William Sealy Gosset - An Inspiring 'Student'

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William Sealy Gosset was born on June 13, 1876 in Canterbury, England, the first of five children of Colonel Frederic Gosset and Agnes Sealy Vidal. He had poor eyesight and could not follow his father into the Royal Engineers but he was a very good student and won several scholarships. W.S. Gosset was a Scholar of Winchester and later New College Oxford, where he obtained First Classes in Mathematical Moderations (1897) and Chemistry (1899).

Gosset joined Guinness in Dublin in 1899 as a junior brewer, and immediately set out to learn the processes involved in brewing. In 1907 Gosset was appointed Brewer in charge of the Experimental Brewery at Guinness, and he later established the statistical department (and became Brewer i/c Statistics), which he directed until leaving Dublin in 1935. At that point he transferred to the new Park Royal Brewery in London, - the first Guinness Brewery to be built outside Dublin. At Park Royal, he became the first Head Brewer, but only for a couple of months until his untimely death (heart attack) on 16 October 1937.

William Sealy Gosset was a practical scientist, and published 22 scientific papers while working for Guinness. The research and methods developed were for the main part all written in response to problems in the brewery dealing with the production of stout, arising in response to variations in barley, hops, malt and other experimental conditions.

R.A. Fisher, the great statistician and mathematician, wrote (Fisher, 1939) in his tribute entitled 'Student' that "The untimely death of W.S. Gosset, at the age of 61, in October 1937, has taken one of the most original minds in contemporary science."

Early times in the Guinness Brewery

Prior to 1893, when the recruitment of science graduates began at Guinness, the brewery was somewhat 'innocent' of scientific methods in brewing. It was during this period that the policy of recruiting brewers with scientific degrees (although only from Oxford or Cambridge) was initiated, and it was decided that anyone wishing to make a mark as a brewer in the future must have training in 'the application of science (chemistry and bacteriology) to the fermentation industries' (Dennison and MacDonagh, 1998, Ch.6). When Gosset joined the Guinness Brewery in Dublin on 1 October 1899 as a junior brewer, he was the 5^{th} in this series of new 'scientific' brewers (the first in 1893 was T.B. Case, who later became a housemate of Gosset and eventually Managing Director of Guinness from $1927 - 1941$).

At the Guinness Brewery the position of a 'Brewer' has always been quite special, and up until the end of the late 19^{th} century brewers were essentially managers. However the recruitment of scientists as brewers brought them very much into research. Given that Gosset had read (studied) mathematics as well as chemistry at Oxford, it was perhaps only natural that he should, almost at once in the Guinness brewery, turn his attention to the use of mathematical methods in the working of the brewing process.

In the early part of the 20th century, Guinness established an Experimental Brewery (with Experimental Maltings) in order to test (usually small) samples of raw materials and certain variations in the processes being used to produce beer. As an experimental brewer, Gosset was asked "having obtained a given result in a series of trials, what reliance can be placed on this result being a true one, and not depend merely on random variations in the process or of observation? For instance, two malts are being tested. An important economic factor is the extract which can be obtained from a given malt. The two malts are found to give different extracts. What reliance is to be placed on this difference, having regard to the unavoidable variations of brewing and observation?" (Williams, 1962).

Problems of this type in the Experimental Brewery led Gosset to turn his attention to "the error of the mean of a small sample." According to Lance McMullen (a younger colleague of Gosset who was Head Brewer at St. James's Gate from $1956-1960$) writing in Biometrika in 1939, "he could calculate a probable error in 1903. This was of critical importance, for without adequate methods of sampling it would have been impossible to have derived valid results from many of the experiments in the brewery or even to have introduced adequate methods of control ... At this time mathematicians were not able to answer the problem of determining the error of the mean of a small sample."

