STATISTICAL MODELING OF DATA FROM LIFELONG LEARNING SURVEYS AT THE OHIO STATE UNIVERSITY COLLEGE OF ENGINEERING.

Alfred B. O. Soboyejo and
Robert J. Gustafson
The Ohio State University,
Columbus, Ohio, 43210, USA.

ABSTRACT

In addition to the work already carried out by the Life Long Learning Study Task Group, in The Office of the Dean, College of Engineering at The Ohio State University, Columbus, Ohio; further statistical studies of the data received from the surveys conducted, had been carried out. New statistical models for the data had been produced. The models provide additional tools that are necessary for the enhancement of decision making processes.

Linear multiparameter models had been successfully developed for the three sets of data, from the 2^{nd} year, 6^{th} year and 15^{th} year alumni. The effects of the following variables had been considered in each of the three models developed:

(i) the eighteen desirable indicators in the surveys; and (ii) the fourteen categories of the engineering background of the alumni.

A fourth statistical model was also developed to characterize not only the combined effects of the variables mentioned in (i) and (ii) above; but also the quantification of the effects of the variables due to the years of experience of graduation of the engineering alumni. Partial statistical correlations were developed for any pair of variables, in each of the four statistical models developed in these studies. Validations of the theoretical statistical models developed were carried out using the data received from the surveys. These validations yielded excellent multiple statistical correlations, which indicate that the new models developed can provide accurate and reliable predictions of the data. Bayesian methodology in statistical decision theory was also developed in the studies conducted, in order to combine the results from any future survey, with the results from the present studies. This is an important feature of the present studies, since the result of the present and any future studies can be combined and used, in order to formulate future policy guidelines, for the enhancement of future programs of development in the College of Engineering at The Ohio State University.

1.0 STATISTICAL MODELS

The Linear Model

$$Y_j = a_0 + \sum_{i=1}^{k} a_i X_{ij}$$

$$i = 1,2,\ldots k$$

$$j = 1,2,,\ldots n; n > k$$

Proceedings of the 2002 American Society of Engineering Education Annual Conference & Exposition

Any output random variable Y can be expressed in terms of k related input random variables X_i for i=1,2,…k,, by the mathematical function,

$$Y = f(X_1, X_2, ... X_k) \tag{1.1}$$

where k is the number of input random variables X_is.
If a linear relationship exists between the variables Y and X_is in the above equation, then we have,

$$Y = a_0 + \sum_{i=1}^{k} a_i X_i \tag{1.2}$$

where a_0, and a_i for i=1,2,…,k are constants of the linear mathematical model of Y as a function of related input variables X_is. When cumulative distributions function CDF = α, for each random variable, where ($0<\alpha<1.0$), it can be shown that (Ross S. M., 1997, Soboyejo, 2001)

$$Y(\alpha) = a_0 + \sum_{i=1}^{k} a_i X_i(\alpha) \tag{1.3}$$

In equation (1.3), $Y(\alpha)$ and $X_i(\alpha)$ for i=1,2,…k, are the values taken by the output and the input random variables, at a given level of the CDF of each random variable.
It is important to note that at a given level of CDF=α, the generalized form of equation (1.3) is

$$Y(\alpha) = f[X_1(\alpha), X_2(\alpha), ... X_k(\alpha)] \tag{1.4}$$

Equation (1.3) is the linearized form of equation (1.4). Equation (1.3) should therefore be used to solve problems requiring the application of multivariate linear regression analysis.

For a data set of size n values of Y_j and the corresponding values of X_{ij}, at the same level of CDF=α_j, then we have the following n results.

$$Y_j = a_0 + \sum_{i=1}^{k} a_i X_{ij} \tag{1.5}$$

for j = 1,2,…n and n > k.

Equation (1.5) can be expressed in the matrix form as follows:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ . \\ . \\ Y_n \end{bmatrix} = \begin{bmatrix} 1 & X_{11} & X_{21} & ... & X_{k1} \\ 1 & X_{12} & X_{22} & ... & X_{k2} \\ . & & . & & . \\ . & & & . & . \\ 1 & X_{1n} & X_{2n} & ... & X_{kn} \end{bmatrix} \bullet \begin{bmatrix} a_0 \\ a_1 \\ . \\ . \\ a_n \end{bmatrix} \tag{1.6}$$

The solution for the model constants a_0, a_1, … a_k, are expressed in vectorial form as follows:

$$\begin{bmatrix} a_0 \\ a_1 \\ . \\ . \\ a_n \end{bmatrix} = \begin{bmatrix} 1 & X_{11} & X_{21} & ... & X_{k1} \\ 1 & X_{12} & X_{22} & ... & X_{k2} \\ . & & . & & . \\ . & & & . & . \\ 1 & X_{1n} & X_{2n} & ... & X_{kn} \end{bmatrix}^{-1} \bullet \begin{bmatrix} Y_1 \\ Y_2 \\ . \\ . \\ Y_n \end{bmatrix} \qquad (1.7)$$

