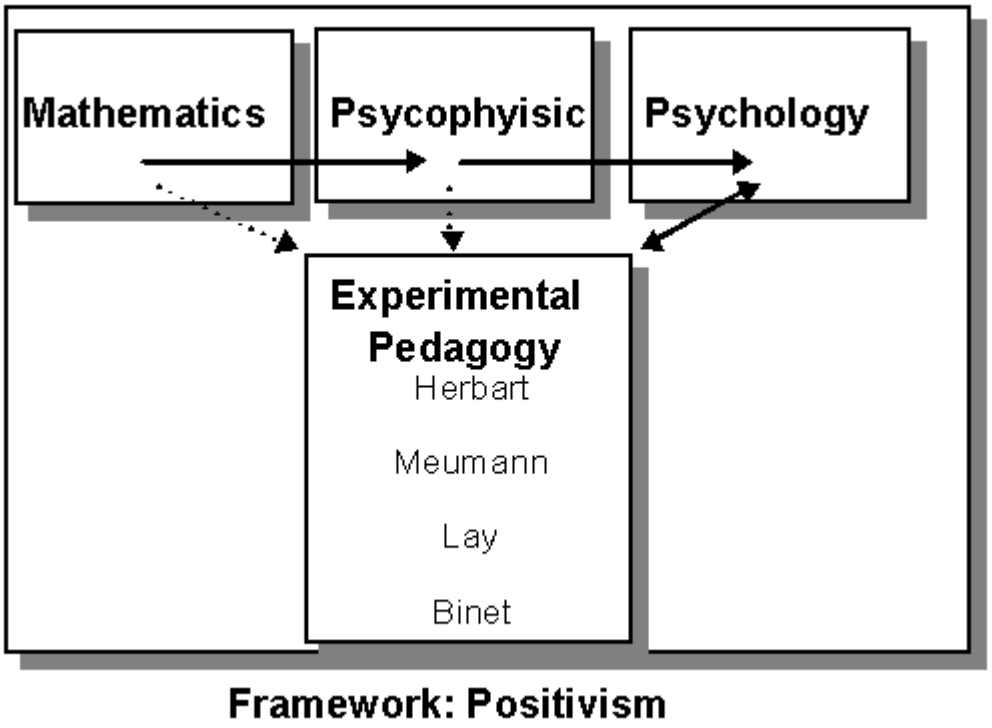
Keywords: Pedagogy History, Statistics History, Experimental Pedagogy.

1.- Introducción

The presence of statistics has been constant in pedagogy throughout the twentieth century. The aim of this report is to offer a historical survey of the first moments in which this very productive relation between both disciplines came about. This historical survey commences with the first occasion on which certain mathematical procedures (which are now integrated within what is now known as "statistics") , began to be applied in the field of Pedagogy, and extends up to the 1930's, when statistical knowledge can be considered as being consolidated within the Sciences of Education in general. In this sense, Fisher can be taken as author of reference. Fisher's work, together with Snedecor's interpretation of it, illustrates the complete integration of statistical knowledge in this discipline.

In order to do this, it is necessary to go back to the nineteenth century so as to identify the first occasions on which mathematical content was applied to educational studies. From the very beginning of experimental pedagogy with Herbart, mathematics was considered necessary for the scientific advance of investigation in education. The fact that Herbart stated this necessity, must be understood, however, from the personal point of view of the discipline held by this author.

In the following pages an analysis will be made of the process by which the content of statistics, ordered into fields of knowledge, was incorporated as an important part of investigation in Pedagogy. This process commences within the general framework of positivism, in which objectivity and experience are valued above other principles. The development of psychophysics established the connection between observable reality and the sensations of individuals. In psychology, certain topics pertaining to psychophysics were studied with its methods, the most important investigators being Wundt, Galton y Pearson. This last investigator carried out certain applications of statistics which had a definite utility for investigation in education. Herbart evolved a new empiric pedagogy, which integrated the scientific reality of that time with his own ideas on education and psychology. This experimental pedagogy would be consolidated with studies on the measurement of intelligence and aptitudes.



Graph 1

Graph 1 shows the relations existing between the different scientific disciplines, which allowed the incorporation of the procedures of statistics into the social sciences. Throughout the following pages this exposition will be carried out organizing into areas of knowledge some of the historical events which have been most meaningful for investigation in education. This structure has been chosen so as to allow a certain degree of detail in the analysis of the historical facts in their context, explaining them in a detailed and concrete form. A chart-summary (table 1) is also included showing, in chronological order, the events commented on in this report.