Gosset wrote an internal report for Guinness in 1904 entitled on "The Application of the 'Law of Error' to Work of the Brewery". The report emphasized the importance of the use of probability theory in order to set exact values on the results of experiments in the brewery. The Guinness Board endorsed this report on 9th March, 1905 with the recommendation (by the MD, C.D. La Touche) that "Mr. Case will make arrangements for Mr. Gosset to have an interview with Prof. Karl Pearson."

Gosset was already using correlation methods extensively in the brewery in 1905 when he wrote another internal report entitled "The Pearson Co-Efficient of Correlation." The Guinness Board endorsement of this report on 20th September, 1906, said "It is to be noted that for the present the Karl Pearson method of correlation is to be adopted in all reports which admit of it being done, and this endorsement is to be regarded as a formal instruction in the matter." Another 1906 report by Gosset entitled "Our present knowledge of connection between life and Ready Formed Sugars" is commented on in a Board Endorsement on July 19th in which La Touche writes "This report calls for no formal endorsement, but is specially interesting as illustrating the great utility of the new statistical method introduced in the Brewery by Mr. Gosset." In the report Gosset shows that "of Malts made from the same barley those with more R.F.S. (Ready Formed Sugars) would also produce the less stable beer." (Guinness Archive, file GDB/BR01/1100.)

The Probable Error of a Mean

Karl Pearson $(1857-1936)$ headed at University College London an industrious biometric laboratory that was much concerned with large sample statistical analysis. Gosset first met Pearson in 1905, and in 1906 received a year's leave from Guinness for specialized study in his laboratory. There he studied Pearson's probability distributions and correlation coefficients, and obtained statistical foundations for much of his later work at Guinness. He was aware, however, that modifications of the large sample methods of Pearson, which were being extensively used by biometricians at the time, would be necessary in order to deal with the special small sample problems arising in the brewery.

It was during this period that he laid the basis for his most famous work, "The Probable Error of a Mean", published in 1908 in Biometrika. Through a mixture of mathematical ability, intuition and experiment (he wrote down on cards figures relating the middle finger length and height of 3,000 criminals, drew 750 separate samples of fours cards, and from each of these samples calculated the average of the four figures on the cards) he developed (with help beginning in 1912 from the then Cambridge undergraduate student R. A. Fisher) what is now known as 'Student's t-test". Gosset also published his second seminal and truly classic paper in Biometrika in 1908 entitled "The Probable Error of a

Correlation Coefficient." In his tribute to Student in 1939, Fisher wrote: "How did it come about that a man of Student's interests and training should have made an advance of fundamental mathematical importance, the possibility of which had been overlooked by the very brilliant mathematicians who have studied the Theory of Errors ... One immense advantage which Student possessed was his concern with, and responsibility for, the practical importance of experimental data. If more mathematicians shared this advantage there can be no doubt that mathematical research would be more fruitfully directed than it often is."

Gosset the Brewer i/c Statistics

The first decade of the 20^{th} century $(1900 - 1910)$ saw big transformations in Guinness. Large areas of the brewing business became more scientifically instead of empirically based, and in several matters Guinness became ahead of, instead of behind, the other breweries. One outstanding example of this was the work on barley, yeasts and fermentation. Research results of this period were probably more important in their impact on the selection of raw materials than on the control of the brewing process (e.g. from 1901 the purchase of barley was more based on chemical analysis content (assisted by Gosset's statistical techniques) than by visual inspection). Another example would be the improvements in the techniques of malting (e.g. more exact control of the temperature of water in which barley was steeped). For very small expenditure the company undoubtedly made large gains. Much of this would have been impossible without the brewer and statistician W.S. Gosset, for without adequate methods of sampling (in particular without the t-test and correlation theory) it would have been impossible to have derived valid results from many of the experiments in the brewery or established adequate systems of control.