For the linear model defined in this problem, we have k=14 and j=18.
These conditions should be applied to the linear model defined by the equation (1.5). The entire problem can be considered as that with a joint probability distributions with a marginal probability defined by a total probability of one as follows:

$$\sum_{j=1}^{18} p(Y_j) = 1.0 \qquad (1.8)$$

where $p(Y_j)$ is the probability mass function at j, for j=1,2,…18)

The joint probability mass function can also be defined by a total probability of one as follows:

$$\sum_{i=1}^{k=14} \sum_{j=1}^{n=18} p(X_i, Y_j) = 1.0 \qquad (1.9)$$

The statistical correlation between any pair of the output and the input random variables can also be established. For example between any pair of input random variables, the statistical correlation is:

$$\rho_{pq}(X_p, X_q) = \text{cov}(X_p, X_q) \Big/ \sqrt{VarX_p . VarY_q} \qquad (1.10)$$

where, $\text{cov}(X_p,X_q)$ is equal to the covariance function between the pair of the random variables X_p and X_q, where $p \neq q$. When the $\text{cov}(X_p,X_q)$ becomes $\text{cov}(X_p,X_q)=VarX_p = VarX_q$, therefore the statistical correlation becomes $\rho_{pq}(X_p, X_q) = 1.0$

Statistical correlation is the degree of linear correlation between the pair of the random variables X_p and X_q. Perfect correlation therefore means that there is a linear relationship between the pairs of random variables. This can only occur when the statistical correlation is 1.0. The value of +1.0 means that there is a positive linear correlation. When there is no relationship whatsoever between the pair of random variables, the statistical correlation between the pairs of random variables tends to the value of zero.

The linear mathematical model of the type

$$Y = a_0 + \sum_{i=1}^{k} a_i X_i \qquad (1.11)$$

is chosen to model this problem because of the additive effects of the related inputs X_i for i=1,2,…k, that are necessary in order to produce the desired output Y. In this model, a_0, a_i for i=1,2,…k are the (k+1) model constants. The k input variables X_is are due to the effects of the opinions of the 14 categories of engineering alumni, of a given year after graduation, on the final state Y of the results of the outcomes of the 18 desirable indicators that were specified in this problem. Since levels of responsibilities of engineers after graduation can affect responses received from engineering alumni, the survey data used in this work were collected from three different categories of engineering alumni; namely 2nd, 6th and 15th year alumni. Table 1 shows the survey distribution and returns. Multiparameter statistical linear regression models were successfully developed for each category of alumni, and for the combined effects of the three categories of engineering alumni.

Before the data were collected, detailed preliminary studies were carried out including the determination of the best statistical sampling methodology to be adopted for this work. Some aspects of the preliminary studies included studies of previous data collections of other organizations.

It can also be shown that (Ross S. M., 1997, Soboyejo A. B. O., 2001) the function Y is a stochastic model, with linear inputs of the variables X_is such that the transfer function is given by

$$F(X_i) = Y_i - Y_{i-1} = a_i X_i \text{ for i=1,2,...k} \qquad (1.12)$$

The above expression shows that the transfer function depends only on the contributions $a_i X_i$, of the effect of the incoming variable X_i during the transition from the state (i-1) to state i.

Furthermore, the transfer function $F(X_i)$ does not depend on the contributions of the effects of the variables X_1, X_2, … X_{i-1}, that had to come into the model before the effect of the contributions of the variables X_i at states i=1,2,…k, then the validity of the linear model $Y = a_0 + \sum_{i=1}^{k} a_i X_i$ can be established. The values of the (k+1) model constants a_0, a_i for i=1,2,…k can be determined from a given set of data by using linear regression in statistics.

2.0 STATISTICAL MODELS OF OUTPUT RANDOM VARIABLE X AS A FUNCTION OF k=18 INPUT RANDOM VARIABLES Y_1, Y_2 … $Y_{k=18}$.

The effects of the eighteen (18) desirable indicators given to each of the fourteen (14) categories of engineering alumni had also been considered and appropriate statistical models had been established, by making use of the relationship

$$X_j = b_0 + \sum_{i=1}^{k} b_i Y_{ij} \qquad (2.1)$$

where i=1,2,…k=18, j=1,2,…n=14, b_0, and b_i for i=1,2,…18 are the model constants. Strictly speaking, we do not have enough statistical data of the output variable X, in order to carry out the statistical analysis necessary for this work. We need to have n=k+2=18+2=20, in order to carry out the statistical analysis, since (n-k)≥2. The value of 2 is the number of unknowns in the probability distribution function (PDF) assumed to model the statistical variabilities in the random variables, Y and X. The assumed PDF here is the normal distribution. The two unknowns are the mean and the standard deviation of the normal distribution.

In order to solve this problem, all the n=14 data of X_j for j=1,2,…n=14 were used in this statistical analysis. The twelve highest values of the random variable Y_i were used, such that, (n=14 and k=12). The statistical analysis was therefore carried out using these data.