Year	PHILOSOPHY	PSYCHOLOGY	PEDAGOGY	PSYCOPHYSIC	STATISTIC	MEASUREMENT
1654					Born Jacob Bernouilli	
1703					J. Bernouilli published "Ars Conjectandi"	
1705					Die J. Bernouilli	
1724	Born Kant					
1749					Born P.S. Laplace	
1776			Born Herbart			
1777					Born K.F. Gauss	
1781					Born S.D. Poisson	
1795				Born W. Weber		
1796					Born Quételet	
1798	Born Comte					
1801			Born Littre y Müller	Born Fechner		
1804	Die Kant					
1806			Born J.S. Mill			
1809			Herbart obtained doctorate and occupies professorship of Kant			
1816			Herbart published "Lehrbuch zur Psychology"			

1816					Gauss published "Zeitschrift für Astronomic"	
1818			Born Bain			
1820	Born Herber Spencer					
1821		Born Helmholtz				
1822		Born Galton				
1825			Herbart published "Psychologie als Wissenschaft"			
1827					Die P.S. Laplace	
1829			Herbar published "Metaphysik"			
1830						Born Beaunis
1832		Born Wundt				
1835						Quételet used the law of the error to describe the human tear.
1837					Poisson published his probabilties law	
1840					Die S.D. Poisson	
1841			Die Herbart			
1854					The Boole’s	

					algebra is diffused	
1855					Die K.F. Gauss	
1856					Born G. Boole	
1857	Die Comte				Born Pearson	Born Binet
1859			Die Müller			
1862			Born Meumann			
1863					Born Spearman	
1864					Die G. Boole	
1869						Galton started the studies over the inheritance and the geniality.
1873	Die J.S. Mill					
1874					Die Quételet	
1875					Helmert developed the Chi distribution.	
1878				Die Weber		
1880						Galton realized an inventory of Britanics Abilities
1881			Die Littre			
1885						Galton studies the relation between the height of the peoples
1887				Die Fechner		

1889						O'ehrn develop a instrument to measurement the memory, the perception, the asociation and the motorics' functions
1889		Binet y Beaunis Found the first laboratories of psychology in La Sorbona				
1890					Born R.A. Fisher	Cattell published "Mental Tests and Measurement" where appearences the word: "test mental"
1891						Boas presents his program to measurement tears the children
1894		Die Helmholtz				
1896			Meumann completed his studios			
1896			Lay published "Guides for the Teaching of the Spelling"			

1900		Stern published "Veber Psychologie der Individuellen Differenzen"				
1902			Lay published "Experimental Didactic"			
1902					Pearson founded "Biometríc"	
1903			Meumann published "Veber Oekonomie und Technik des Lernens"			Binet published "L'etud Experimentale de L'inteligence"
1903	Die Herbert Spencer		Die Bain			
1905						Binet y Simon published their first Intelligence Scale.
1908					Gosset published with the alias "Student"	
1911		Die Galton	Binet published "Moderns Ideas over Children"			Die Binet
1915			Die Meumann			
1920		Die Wundt				
1921						Die Beaunis
1923					Fisher	

					developed the ANOVA	
1923		Spearman published "Nature of Intelligence and Principles of Cognition". Develops the analysis factorial in Psychology				
1933					Kolmogorov realized the first systematic presentation of the theory of probabilities over based axiomatic	
1936					Die K. Pearson	
1937					Snedecor published "Statistical Methods" where explain the Fisher's ideas.	
1945					Die Spearman	
1962					Die R.A. Fisher	

Table 1

2.- General framework: Positivism

The nineteenth century saw the development of a important movement known as positivism. The philosopher August Comte (1798-1857), who has born in Montpellier and died in Paris, is considered the founder of positivism with the publication of his work "La Philosophie Positive". His aim was to foster a total change in society, as an alternative to the obsolete illuminism and its effects (the revolution). Comte constructed a system of education convinced that an authentic educational system could only be organized by positivism. In Comte's opinion, this is the best resource for social reform.

Science would take on the responsability of leading this change, as against the affirmations of traditionalist and socialists. In order to do this, true science must be based on facts and the relations between them (laws). In this way it is not necessary to speak of original causes. For Comte, positive is something which is directly observable, as "facts" cannot be doubted. Basing himself on these concepts, he questions methods like introspection. According to positivism, the classification of sciences is a reflection of the evolutionary development of human knowledge: maths, astronomy, physics, chemistry, biology and sociology. At the same time, this classification also shows an evolution of the sciences from the most concrete to the most complex. Within this continuum constituted by fields of scientific knowledge, sociology is considered the science which is most fully developed. The positivist system is based on three basic principles: the law of the three states, the classification of sciences and the religion of humanity (Larroyo, 1984).

In spite of appearing to have a robust structure, criticisms of positivism surged immediately. One of the first lines of argument against positivism was to do with the weakness of the foundations of positive pedagogy, for not taking into account the historical aspects of classical pedagogy. This is due, amongst other reasons, to ignorance of this history (Larroyo, 1984). Moreover, the law of the three states does not explain satisfactorily the evolution of science. Comte had a decisive influence on many other investigators of the nineteenth century, such as for example Littré (1801-1881), who was one of his students, and certain other notable people like Stuart Mill (1806-1873), Taine (1828-1893) or Ribot (1839-1923).

In spite of the principles of his premises, Comte was conscious of the limitations of intellectualism, and he openly recognised the importance of the emotional component in philosophy and education. Conversely, Herbert Spencer (1820-1903) radicalized this doctrine, accentuating the importance of science in educative work. According to this philosopher, the basis of pedagogy is evolutionism. Spencer shows the influence of Comte and also of the doctrine of "The Origin of the Species" by Charles Darwin (1809-1882). He understands education as an evolutionary process which develops in the progressive maturation of the individual, at the same time as it reveals "in the act" his potential and aptitudes.