In spite of Gosset's impressive research publications in statistical journals over the years, he was always a full time Guinness Brewer. As his colleague and fellow brewer Dr. Edward Somerfield wrote in a letter to Jerzy Neyman on 14^{th} February 1938 (Guinness Archive, file GDB/BR01/0666), "It should perhaps be pointed out that most of Mr. Gosset's time was taken up by business matters and that the proportion he was able to devote to statistical questions was relatively small." As the Brewer i/c Statistics for many years, however, he was involved with a huge number of experiments and projects across the brewery. During the period $1902 - 1937$ he wrote over 350 reports in the brewery, and in the Table below I have selected the title of one such report in each year (as well as the number of such reports) to give an indication of the diversity of his 'brewery' work. L.E. Hudson (Brewer i/c Research) wrote in 1959 that "he and his colleagues ... were also an important part of the managerial hierarchy of the brewery in which they worked ... their statistical mode of thinking came to permeate the whole of that part of the organization." (Guinness Archive, file GDB/BR01/0952.)

In 1930 he wrote a report on the Employment of Labouring Staff where he compared the then current age distribution of brewery labourers with that in 1914, and made interesting projections and recommendations for future hiring of labourers. In another report he performed actuarial work for the brewery (Dennison and MacDonagh, 1998, pp$132 - 133$) in order to revise pension and life insurance schemes where he investigated mortality rates amongst workers in the brewery covering the period $1878 - 1902$. This report showed that the mortality rates of the brewery workers were lower than those among Dublin trade unions (the skilled workers), considerably higher than those in England and above the actuary's rate for healthy males. (It seems that tuberculosis was one of the major causes of high mortality rates in both Dublin and the Guinness brewery at the time).

Table: Examples of Reports written by Gosset at Guinness 1902 – 1937**.**

Year	# Reports	An Example of a Report in that Year.
1902	1	Comparison of the attentuation and temperatures of different vessels.
1904	1	The application of the "law of error" to work of the brewery.
1905	4	The Pearson co-efficient of correlation.
1906	4	The value of barley analysis in predicting the extract in the Experimental Brewery.
1907	3	Cooled v. uncooled hop experiments, brewed in the autumn of 1906 in Exp. Bry.
1908	9	The present position of our knowledge of the connection between life and hops in the Experimental Brewery
1909	7	The connection between moisture in malt and life.
1910	11	Prediction of extract to be obtained from barley, from the analysis of barley.
1911	8	The effect of various added beers on the life of D.S. and S.S.
1913	4	Brewing of unfloored malt.
1914	11	Yeast from Vartry brewings.
1915	3	Introduction of finings into the beer as it is being pumped into the racking vat.
1916	7	Double Stout Finings (Instruction that these should be diluted to twice usual bulk.)
1917	3	Effect of Foreign malt on the life and brightness of the beer in the Exp. Bry.
1918	4	Extract under the new conditions.
1919	3	Caps.
1920	9	Australian karri wood and Brazilian oak.
1921	10	Arsenic in malt.
1922	23	How should the arsenic problem be dealt with?
1923	7	The question of the value of extract expressed from spent hops by squeezing.
1924	7	Fresh and Dried Grains.
1925	10	An experiment of hot steeping and short flooring systems.
1926	11	Main Brewery hop experiments.
1927	17	Goods Temperatures - Comparison of Electrical and Mercury Thermometers.
1928	18	The relationship between fresh flavour, excess order and trade.
1929	22	Effect of Temperature on the sales of Guinness's stout.
1930	15	Advertising and sales.
1931	23	Correlation between monthly figures.
1932	16	Importation of British malting coal.
1933	28	Proposed experiment on the flavour of wild and secondary yeasts.
1934	18	Correlation between sales and unemployment.
1935	12	Sterile Plant - Conditioning and brightness.
1936	4	Acidity in casks.
1937	16	Tasting pairs and triplets.
1938	1	Caskiness.
Total	355	

In 1929 the decision was made to start advertising Guinness, and today we are all aware of how successful and entertaining Guinness has been in marketing its product (particularly the pint of 'stout'). This decision was not taken without considerable debate however as the relationship between sales and advertising was, in fact, far from simple. Gosset produced an analysis which showed that in the first months of 1929 'there had been a fairly close correspondence between expenditure on advertising and variations in sales, but that more recently sales have continued to rise in spite of the decrease of money spent. He did not elaborate, and the assessments of the effects of advertising continued to be impressionistic. The various methods of market research in general use today were of course hardly known at this time. Although Gosset occasionally undertook statistical analyses until his death in 1937, there was no attempt to develop new techniques of investigation comparable to those which had been discovered and applied to the brewing process in the early years of the century." (Dennison and MacDonagh, 1998, p91).