The model constants b_0 and b_i for i=1,,2,…k were established for each category of engineering alumni namely 2nd year alumni, 6th year alumni and 15th year alumni. The complete data of all the alumni were put together, in order to develop a new statistical model for the combined effects of all the alumni. The different values if the model constant b_0 obtained from the three models of the three categories of alumni were considered as an addition random variable Y_i in the new combined model. New values of the constants of the new combined model were then established using multivariate statistical regression analysis.

The results of statistical regression analyses are valid only within the limits of the actual data used for all the random variables in the regression model. These limits are therefore the relevant minimum and maximum recorded data, in each column and row, of Tables 2, 3, 4, 5 and 6 in this paper.

3.0 RESULTS OF STATISTICAL ANALYSES OF DATA

(1) Statistical Models had been developed for each of the 2nd year, 6th year and 15th year engineering alumni that took part in the survey. The models are:

$$Y_{j_1} = a_0 + \sum_{i=1}^{k_1} a_i X_{ji_1} \qquad (3.1)$$

j_1=1,2,…18
k_1=1,2,…14

$$X_{j_2} = b_0 + \sum_{i=1}^{k_2} b_i Y_{ji_2} \qquad (3.2)$$

j_2=1,2,…14
k_2=1,2,…12

(2) In order to consider the effects of different years of alumni after graduation, statistical models had been developed for the combined effects of the 2nd year, 6th year and 15th year engineering alumni. The models are:

$$Y_{j_3} = C_0 + \sum_{i=1}^{k_3} C_i X_{ji_3} \qquad (3.3)$$

j_3=1,2,…54
k_3=1,2,…15 = (k_1+1)

The 15th variable $X_{i=15}$ comes from a_0 in equation (3.1)

$$X_{j_4} = d_0 + \sum_{i=1}^{k_4} d_i Y_{ji_4} \qquad (3.4)$$

j_4=1,2,…42

$k_4=1,2,\ldots 13 = (k_2+1)$

The 13th variable $X_{i=13}$ comes from b_0 in equation (3.2)

(3) Statistical correlations had been developed for any pairs of variables, in each of the 8 models developed in (3.1) and (3.2). These results are extremely useful in providing guidelines concerning which of the desirable variables should be combined or used, in the decision making process. Results of Pearson Correlation analyses show that the higher the rankings of any pair of random variables Y in equations (3.1) and (3.3), or any pair of random variables X in equations (3.2) and (3.4), the higher the positive or negative value of the corresponding statistical correlation coefficient. The conclusion can be made that in general as the total number of the related input variables are used in the regression analyses for the models of equations (3.2 to 3.4), the corresponding values of multiple correlation coefficients become very close to unity. This shows that the theoretical models are good predictors of the data under these conditions.

(4) Bayesian approach can be developed in order to combine results of the present and any future surveys, in the decision making process. (Ang and Tang, 1975; Soboyejo, 2001)

The same Bayesian statistical approach can also be used to provide useful extensions to the statistical models developed in this paper. This can be carried out by the choices of appropriate additional new input variables if necessary, in future surveys. This will enable a wider range of studies to be carried out, in order to establish new criteria for the enhancement of decision-making processes. Some of these criteria could be possible changes in positions at work, type of work or opportunities, and any other factors. The new statistical multiparameter modeling methodology developed in this study can also be used in several other Universities, where employment patterns may vary, depending upon the interests of such Universities to produce engineering students for certain specific industries. For such universities the surveys should be targeted to produce useful statistical data from the appropriate engineering alumni, that are actually working in the fields of engineering that are in the same focused areas of specializations as the Universities.

(5) Validations of all theoretical models developed had been carried out, using the data received from the present surveys. Excellent statistical correlations had been recorded, from these theoretical models and the actual data. (Gustafson et al, 2002; Soboyejo and Gustafson, 2002)

(6) The variables Y and X can be reasonably considered as normally distributed random variables.

All the variables in the linear statistical models used in this paper are assumed to obey the normal probability law of statistics. In order to demonstrate this quite simply, the normal probability plot of the random variable Y that represents the desirable 18 indicators summed across all the years of engineering alumni and across all the 14 engineering programs, is shown in Figure 1. The relevant data used to produce Figure 1 is given in Table 7. The normal probability plot shown in Figure 1 contains the plots of the lower and upper bounds of the 95% confidence interval. Figure 1 shows that the data fall quite well within the 95% confidence interval. Figure 2 is the plot of the response rate against indicators in rank order, and combined for all years of engineering alumni.