Positivism experimented an important advancement within pedagogy due to John Stuart Mill (1806-1873), who in his speech at the inauguration of the University of Saint-André in Scotland, emphasized the importance of the education of the humanities and social sciences. Stuart Mill used an analogy from chemistry in his explanations. He affirmed that the combination of elements originate new components with characteristics that were not formerly present. This is the doctrine of creative synthesis. Moreover, this author maintains

that the general law of psychic causality includes the rest of the laws on causality and amongst them, the law of creative synthesis or of psychic results. Underlying this argument is the concept of "mental chemistry" developed later by Wundt.

However, it is Alexandre Bain (1818-1903), a friend of John Stuart Mill, who is the best theoretical representative of the scientific tendency in education. Bain published in 1842 in the Westminster Review his associative law of similitude. The same year he helped Stuart Mill to revise the termination of his book "Logic". Subsequently, in 1851, he began to write up his systematic psychology, which would be published in two volumes: "The Sence and the Intellect" (1855) and "The Emotions and the Will" (1859). In 1876 he founded the journal "Mind", the first psychology, journal, although its contents would still be basically tied up with philosophy. He emphasizes that the science of education is based on psychology and logic, an idea that was commonly held at that time. In practical terms, he upholds the necessity of knowing the order of the development of faculties in the individual and the role played by this order in the distribution of educational content. Psychology would have the responsibility of carrying out this task. Secondly, he considers that there is an order that proceeds from the subject matter itself, which is sometimes evident, but on occasions is difficult to identify. This distinction would be dealt with by logic. Bain represents the chief exponent of associationism as well as the beginning of its absorption by physiological psychology.

With regards to positivism, it is necessary to refer to the presence of two tendencies in the social sciences: the deterministic conception as against the probabilistic point of view. The first applications of statistics registered after Descartes were carried out in sociodemographic fields, and were used to register the number of deaths, then of marriages and births, becoming useful in the control of censuses. During the eighteenth century and the main part of the nineteenth, the statistical tradition was still in force, centred above all on description, and not connected to probability, although Moivre and Laplace were already applying the calculation of probabilities to demographic data. Adolphe Quételet (1796-1874) was decisive in this synthesis of probability and description; he applied with a certain degree of success the theory of Probability to the Social Sciences and to Anthropology. He was the first to reveal the possibilities that Statistics and Probability could have as instruments of measurement of social phenomena. Through his initiative, the first International Congress of Statistics was celebrated in Brussels, a precursor of the modern-day Institute of Statistics Founded in London in 1885 (Angulo, 1992).

The apparent certainty of physics became an ideal for new-born sciences like psychology and experimental pedagogy. In imitation of the laws of physics during the nineteenth century and for a large part of the twentieth, determinism and objectivity predominate. It was argued that phenomena are independent of the instruments and processes used to measure them, thus attaining the sense of objectivity which was maintained as a desirable goal. Nevertheless, in physics itself, the opinion spread that the process of measurement, the investigator, etc., intervenes in the phenomenon itself, and therefore knowledge is generated from the interaction of all these variables. This idea was widely spread by investigators such as Niels Bohr (Balibar, 1999). In the first half of the twentieth century determinism exists along with probabilistic thinking. This was possible in that the probabilistic perspective was "enlisted" in the service of determinism (Gigerenzer & Murray, 1987:15), for example in Thurstone's law of comparative judgement, which relates the

variability of brain activity with Weber's concept of threshold. In other words, probabilistic models were incorporated as a part of some determinist theories.

The entusiastic reception afforded to probabilistic thought in the ambit of inference was due precisely to its integration within the traditional idea of objectivity. This idea created the illusion of a mechanical process of inference (Gigerenzer & Murray, 1987). In this way, probabilism, integrated within determinism, grew in importance, developing as an independent model, surpassing in this way previous propositions during the first half of the twentieth century.

From was has been said up to now, it can be deduced that in the nineteenth century (including the last decades of the eighteenth) a phenomenon is produced in scientific knowledge characterized by a drift towards the domain of physical sciences. Most disciplines take on the basic suppositions of these areas of knowledge. In this scientific environment, in social sciences in general, and especially in psychology and pedagogy, it was felt necessary to incorporate mathematical techniques which afforded the "sensation" of objectivity sought by the investigators of the time. In this way, the incorporation of statistics (in its most basic sense) was a natural and accepted process.