Roy C. Geary and William S. Gosset.

Roy C. Geary ($1896 - 1983$) was an eminent Irish statistician and economist well known for his contributions to mathematical statistics. A number of statistical terms are named after him including 'Geary's Ratio', the 'Stone-Geary Utility Function', and 'Geary's Theorem'. In 1949, he became the Director of the Irish Central Statistics Office (CSO) and in 1960 he founded the Economic and Social Research Institute (ESRI) in Ireland. The Geary Institute at University College Dublin is named in his honour. He held the post of Head of the National Accounts Branch of the United Nations in New York from 1957 to 1960.

Roy Geary graduated from University College Dublin in 1916 and then studied at the Sorbonne before taking up a post in the Statistics Branch of the Department of Industry and Commerce in Dublin. It is in that capacity that he got to know Gosset (the Brewer i/c Statistics) at Guinness in the 1930s. In particular they often corresponded (on business) about sales of stout and porter in Ireland. The following exchange is typical of their correspondence.

Geary wrote (22 March 1934) "Dear Gosset, I am exceedingly obliged for your graphs. The different trends in the Irish Free State sales of porter and of double stout during the last two years are extremely interesting: porter up, stout down. Does it mean that the porter-drinking class are prospering while the stout-drinking class decline: or have the stout drinkers fallen to porter? If you have no direct knowledge of this, the areal figures may furnish a clue. . . .".

Gosset replied (10 May 1934) "Dear Geary, Somerfield has handed me the enclosed table giving the figures for April, 1934, which will enable you to bring your diagrams up to date. I do not know that there is anything very remarkable. Town and Vicinity appear to be fairly prosperous and the rest of the country going to - Connacht! Yours sincerely, W.S. Gosset." (Guinness Archive, file GDB/BR01/0986.)

The Table of April, 1934 referred to above dealt with quarterly figures on extra stout and porter showing favourable results for Town and Vicinity (Dublin town and vicinity - vicinity being within 10 miles of the GPO - the Irish General Post Office where the Easter uprising of 1916 took place).

Roy Geary seconded (with discussion) the vote of thanks on the paper "The use of statistical methods in agricultural experiments" read to the Statistical and Social Inquiry Society of Ireland (SISSI) by F.P. Hussey on 20^{th} November, 1936 (Geary, 1936/1937). In doing so he said (wrote) "in most statistical societies it was traditional that there should be one paper in each session completely incomprehensible to the great majority of members; and it was right that our Society (SISSI), as one of the oldest in the world (1847), should be true to this tradition. . . . The method known as the "analysis of variance", which Mr. Hussey has utilized, is due principally to Professor R. A. Fisher, who in recent years developed certain results of Mr. W. S. Gosset, better known under the pseudonym of

'Student', who has lived and worked for the past thirty years in Dublin. Mr. Gosset amuses his friends when he says he that he is "no mathematician", for his discoveries of the frequency distribution of the variance of normal samples and of the ratio of the mean to the standard deviation (the square root of the variance) are generally regarded as the most important contribution to the theory of statistics in the last half century."

R. A. Fisher certainly agreed when he wrote in his 1939 tribute to 'Student':

"His life was one full of fruitful scientific ideas and his versatility extended beyond his interests in research. In spite of his many activities it is the student of Students's test of significance who has won, and deserved to win, a unique place in the history of scientific method."

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