Tables 2, 3, 4, 5 and 6 show summaries of returns from surveys carried out in this work for the 2^{nd}, 6^{th} and the 15^{th} year engineering alumni. Further details about these surveys are available in the following technical paper (Gustafson R.J., McCaul E., and Soboyejo A. B. O., 2002)

It is important to point out that the sampling techniques adopted in this study were based on results of guidelines that were drawn up by the Lifelong Learning Study Task Group of Experts in Office of the Dean, College of Engineering, The Ohio State University. The guidelines gave eighteen ($N_y = 18$) desirable objectives for each of the fourteen ($N_x = 14$) categories of 2^{nd}, 6^{th} and 15^{th} year engineering alumni that were considered in all the statistical analyses in the present study. Appropriate statistical sampling techniques were developed and used in this study to ensure that responses from certain segments of the industry do not have a significant effect on the outcome of the statistical analyses that will play down the effects of other industries. For this particular work, each particular group of the 2^{nd}, 6^{th} and 15^{th} year engineering alumni had been given equal weighting or importance in the statistical modeling of the combined effects of the 2^{nd} 6^{th} and 15^{th} year engineering alumni. These are developed using multiparameter regression analyses from equations (3.1, 3.2, 3.3 and 3.4) in this work. It is also essential that the same desirable indicators should be applied to the same group of engineering alumni, with a known level of engineering experience in years after graduation.

4.0 COMPUTERIZATION OF THE STATISTICAL MULTIPARAMETER MODELING METHODOLOGY

The MINITAB Statistical Software Package can be used for this exercise. The essential steps are as follows:

Step 1: Using the linear models $Y_j = a_0 + \sum_{i=1}^{k} a_i X_{ij}$ for any data, put the relevant data for Y_j and X_{ij} into the MINITAB Statistical Software Package.

Step 2: Carry out regression analysis for each of the n^{th} year alumni.

Step 3: Print out the statistical results of the regression analysis.

Step 4: Determine the model constants a_0, a_1, $a_2 \ldots a_k$ from regression analysis.

Step 5: Determine r^2, the multiple correlation coefficients and the Pearson's Statistical Correlation Coefficients.

Step 6: Repeat step (5) described above in order to show the effects of additional input variables.

Step 7: Repeat step (5) described above in order to show the effects of ALL input variables.

Step 8: For the combined data, $\sum Y$ of the effects of different n^{th} year alumni, use the a_0 computed in the linear model for each of the n^{th} year alumni, as an additional variable X_i. Carry out regression analysis for the combined data, determine r^2 and the model constants.

Step 9: Carry out Bayesian Statistical Analysis for any new data, and combine results with previous results of statistical analysis.

Step 10: Repeat steps (1) through (9) for the linear model $X_{j_2} = b_0 + \sum_{i=1}^{k_2} b_i Y_{ji_2}$

Step 11: Take actions based on decisions from ranked data of probabilities $P(Y_j)$ for j=1,2,…n from the highest to the lowest. Higher considerations in the decision-making process should be given to indicators with higher probabilities.

CONCLUSIONS

The new statistical models can be used as essential tools for planning of quality improvement of programs. These will enable engineering students to prepare properly for life long learning and also enable them to make more meaningful contributions to the development of their societies in future.

A technical report of this paper and a second related technical paper (R. J. Gustafson, E. McCaul and A. B. O. Soboyejo, 2002), will be made available to those who may want the technical report, at the 2002 American Society of Engineering Education Annual Conference and Exposition in Canada.

By using the statistical sampling methodology and the multiparameter regression techniques developed in this work, the responses from this study are not affected by any other considerations outside those that had been strictly considered as the essential input random variables in this study.

The statistical principles of Bayesian decision theory can be applied to the present and future results of the statistical analyses, in order to enhance the quality of the decision making process.

The recommendation is hereby made that the methodology developed in this study should be applied to similar studies in other Engineering Colleges, not only in the US but also outside the US, for the planning of top quality improvements of educational programs in engineering.

ACKNOWLEDGMENTS:

The authors would like to thank the Office of the Dean, College of Engineering at The Ohio State University, for the opportunities given to serve the College of Engineering, and also for the permission to publish the results of this study, so that other educational institutions can gain from the beneficial results of this work. Finally, the authors thank Mr. Kaustubh D. Bhalerao, Graduate Research Assistant to Dr. A. B. O. Soboyejo, in the Department of Food, Agricultural and Biological Engineering, at The Ohio State University, for providing secretarial assistance in producing this paper.

REFERENCES:

1. Ang A.H.S and Tang W.H., 1975, "Probability Concepts in Engineering Planning and Design" John Wiley and Sons; New York, NY.
2. Gustafson R.J, McCaul E. and Soboyejo A.B.O., 2002, "Alumni Perspectives on Life Long Learning" Proceedings 2002, American Society of Engineering Education, Annual Conference and Exposition, Montreal, Canada, 2002.
3. Ross S.M., 1997, "Probability Model", Academic Press, San Diego, California, pps 669.
4. Soboyejo A.B.O., 2001, "Probabilistic Methods in Engineering Analysis, Planning and Design" Volume I – Fundamental Principles of Probability, Statistics and Decision Theory., Volume II – Applications in Engineering and Applied Sciences. Department of Food, Agricultural and Biological Engineering, The Ohio State University, Columbus, Ohio, USA, 43210, Under Reviews, for publication as new Books.