3.- Statistics in the nineteenth century

Pierre Simon de Laplace (1749-1827), a french mathematician, published in 1812 the analytic theory of probability, in which he proposed the expression "the number of favourable cases divided by the number of possible cases" as the definition of probability, which proved to be inappropriate in certain cases. The theory of probability of Laplace was prevalent throughout the nineteenth century. The function of normal distribution appears for the function of distribution of the binomial. However, it would be Laplace who would generalize the results of Moivre in 1812. In the same century, Karl Friederich Gauss (1777-1855), a German astronomer, mathematician and physicist, had a notable importance. In December 1801, he used the method of minimum squares to determine the trayectory of the "planet Ceres". This method had an extensive application later on in the social sciences. Another important contribution was made by Gauss in 1809, when he demostrated that if it is accepted as a postulate that the arithmetic mean is the most probable value a posteriori, in the sense of Bayes, then true errors must follow a certain distribution of probability (later called gaussian or normal). This way, the normal distribution was obtained in an empiric way (Angulo, 1992). Other mathematicians had arrived at the expression of normal distribution before, from a theoretical perspective, starting from the limit of another distribution. Another important mathematician who would have an undeniable influence subsequently was Simón Denis Poisson (1781-1840) . This author first published his law of probabilities in 1837 in the book "Recherches sur la probabilité des jugements en matiére civile". Six decades later, in 1907, Gosset (who used the pseudonym of Student) deduced the law of Poisson as the distribution of the number of tiny corpuscles found in the drops of samples of a liquid.

An important point in modern day statistics applied to investigation in social sciences is the one related to the central theorem of limit. The validity of this theory in conditions where there are few restrictions of random variables, was a conjecture of Laplace and Gauss

at the beginning of the nineteenth century. However, the first satisfactory conditions, corroborated by a rigorous demostration of the validity of the central theorem of limit, were presented by Lyapunov in 1901. Markov (1856-1922), a follower of Chebyshev (1821-1894), propounded the first statement of the central theorem of limit. He also studied the successions of random variables, creating in this way what are known today as "Markov chains". George Boole (1815-1864), a British mathematician, applied algebra to the logic of classes, giving origin to the algebra of Boole in 1854. Later, probability would be defined in an axiomatic form upon this algebraic structure.

Statistics and the theory of probabilities would not be used jointly until the second half of the nineteenth century, with the work of Quételet, Galton, Pearson, etc. Quételet got his inspiration from the theorem of limit of Laplace. From his work it was deduced that the observation of a normal can be used to verify two propositions, that of the existence of a constant cause (the average man), and the fact that all other causes are accidental.

The analysis of regression derives from Sir Francis Galton (1822-1911), who in 1885 studied the relation of people's statures. He incorporated and extended the ideas of Quételet in his work. Galton was the first to apply the "Norma Distribution" in the study of errors from the mean of mental skills. He developed the coefficient of correlation *?*, which would be demonstrated by his successor K. Pearson in Galton's own laboratory.

Karl Pearson (1857-1936), an English statistics mathematician, was one of the founders of Statistics as we know it today, granting it an institutional basis at the University college of London. Basing himself on the work of Quételet and Galton, Pearson founded "Biostatistics". In 1902 he edited the periodical publication "Biometry". One of his contributions was the chi-square test of the excellence of adjustment from the distribution of the same name, developed by Helmert in 1875.

Ronald Aylmer Fisher (1890-1962) worked in Agronomy and, together with Mackienzie, carried out the first practice of variance analysis in 1923. The terminology used by Fisher was not well understood by investigators of other sciences. It was Snedecor who stated Fisher's ideas more clearly, in his book "Statistical Methods" in 1937. Fisher was also one of the percursors of the contrast of hypotheses. He believed that the presence of an alternative hypothesis was not necessary, and it was Jerzy Newman and Egon Sharpe who proposed the tests of hypotheses as they are carried out today, with the void hypothesis and the alternative hypothesis, and type II, as well as the potency of contrast (Angulo, 1992).

Charles Edward Spearman (1863-1945) worked in human sciences, in studies on the behaviour of individuals. His work provided the basis for the development of methods of factorial analysis in psychology. His most important work is "The Nature of Intelligence and the Principles of Cognition", published in 1923.

As it can be seen, different techniques of analysis were developed at the beginning of the nineteenth century, as well as certain theoretical bases related above all to probability. Subsequently there followed a series of investigators and authors that began not only to study these strategies but, more importantly, to apply them to certain fields of knowledge, especially the studies carried out in the fields of psychology anthropology, demography, sociology and education. In this way, the same authors of some of the most productive propositions in

statistics, also developed applied studies in the social sciences, which guaranteed a direct exchange of knowledge between disciplines. At the same time it must be emphasized that the nineteenth century brought the appearance of statistics as it is known today.

4.- Wundt and experimental psychology

As an antecedent to experimental pedagogy (and its origins) it is necessary to mention Wundt (1832-1920), who related all the previous elements with new discoveries of his own. Wundt, considered the father of experimental psychology, believes that there exist two main lines in psychology:

* Physiological psychology, which studies the phenomena of the conscious. The experimental methodology of physiology is used to study the objective characteristics of the conscious. Wundt believes this is possible because the conscious is not a product of a substance or entity as the "soul" could be, as was traditionally maintained, but the result of a series of lived experiences.
* The psychology of peoples, which studies cultural matters such as language, religion, customs, art, etc.

