Professional Organizations and the Learning of Statistics After College

Jorge Luis Romeu, Ph.D.
Dept. Mech. & Aerospace Engineering, 225 Link Hall, Syracuse University, NY 13224
Web: http://myprofile.cos.com/romeu Email: jlromeu@syr.edu

In Proceedings of ASA Education Section; JSM, Vancouver CA. August 2011

Abstract
In the ICOTS-7 (Salvador, Brazil; 2006), and later in the FTC (Jacksonville, FL; 2007) statistics conferences, we discussed how engineers receive insufficient instruction on statistics during college, and how they later need to learn Stats on their own. In the present paper, we look at several statistics-oriented professional organizations, research institutes and government agencies that generate educational materials of different types, to help engineers learn statistics, on their own, after college. We overview their products and their contents, and discuss how some of these organizations work together. We discuss successes and shortcomings of such efforts. Finally, we propose creating *Institutes* that would help coordinate the use of, and advertise the presence of existing as well as newly created statistics tutorial education materials. Such *Institutes* would also organize and coordinate seminars and presentations of varying levels and topics, as well as assess and sequence web tutorials. Institutes would use college students as interns, thus providing hands-on training, and they would develop special programs for secondary teachers and students, to help entice the study of STEM careers since an early age.

Key Words: statistics education, lifelong learning, professional organizations

1. Problem Statement

In the US, most practicing engineers do not study sufficient statistics in college, for logistics reasons (i.e. lack of time, of space in the curriculum, etc). This situation is not unique to statistics. For, the same happens with say, corrosion, as shown by Rose (2007).

However, they soon find out, as they compare the material taught in their semester of college stats: descriptive, intro to probability, confidence intervals, hypothesis testing and elementary regression). And then read the certification requirements (body of knowledge) of professional organizations such as the American Society for Quality (ASQ), Quality (http://www.asq.org/certification/quality-engineer/bok.html, or Reliability examinations (http://www.asq.org/certification/reliability-engineer/bok.html). The large gap that exists between the two becomes apparent as certification topics such as Design of Experiments, including advanced Fractional Factorials, logistics regressions, etc. have to be learned with a background on two sample t tests, simple linear regression and one-way ANOVA.

To bridge such large gap, practicing engineers take short courses, read papers on their own, go to conferences and society meetings, receive mentoring, etc. But this is usually done in an "as needed" basis, that is: unsystematically and therefore, inefficiently. The result is the creation of what we call a *Knowledge Quilt,* in lieu of a *Knowledge Base*.

This situation has several detrimental side effects. First, many industrial organizations complain about not finding enough American born and trained engineers to fill their technical positions. And they advertise to bring them from abroad. Then, they use this situation to take their industrial plants abroad. As they state that the know-how is less expensive and more plentiful in say, India, China, and other countries in the East.

Our American students and practicing engineers usually finish their BS degrees with a significant debt, and are eager to start working and earn money to pay these back, and to start a family. As they already are legally qualified to work in the US they do not need, like some foreign students do, to continue full-time their graduate studies, toward an MS or PhD. Degree. This situation places American engineers and students in a significant disadvantage with respect to incoming foreign students, regarding the technical level that they will eventually obtain. And this makes finding an efficient way to help engineers get a significantly higher level of technical education, on their own time, while earning a living and taking care of their families, a very important endeavor.

To help solve said problem, Romeu (2007) proposed a tri-part solution: teaching descriptive stats and probability in grade school, leaving space for teaching statistical thinking, sampling distributions, inference, linear regression and simple ANOVA in college. Finally, building an all-inclusive, life-long learning process, where practicing engineers can self-teach specific topics they need, when and as needed.

The study of the problem of lifelong statistics education of practicing engineers, and the search for more efficient educational alternatives that can help American engineers to learn statistics, on their own time, while earning a living and taking care of their families, constitute the two main objectives of our research, as well as of the present paper.

2. Background

Statistics education has been well studied at various levels. At the grade school, Batanero, Bickel, Bailar, Blumberg, Chance, Garfield, Joliffe, Locke, McGillivary, Moore, Ottaviani, Pearle, Rumsey, Sanchez and Wilde, among others, have studied the issue. Improvements in college engineering statistics have been proposed by Hogg et al. (1985), Hoadley and Kettenring (1990), Kettering (1995), Bisgaard (1991) and Snee (1993), Romero et al. (1995) and Romeu (2006), among others. However, few researchers have tackled directly the crucial problem of the education of already-practicing engineers.

Among those few, Bakker (2006), and Spedding (2006), have discussed what practicing engineers need to know, how these can be trained, and given specific ways of delivering statistical concepts in the workplace. McGillivray (http://ssaqld.wordpress.com/page/2/), in ALTC *Networks in Statistics Education*, discusses programs to help create and develop new *communities of statistical learners*. However helpful, most of these efforts are uncoordinated, overlap, or leave unaddressed technical areas untouched.