Robert J. Gustafson is a Professor of Food, Agricultural and Biological Engineering and Associate Dean for Academic Affairs and Student Services for the College of Engineering of The Ohio State University. Dr. Gustafson is a registered professional engineer and is actively engaged in development of first-year engineering programs and teaching improvement. He received B.S. and M S. degrees in Agricultural Engineering from the University of Illinois and a Ph.D. in Agricultural Engineering from Michigan State University.

Alfred B. O. Soboyejo is an Associate Professor of Food, Agricultural and Biological Engineering and Aerospace Engineering of The Ohio State University. His research and teaching includes probabilistic methods, materials, structures, theoretical and experimental aerospace structural engineering and applied mechanics and biomechanics. He received his BS degree in Civil Engineering from University of London, UK; MS and PhD in Structural Engineering and Mechanics from Stanford University. He is a registered professional engineer. Dr. Soboyejo is also a member of the NSPE and a fellow in ASCE, ASME and the Nigerian Society of Professional Engineers.

Table 1. Survey Distribution and Returns

Alumni Year	No. Mailed	Survey Returned	Percent
2nd (1998)	522	86	16.5
6th (1994)	508	118	23.2
15th (1985)	690	76	11.0
Total	1720	280	16.3

Table 2. 15th Year Alumni

	Statement	Aero (6)	Cer (1)	CE (12)	Chem (6)	CSE (4)	EE (11)	EnPh (1)	FABE (1)	ISE (11)	Mat (0)	ME (13)	Met (4)	Sur (1)	WE (5)	Total (76)	Percent of Respondents (Count/Total)
1	Attending a professional conference	4		9	3	1	4		1	5		6	2		4	39	51.32%
2	Reading trade or professional journals	4	1	7	5	1	8	1		9		9	2	1	5	53	69.74%
3	Membership in a professional organization	1		4	1	2	4		1	6		1	1		2	23	30.26%
4	Taking college courses for credit			5	3	3	4	1		2		4	4			26	34.21%
5	Conducting corporate training sessions				2	1	2			1		2	1			9	11.84%
6	Earning an advanced degree	1	1	5	2	2	3	1		5		10	3			33	43.42%
7	Increasing job responsibility	3	1	1	2	2	6			6		3	1	1		26	34.21%
8	Advising/mentoring middle school, high school, or college students				1		2							1		4	5.26%
9	Holding an office in a professional organization	1								1		1			1	4	5.26%
10	Web-based professional training	2			1	2	1			3		2			2	13	17.11%
11	Attending corporate training sessions	2	1	3	1	2	4			5		3	1		3	25	32.89%
12	Writing for professional journals	3		7	3	1	1	1	1	2		8	2			29	38.16%
13	Moving into supervisory positions	1	1		1	1				1			1	1	1	8	10.53%
14	Research or working on design projects with a college or university	2		5	1	1	3			1		7				20	26.32%
15	Attending technical/training seminars or short courses	2		8	5	3	7	1		6		6	3		5	46	60.53%
16	Professional registration	1		2			2		1	5		2	1	1	1	16	21.05%
17	Reading technical books	1		5	2	1	6		1	3		5	1	1	3	29	38.16%
18	Presenting a paper at a professional meeting	3	1	6	2	1	2	1	1	3		7	1		3	31	40.79%
	Others				*												
	Total	31	6	67	35	24	59	6	6	64	0	76	24	6	30	434	

* Vendor Certification

Table 3. 6th Year Alumni

	Statement	Aero (8)	Cer (0)	CE (22)	Chem (12)	CSE (12)	EE (12)	EnPh (1)	FABE (6)	ISE (12)	Mat (2)	ME (24)	Met (1)	Sur (0)	WE (6)	Total (118)	Percent of Respondents (Count/Total)
1	Attending a professional conference	6		18	8	6	9	1	3	8	2	14	1		6	82	69.49%
2	Reading trade or professional journals	5		15	7	8	10		3	9	2	16	1		6	82	69.49%
3	Membership in a professional organization	1		6	3				2	7		6			1	26	22.03%
4	Taking college courses for credit	3		6	2	6	5		2	3		9			1	37	31.36%
5	Conducting corporate training sessions			1	2	3	3	1	1	3		8			1	23	19.49%
6	Earning an advanced degree	7		10	3	2	6		3	6		10			3	50	42.37%
7	Increasing job responsibility	2		7	6	6	2		3	2		5			2	35	29.66%
8	Advising/mentoring middle school, high school, or college students			1	1	1				2		4			1	10	8.47%
9	Holding an office in a professional organization			2	2	1				1		2	1			9	7.63%
10	Web-based professional training	2		4	4	5	2	1	1	2	1	4			1	27	22.88%
11	Attending corporate training sessions	2		8	6	7	4	1	4	5	1	6				44	37.29%
12	Writing for professional journals			8	1	2	3			2	1	9				26	22.03%
13	Moving into supervisory positions	1		3	2	1			1	2		2				12	10.17%
14	Research or working on design projects with a college or university	5		6	4	2	4		1	2		12	1		4	41	34.75%
15	Attending technical/training seminars or short courses	7		18	7	7	9	1	5	8	2	13	1		4	82	69.49%
16	Professional registration	2		4	2		2		4	2		2				18	15.25%
17	Reading technical books	4		5	5	8	8		1	3	2	7			5	48	40.68%
18	Presenting a paper at a professional meeting	1		5	1	2	2			3	1	8	1		1	25	21.19%
	Others			*					**								
	Total	48	0	127	66	67	69	5	34	70	12	137	6	0	36	677	