Psychology, regarded as a natural science, uses two methods: observation and experimentation. The experimental method supposes an intervention made in order to provoke the phenomenon to be studied. On the other hand, observation is centred on the study of reality as it is presented to the observer. The propositions of Wundt would find an alternative in Galton and this way two theoretical models evolved: one presented by Galton, and the model of Wundt (Dazinger, 1987:37). Wundt carried out his investigations by provoking changes in the enviroment, observing the effects on behaviour, and formulating assumptions about certain psychic activity which relates these changes to observable behaviour. The galtonian model, on the other hand, was centred on the study of the population analyzing, the distribution of characteristics, in large group of subjects, as well as on the difference of characteristics in different populations. The direct antecedents of the model of Wundt are the psychophysical studies of Fechner, where statistics is used to combine observations from which the reality of the phenomena is established. The Galton-Pearson model recurs to the science of statistics to carry out exploratory studies of the groups, which the object of describing the concurrence of attributes of populations. These differences between approaches have important practical consequences. With Wundt causal relations are established between variables. In this approach, the error of measurement is seen as fluctuations around a true score. With Galton, on the other hand, the experimenter has no control over the variables. He uses as techniques of development those provided by correlational statistics. The model of Wundt helped to confer a respectable scientific appearance to psychology, although its range of application is very limited, an aspect which was criticised from the beginning by young German psychologists. The Galtonian model, on the other hand, establishes the correlational lines as a form of investigation in social sciences.

At the beginning of the twentieth century a desire emerged among investigators to find an alternative to Wundt, which originated the development of methods such as introspection

and some others which consisted basically of variations of the Wundtian propositions. Galton, nevertheless, would still be most appropriate alternative, as much for the method followed as for the object of study: heredity, and later on, intelligence. All this had a very important effect on the educational system, and a close relationship was established between psychology and education in the first decades of the twentieth century, centred on aspects such as teacher training, as well as the formation of educative administrators. Subsequently, this relationship evolved to the point that a symbiotic interaction between sciences, was achieved, where the galtonian perspective predominated (Danziger, 1987). The Galton-Pearson model prevailed over that of Wundt's for the following reasons, among others:

* Galton's studies do not establish causal relations. Although much of the research had this as its objective, it would be carried out by methods other than by experimentation.
* The most significant topics in the galtonian studies were of evident relevance for education, for example the training-fatigue relationship.
* Investigators began to carry out concrete studies of individuals in the populations of interest.
* Subsequently new forms of research were such as "group treatment", which was still studies of developed, based on the description of characteristics. This approach dominated the decade of the 1920's.

For the study of causality the artificial construction of experimental groups was used, recurring to hybrid models of propositions of both Wundt and Galton. Starting from these studies, the study of the differences between groups became widely known, giving way to the emergence of new techniques of statistical analysis such as the *t-test* or the analysis of variance (anova), well into the twentieth century. In short, it can be considered that, at the beginning of the twentieth century, two methodological approaches coexist in psychology:

* Experimental psychology: with its origins in Fechner ald Wundt, whose objects of study are memory, perception and learning. Brunswik (1903-1955) and similar authors defended conductism, together with a mechanistic concept of man, so subjective aspects are discarded. This is a nomothetic approach.
* Correlational or differential psychology: this is generated from the studies of Galton and Pearson, based on their ideas on natural skills and differences between subjects.

With respect to the initial probabilist-determinist debate it must be said that both propositions concur in the models indicated. It cannot be maintained that Wundt was a determinist or that Galton was a probabilist. It is not possible in either case to maintain such a direct identification. Conversely, it is viable to identify some authors with each line of thinking. Those who could be considered determinists are Herbart, Fechner (strongly influenced by Weber and Bernoulli, as well as by the astronomer Pliskoff), Hull (1943), etc. Moreover, the definitive use made of the probabilistic models, which would be definitively established in the second half of the twentieth century, began with research concerned with

learning, made according to the stimulus-response model. Other important authors were Atkinson, Bower and Crothers (1965), Estes (1964), Brush and Monsteller (1955), etc. Most of these authors began with determinist concepts, which envolved when they discovered the advantages of incorporating probability models in their studios. Propositions that were intermediate between both tendencies developed, like those of Luce (1959) expressed in his studies on the measurement of the level of preference. To sum up, psychology furthered new methods of study, which implied two basic consequences:

* The need to incorporate new techniques of analysis and therefore of development, and
* The appearance of new topics of research, very important to education.

Also, probabilistic models were incorporated starting from the studies on learning. A subject of special attention for investigation in education.

5.- Experimental pedagogy

The nineteenth century saw the origin and evolution experimental pedagogy. It was Herbart (1776-1841) who would be responsible for laying the foundation of this discipline with his work, which reveals the influence of Kant and Comte. This author explains psychic life using a "mechanics of representation" (Larroyo, 1984:585). which recurs to mathematics to express its laws. Herbart and his followers, who have an empiric conception of psychology, pedagogical upheld the need for demonstration in Pedagogy at their pedagogical seminar in Koenigsberg. Two main reasons explain the influence of Kant in psychology and pedagogy:

* On one hand, he favours subjectivism.
* On the other, he endorses nativism in the theories of space, when he makes subjective the concepts of space and time, which are understood in Kantian philosophy as "a priori" forms.

When Kant founded German idealism, he was re-establishing Cartesian dualism, threatened by British empiricism. All this lay the ground so that investigators such as Herbart. Fechner, or Wundt could accept in a natural way the idea of the mind as something distinct from the action of the brain. With respect to the nativist conception of the concepts of space and time, Kant limits himself to affirming that the "speciality" is already given, without clarifying the process which generated it. This conception is shared by Müller, leading to the German school of thougth which would lead up to the Gestalt theory, along the scientific line marked out by Kant, Müller, Hering, Mach and Stumpf.