*Recertification of P.E.; Private Research and Studies; Exposure & involvem ent in complex projects

**Attending trade shows

Table 4. 2nd Year Alumni

	Statement	Aero (1)	Cer (1)	CE (14)	Chem (8)	CSE (10)	EE (18)	EnPh (1)	FABE (2)	ISE (10)	Mat (2)	ME (13)	Met (1)	Sur (0)	WE (5)	Total (86)	Percent of Respondents (Count/Total)
1	Attending a professional conference	1	1	8	5	7	13	1	1	5	1	7	1		5	56	65.12%
2	Reading trade or professional journals	1	1	6	6	4	15	1	2	10	1	9			3	59	68.60%
3	Membership in a professional organization		1	4	2	1	5		1	5		1	1		1	22	25.58%
4	Taking college courses for credit			5	1	3	4			2	1	6				22	25.58%
5	Conducting corporate training sessions			3		2	3					1			2	11	12.79%
6	Earning an advanced degree	1		6	5	4	7	1	1	1	2	7			1	36	41.86%
7	Increasing job responsibility		1	4	4	6	4		1	6		2	1		4	33	38.37%
8	Advising/mentoring middle school, high school, or college students						1			1		2			1	5	5.81%
9	Holding an office in a professional organization			2	1		1		1		1	1			2	9	10.47%
10	Web-based professional training			4	1	2	4				1	8			2	22	25.58%
11	Attending corporate training sessions	1	1	4	3	4	6		1	5	1	5	1		2	34	39.53%
12	Writing for professional journals			5	3	3	4	1		1		2				19	22.09%
13	Moving into supervisory positions			1			2		1	5			1		1	11	12.79%
14	Research or working on design projects with a college or university	1		5	2	2	7	1	1	3	2	6			2	32	37.21%
15	Attending technical/training seminars or short courses	1	1	8	3	6	14		2	8	2	9	1		3	58	67.44%
16	Professional registration			7			2			2		2				13	15.12%
17	Reading technical books			6	3	5	8			3		6				31	36.05%
18	Presenting a paper at a professional meeting			1	5	2	4	1		2		2			1	18	20.93%
	Others			*						**		***					
	Total	6	6	79	44	51	104	6	12	59	12	76	6	0	30	491	

*Professional experience, **Staying in touch with past professors, ***Attending trade shows

Table 5. Summation

	Statement	Aero (15)	Cer (2)	CE (48)	Chem (26)	CSE (26)	EE (41)	EnPh (3)	FABE (9)	ISE (33)	Mat (4)	ME (50)	Met (6)	Sur (1)	WE (16)	Total (280)	Percent of Respondents (Count/Total)
1	Attending a professional conference	11	1	35	16	14	26	2	5	18	3	27	4	0	15	177	63.21%
2	Reading trade or professional journals	10	2	28	18	13	33	2	5	28	3	34	3	1	14	194	69.29%
3	Membership in a professional organization	2	1	14	6	3	9	0	4	18	0	8	2	0	4	71	25.36%
4	Taking college courses for credit	3	0	16	6	12	13	1	2	7	1	19	4	0	1	85	30.36%
5	Conducting corporate training sessions	0	0	4	4	6	8	1	1	4	0	11	1	0	3	43	15.36%
6	Earning an advanced degree	9	1	21	10	8	16	2	4	12	2	27	3	0	4	119	42.50%
7	Increasing job responsibility	5	2	12	12	14	12	0	4	14	0	10	2	1	6	94	33.57%
8	Advising/mentoring middle school, high school, or college students	0	0	1	2	1	3	0	0	3	0	6	0	1	2	19	6.79%
9	Holding an office in a professional organization	1	0	4	3	1	1	0	1	2	1	4	1	0	3	22	7.86%
10	Web-based professional training	4	0	8	6	9	7	1	1	5	2	14	0	0	5	62	22.14%
11	Attending corporate training sessions	5	2	15	10	13	14	1	5	15	2	14	2	0	5	103	36.79%
12	Writing for professional journals	3	0	20	7	6	8	2	1	5	1	19	2	0	0	74	26.43%
13	Moving into supervisory positions	2	1	4	3	2	2	0	2	8	0	2	2	1	2	31	11.07%
14	Research or working on design projects with a college or university	8	0	16	7	5	14	1	2	6	2	25	1	0	6	93	33.21%
15	Attending technical/training seminars or short courses	10	1	34	15	16	30	2	7	22	4	28	5	0	12	186	66.43%
16	Professional registration	3	0	13	2	0	6	0	5	9	0	6	1	1	1	47	16.79%
17	Reading technical books	5	0	16	10	14	22	0	2	9	2	18	1	1	8	108	38.57%
18	Presenting a paper at a professional meeting	4	1	12	8	5	8	2	1	8	1	17	2	0	5	74	26.43%
	Others																
	Total	85	12	273	145	142	232	17	52	193	24	289	36	6	96	1602	