Herbart, educated as a philosopher, considered the father of scientific pedagogy, and regarded as an important psychologist, maintained contacts with Pestalozzi and studied Fichte, although he did not agree with all his teachings. He defended the fact that scientific pedagogy was both influenced by and dependent on Psychology, which he distinguished from

methaphysics. He studied in Göttingen where he obtained his doctorate (1802-1809), being appointed at this university as a "donzent". In spite of Kant's influence on Herbart he expressed disagreement with part of his doctrine. Neverthless, in 1809 he held the professorship of Kant in Koningberg. In 1816 he published "Lehrbuch zur Psychology". Subsequently, he wrote "Psychologie als Wissenschaft", between 1824 and 1825. His book "Metaphysik" appeared between 1828 and 1829. In 1833 he returned to Göttingen to the professorship of philosophy, which he occupied until his death in 1841. The work of this author was influence by three main sources:

* Firstly, its social and scientific reality. Herbart was a man of his times, and as such he was educated according to the perspective of the model which predominated throughout the nineteenth century, which was positivism. This is the framework of reference which must be analysed at a philosophical and scientific level in order to understand the tendency of experimental pedagogy to use mathematics, in imitation of other sciences, like physics.
* Secondly, the evolution of experimental psychology, which also recurs to mathematics and experimentation. Not only is psychology converted into a kind of science which serves as a model in empiric development for pedagogy, but also a relation of reciprocity was established between both disciplines, in content and in application.
* Lastly, psychophysics. This science is the entry point of mathematical procedures into psychology and pedagogy. With physics as a starting-point, psychophysics establishes a connection between the world of mathematics and the subjective reality of the individual. This bridge was the factor that was needed for a transfer of knowledge between the natural science and the new discipline of education. In this way the need is satisfied to offer science which is coherent with positivism and its need of objectivity.

Herbart believes that psychology is a science based on experience, metaphysics and mathematics. However, although it is necessary to apply mathematical method, because it is the instrument of experimental sciences, he refuses to accept that psychology could be experimental. Whereas sciences such as physics recur to mathematics and experimentation, psychology and experimental pedagogy should make use only of mathematics. The reason for this negation can be found in his concept of the mind. The mind is integral and cannot be divided. However, it is understood that the experimental method is analytic because it attempts to divide the object of study in order to analyse it. In this way, no science that studies the mind can be analytic. This argument leads him to go counter to the belief of the time, which considered science as necessarily analytic. Herbart gets over this contradiction maintaining that the analytic feature is possible but not necessary, in order to consider a discipline a science. Consequently, in the opinion of Herbart, psychology and pedagogy are sciences, because they are based on experience and mathematics, even though they do not recur to the experimental method.

This important author can be regarded as the most obvious exponent of the transition between the speculations of Kant, Fichte, and Hegel and the antimetaphysical experimentation of Fechner, Wundt and Helmholtz. Although this investigator laid the

foundations of the new Experimental Pedagogy, the first general system of experimental pedagogy was produced by the German Ernst Meumann (1862-1915). A student of Wundt's, he was the editor of "Archiv für die Gesamte Psychologie". In 1903 he published his work "Veber Oekonomie und Technik des Lernens ", which became a classic of the psychology of education. There is a clear and strong influence of Wundt, with whom he carried out numerous investigations, centred above all on the study of the sense of time. Studies which were continued from 1881 to 1896. In 1905 he founded "Zeitschrift für Experimentelle Pädagogik", which was later called "Zeitschrift für Pädagogische Psychologie und Jugendkunde". Two years later "Vorlesungen zur Einführung in Die Experimentelle Pädagogik und Ihre Psychologischen Grundlagen" appearede, published in two volumes, where certain aspects are described which are indispensable in order to understand his pedagogical conception. According to Meumann experimental pedagogy should undertake three functions (Larroyo, 1984):

* Investigate the development of children.
* Investigate aptitudinal differences between subjects.
* Make an analytical investigation of school work.

Meumann lived in various cities such as Leipzig, Zurich, Königsberg, Münster, Halle, and Hamburgo. In the last year of his life he published various articles on aesthetics. Meummann died prematurely from influenza at the age of 52.

Another noteworthy investigator is W.A. Lay, who carried out important research on the teaching of language, which was described in 1896 in his work "Guide for the Teaching of Orthography", supplemented two years later with the "Guide for the Teaching of calculation in Lower Grades ". In 1902 he wrote "Experimental Didactics", where he presents the general bases of a new pedagogy. In the opinion of this professor, experimental pedagogy recurs to all the natural and anthropological sciences, with its origin in "modern" thought and research, mainly in biology (Larroyo, 1984). This "new pedagogy" differs form the "old pedagogy" in the manner in which it states and solves problems in education. Whereas pedagogy was traditionally based on observation and a subsequent analysis, the new pedagogy entails testing observations with statistics and experimentation.