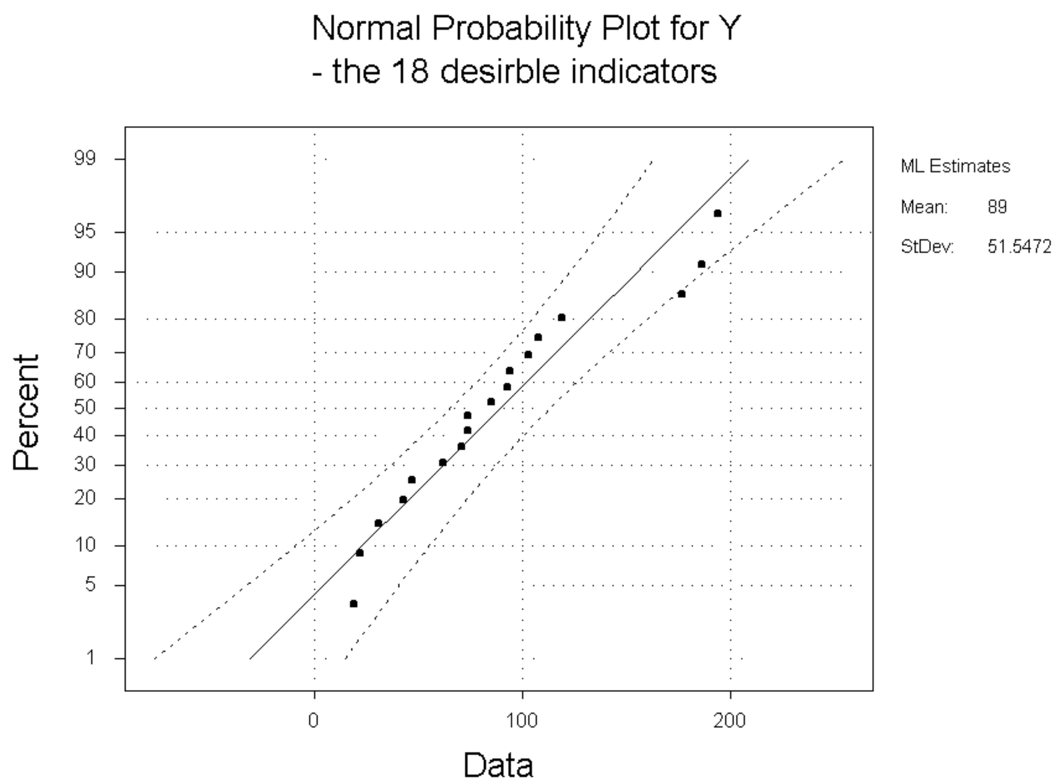
Table 6 Summation by Category

	Statement	Aero	Cer	CE	Chem	CSE	EE	Eng Phy	FABE	ISE	Mat	ME	Metal	Sur	WE	Total	Percent
Participating in formal organized training																	
4	Taking college courses for credit	3	0	16	6	12	13	1	2	7	1	19	4	0	1	85	30.36%
6	Earning an advanced degree	9	1	21	10	8	16	2	4	12	2	27	3	0	4	119	42.50%
11	Attending corporate training sessions	5	2	15	10	13	14	1	5	15	2	14	2	0	5	103	36.79%
15	Attending technical/training seminars or short courses	10	1	34	15	16	30	2	7	22	4	28	5	0	12	186	66.43%
Conducting training and professional publication																	
5	Conducting corporate training sessions	0	0	4	4	6	8	1	1	4	0	11	1	0	3	43	15.36%
12	Writing for professional journals	3	0	20	7	6	8	2	1	5	1	19	2	0	0	74	26.43%
14	Research or working on design projects with a college or university	8	0	16	7	5	14	1	2	6	2	25	1	0	6	93	33.21%
8	Advising/mentoring middle school, high school, or college students	0	0	1	2	1	3	0	0	3	0	6	0	1	2	19	6.79%
Involved in a professional organization																	
3	Membership in a professional organization	2	1	14	6	3	9	0	4	18	0	8	2	0	4	71	25.36%
9	Holding an office in a professional organization	1	0	4	3	1	1	0	1	2	1	4	1	0	3	22	7.86%
18	Presenting a paper at a professional meeting	4	1	12	8	5	8	2	1	8	1	17	2	0	5	74	26.43%
1	Attending a professional conference	11	1	35	16	14	26	2	5	18	3	27	4	0	15	177	63.21%
Engaged in informal independent professional study																	
16	Professional registration	3	0	13	2	0	6	0	5	9	0	6	1	1	1	47	16.79%
17	Reading technical books	5	0	16	10	14	22	0	2	9	2	18	1	1	8	108	38.57%
2	Reading trade or professional journals	10	2	28	18	13	33	2	5	28	3	34	3	1	14	194	69.29%
10	Web-based professional training	4	0	8	6	9	7	1	1	5	2	14	0	0	5	62	22.14%
Progressing organizationally																	
7	Increasing job responsibility	5	2	12	12	14	12	0	4	14	0	10	2	1	6	94	33.57%
13	Moving into supervisory positions	2	1	4	3	2	2	0	2	8	0	2	2	1	2	31	11.07%

TABLE 7.
INDICATORS SUMMED ACROSS ALL YEARS AND ALL PROGRAMS

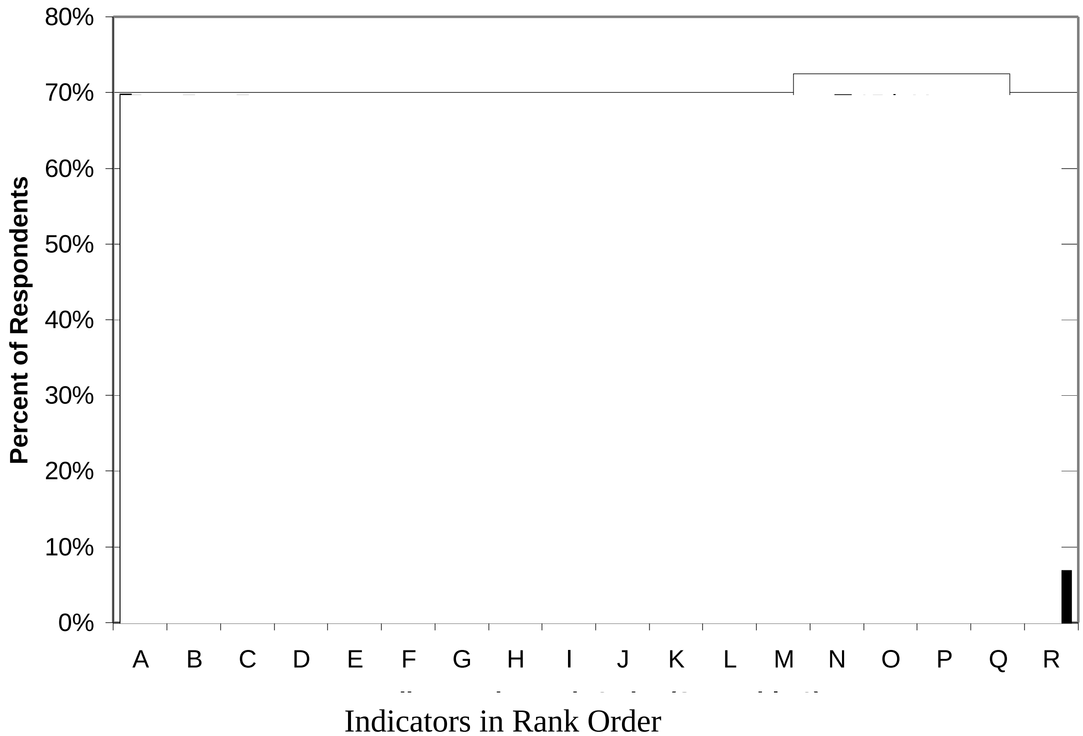
	Indicator	Total	Percent
A	Reading trade or professional journals	194	69.3%
B	Attending technical/training seminars or short courses	186	66.4%
C	Attending a professional conference	177	63.2%
D	Earning an advanced degree	119	42.5%
E	Reading technical books	108	38.6%
F	Attending corporate training sessions	103	36.8%
G	Increasing job responsibility	94	33.6%
H	Research or working on design projects with a college or university	93	33.2%
I	Taking college courses for credit	85	30.4%
J	Writing for professional journals	74	26.4%
K	Presenting a paper at a professional meeting	74	26.4%
L	Membership in a professional organization	71	25.4%
M	Web-based professional training	62	22.1%
N	Professional registration	47	16.8%
O	Conducting corporate training sessions	43	15.4%
P	Moving into supervisory positions	31	11.1%
Q	Holding an office in a professional organization	22	7.9%
R	Advising/mentoring middle school, high school, or college students	19	6.8%
	Total	1602	

FIGURE 1.



Normal Probability Plot for Y
- the 18 desirble indicators
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
0
100
200
Data
ML Estimates
Mean: 89
StDev: 51.5472

FIGURE 2.


80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent of Respondents
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
Indicators in Rank Order