Experimental pedagogy branches out into three main fields:

* Individual pedagogy, like the study of the physical and psychic aptitudes of the learner, together with the ways to improve these.
* Natural pedagogy, which is centred on the study of the relations between the environment and the learner.
* Social pedagogy, which seeks to analyse the influence of social, economic and cultural elements on the learner.

According to Lay, the founder of the journal "Zeitschrift für Experimentelle Paedagogik", "the experimental pedagogy is all pedagogy" (Larroyo, 1984: 589).

Summing up, it is Herbart who estab1ishes the bases for the development of pedagogy. This author argues for the important role of mathematics and psychology in educational research. However, he rejects the experimental method because it requires the division of the basic object of study of psychology: the mind. Research in pedagogy was greatly influenced by this author during practically all the nineteenth century. Mention must also be made of the contribution of later investigators, who were very influenced in their turn by Wundt.

6.- Measurement and the development of experimental pedagogy

In the new physiological psychology, J. Müller (1801-1859) formu1ated the law of specific energy, by which the causa1ity and intensity of the senses depend on the energy of the nerve passages. Helmholtz (1821-1894) carried out research on auditive and visual perception, influenced to a large extent by English associationism. Gustav Theodor Fechner (1801-1889), carrying on from the investigations of the Weber (1795-1878), founded psychophysics (Larroyo, 1984). In the considerations that follow, a more detailed description will be made of the importance of Fechner, on the incorporation of the techniques of statistical analysis into research in education and psychology.

An important development at the end of the nineteenth century and the beginning of the twentieth is the measurement of abi1ities. Fechner developed his work from his experience in physics research and from the idea of psychology of Herbart, from whom the concept of threshold derives, a concept inherited in its turn from Leibniz. Fechner, considered an experimentalist, did not entirely agree with the contribution of Herbart, whom he considered too meta physical, rejecting as he did the principles of experimentation.

In his work Fechner applied experimental measurement to the "mind", in an endeavour to correct the limitations of Herbart's psychology, at the same time as he attacked materialism from a philosophical viewpoint. With a solid training in mathematics, obtained after his doctorate, he acknowledged being indebted to J. Bernoulli, whom he considered the "principal mathematician". Interested in probability, he also makes special reference to Laplace and to Poisson, notwithstanding references to Gauss are scarce (Boring, 1978). One of the main objectives of his work consisted in demonstrating Weber's law, mathematically and experimentally. The main contribution of Fechner consists of having developed a new way of dealing with measurement (Fechner's law). During the nineteenth century three fundamental methods of measurement predominate:

* The method of barely perceivable differences, later called the method of limits.
* The method of correct cases and erroneous cases, later known as the method of constant stimuli.
* The method of the average error, renamed as the method of adjustment or method of reproduction.

In 1835 Quételet (1796-1874) used the law of error (an application of normal distribution) to describe human characteristics. Galton, when acquainted with these initiatives, had the idea of using mathematics with the object of ascertaining the probability of inheriting genius. He carried out this research from 1869 onwards. In the decade of the 1880's, Galton elaborated an inventory of British faculties in his testing laboratory, in the South Kensington Museum. In 1883 he published "Inquiries into Human Faculty". Cattell, as a functionalist, created a series of tests in the University of Pennsylvania, supported always by Galton and in spite of possible criticism by Wundt, with whom he maintained a habitual acquaintance. These tests were described in 1890 in his article "Mental Tests and Measurement" (Cit. Boring, 1978), where the term "mental test" appeared for the first time. From then on, tests underwent a great development. The propositions of Galton, Quételet and Fechner constitute in essence the first methods of mental measurement. At the same time, they can be considered the pioneers of Quantitative Experimental Pedagogy.

In 1889 O'ehrn, a student of Kraepelin in Heidelberg, invented a series of tests with which he proposed to measure four abilities: memory, perception, association and motor function. Boas presented a program for the anthropological measurement of school children in 1891. Gilbert presented a report in Yale on the application of tests on 1200 children of school age, administered between 1893 and 1896. In 1897, Ebbinghaus created in Breslam the test of accomplishment, for its use by the school authorities, etc. All this advancement of tests favoured the appearance of two committes, one formed by the American Psychological Association in 1895, and another by the American Association for the Advancement of Science, in 1896. The first committee sought to increase the colaboration between laboratories as regards tests, while the second sought to endorse with objective tests the results of various surveys whish upheld the supremacy of the white race in the United States. In this same country, Thorndike replaced Cattell in the investigations on fatigue and efficiency in the first years of the 1900's, while Woodworth studied the process of the transference of learning. Another important example of the use of tests is afforded by the work of Helen B. Thompson (who changed her name when she married for that of Helen Thompson Woolley) in her studies on the differences of gender using these instruments. Tests and all that they imply, must be understood as the result of a process of the scientific and technological investigation of the time, and their "invention" cannot be attributed to any one person in particular. Nevertheless, one name stood out at the beginning of the twentieth century. This was that of Alfred (1857-1911). The fact that psychology and experimental pedagogy have historically maintained a very close relationship, is shown as well in the existence of investigators who carried out their activities in both disciplines. This is the case of Alfred Binet, who was a French medical doctor, a pedagogue and a psychologist. He was an experimentalist who followed the French custom, which emphasized individual differences over the study of techniques used to analyse the average faculties. Together with Henry Beaunis (1830-1921) he founded the first laboratory of psychology at the Sorbone in 1889, as well as the first French journal of psychology "L'année Psychologique" in 1886. Subsequently, in 1903, he presented his well-known "L'etud Experimentale de L'inteligence". However, it would be in 1905 when he published, together with Simón, the first scale of intelligence. Binet presented in his book of 1911 "Modern Ideas on Children" a summary of work in psychology with pedagogic application becoming incorporated in this way in the new educative tendencies of the time. Binet helped to advance experimental pedagogy with these three elements:

* He developed methods of measurement of intelligence in children.
* He developed adequate methods for grouping learners according to different types of learning.
* He developed the exploration of aptitudes generating adequate methods that allowed a determination of individual differences in students.

Nevertheless, the theoretical bases of his work, especially that of 1903 and 1905, could also be found, by this time, in the work of authors like William Stern, who in 1900 published "Veber Psychologie der Individuellen Differenzen", adding important ideas for the later concept of "intellectual quotient". In spite of this fact, Alfred Binet and Victor Henri (1892-1940) are considered the first investigators who used tests, establishing a unit of measurement for the quantitative study of intelligence (Cronbach, 1990). Starting with these investigations, there was a great increase in the use of tests, which were understood as reactive experiments which stimulate in the subject behaviour that can be appreciated quantitatively, also grounded on statistical principles. Starting from these studies of aptitudes, important lines of application were developed, destined towards orientation, professional selection and diagnosis in education.

Binet and Henri published seven articles together between 1894 and 1898, establishing the bases of the future "decade of intelligence tests ". During the first half of the twentieth century, studies on intelligence lead to the theory of general ability or factor *G* of Spearman, accepted at the same time that English authors, such as Garnett and Thomson, were starting to discuss the existence of groups of factors. To summarize, it could be said that the use of tests, at that time, implied:

* Evidence of the consolidation of statistics in pedagogy, psychology and sociology.
* The development of a specific line of study.
* The development of processes of construction that required, in their turn, new techniques of control and production.
* The appearance of new techniques of analysis and measurement that were to be applied in this field.

7. Conclusion

Following what has been said, and analysing in some detail the set of events which occurred during the nineteenth century and the first third of the twentieth, it is possible to draw certain conclusions, among which the following are offered as the most important:

* The scientific context which prevails from the end of the eighteen century, predominating in the nineteenth century, favours the presence of mathematics in

most fields of knowledge.

* The first applications of statistics were limited to simple descriptive analyses. The qualitative leap, as regards the type of analysis used, was produced when studies began to be made of aptitudes and abilities of subjects (like intelligence). These new topics required the application of more complex techniques. At the same time, these techniques found in the ambit of social science an important field for their application and perfection.
* The easy flow of the exchange of knowledge between disciplines was due, amongst other factors, to the fact that the scientific context of the nineteenth century favoured the existence of investigators who studied various sciences: Wundt as a psychologist and pedagogue, Herbart as a psychologist, philosopher and pedagogue, Quételet, Pearson, etc.
* The coming of the decade of the 1920's supposed the definitive consolidation of statistics in research within the Science of Education, as they are known today. The same can be said of the other disciplines like Psychology or Sociology. Subsequently, authors like Fisher or Spearman (who established the bases of psychometry) continued to develop lines of research that allowed the application and generation of new techniques of analysis, but always from an already consolidated context characterized by the presence of Statistics in the Sciences of Education.

From the decade of the 1930's, statistics is completely consolidated in the investigation in social sciences. From these years on, progress is characterized above all by the application of techniques of analysis to the different problems of investigation that appear. At the same time, the evolution of new techniques would allow the establishment of new methods of investigation and analysis of classical problems, which in their turn would lead to the identification of new problematic areas. A more details survey will be made in a later report of the events which took place from 1930 on.

8. Referencias

Angulo, J. (1992). *Historia de la estadística*. Inédito.

Atkinson, R.C., Bower, G.H., y Crothers, E.J. (1965). *An introduction to mathematical learning theory*. New York: Wiley.

Balibar, Françoise (1999). *Einstein, el gozo de pensar*. Barcelona: Ediciones B

Boring (1978). *Historia de la pedagogía experimental*. México: MacGraw Hill.

Brush, R.R., y Monsteller, F. (1955). *Stochastic models for learning*. New York: Wiley.

Cronbach, L.J. (1990). *Essentials of psychological testing*. New York: Harper Collins.

Danzinger, K. (1987). *Constructing the subject. Historical origins of Psychological Research*. New York: Cambridge University Press.

Estes, W.K. (1964). Probability learning. En A.W. Melton (Ed.) *Categories of human learning.* New York: Academic Press, 182-189.

Gigerenzer, G., y Murray, D.J. (1987). *Cognition as intuitive statistics*. London: Erlbaum.

Hull, C.L. (1943). *Principles of behaviour*. New York: Appleton Century Crofts.

Larroyo, F. (1984). *Historia general de la pedagogía*. México: Porrua. 20º Edición, primera edición: 1944.

Luce, R.D. (1959). *Individual choice behavior*. New York: Wiley.