Romeu (2005, 2006, 2007, 2010) has dedicated much time to understand and analyze the different ways in which practicing engineers learn statistics on their own, in order to bridge the large gap between what they learned in college, and what they need to learn via certifications and credentials, that will enable them to successfully work in the field.

To investigate how engineers bridge the gap between college curriculum and certification requirements, Romeu (http://web.syr.edu/~jlromeu/SurveyICOTS.html) conducted a pilot survey. In it, engineers were asked to *quantify* how (methods used) they acquired their post-college statistical knowledge: (1) reading books, journals, manuals or other hard copy materials, (2) reading Web and Internet materials, (3) following on-line courses or learning software, etc., (4) attending conferences and chapter meeting talks, (5) pursuing preparation for professional certifications, (6) taking short training courses, (7) receiving mentoring from more experienced work colleagues and (8) other sources, such as hands-on (practical) working experiences and mentoring by more experienced peers.

To characterize the survey taker we asked their education level, area (academe, industry, or government), specialty (mechanical, electrical, industrial, etc.), total number of stats courses taken in college, years practicing engineering, and gender. The survey sample was *self-selected*; hence its pilot character. For further details consult Romeu (2006).

Survey results showed how 1/3 of engineers with a BS degree had never taken a single statistics course in college, and another 1/3 of them had taken only one. The survey showed how *readings* constitute the preferred means of learning: books and journals, as well as *web tutorials*, provide 38% of stats knowledge. The use of *web tutorials* (10%) is increasing with time, especially among the younger ones. *Short courses*, *certifications preparation* and *Black Belt training* constitute 33% of ways. Mentoring received from more experienced colleagues are 22% of the method used for knowledge acquisition.

Reported reasons for the need to learn extra statistics material on their own, after college, include: 1. College curriculum is extremely full, with no space for additional subjects; 2. The expansion of fields of specialization; 3. Not all engineers pursue graduate education. Some reported problems for existing education material includes unstructured, poorly or not sequenced materials, their varying quality, and difficulty to locate and access.

In the rest of this paper we discuss how professional societies, government organizations, and research centers, three pillars of post-graduate education, contribute to the education of practicing engineers. We discuss advantages and disadvantages, point out some strong and weak points and existing synergisms. Finally, we propose the creation of *Institutes* coordinate and support such learning, and discuss its operation and characteristics.

3. Professional Associations

The pilot survey helped identify the main avenues practitioners used to study on their own, which provided certification training and exams, short courses, individual readings, (tutorials) and mentoring. Much of such knowledge is provided by professional society *certifications* as the ASQ Statistics Division http://www.asq.org/statistics/index.html, the Chemical and Process Industries Division, CP&I, (http://www.asq.org/cpi/index.html), and the Reliability (http://www.asq.org/divisions-forums/reliability/index.html) Division. The curriculum is demanding and there are training sessions manuals and study materials. The certifications exams, however, are multiple-choice and emphasize procedural rather than statistical procedures of the areas under study (e.g. SPC, reliability, DOE, etc.)

Training is also conducted by the American Statistical Association (ASA) Section on Physical and Engineering Sciences, SPES (http://www.amstat.org/sections/SPES/), and the Quality and Productivity Q&P (http://www.amstat-online.org/sections/qp/) Section in their annual meeting as well as in their technical conferences.

The four mentioned organizations: ASQ's Stats and CP&I, and ASA's SPES and Q&P constitute an outstanding but infrequent example of synergy. They *jointly* sponsor conferences such as the Fall Technical Conference, *FTC,* Spring Research Conference, *SRC* and, every four years, the Joint Research Conference *JRC.* They *jointly* publish journals such as *Technometrics*, *Quality Technology* and *Quality Engineering*. Many members (including this author) belong to more than one. They, also develop tutorials or *Minipapers*, many freely accessible in their web sites More of the kind is badly needed.

There are also several statistical journals, developed and/or fostered by other professional societies. Selected examples are found in http://www.statsci.org/jourlist.html; in ASQ, http://www.asq.org/pub/; in ASA, http://www.amstat.org/publications/jbes.cfm, and in the Royal Statistical Society (RSS) site, http://www.rss.org.uk/publications.

Other professional societies also develop statistical materials: IEEE Reliability Society (http://www.ieee.org/web/membership/societies/RL007.html), Society of Manufacturing Engineering, (http://www.sme.org/cgi-bin/getsmepg.pl?/new-sme.html&&&SME&), the Institute of Industrial Engineers's (IIE) Quality Control and Reliability Divisions, and Institute for Operations Research and Management Sciences (INFORMS) QSR Section (http://qsr.section.informs.org/). In the UK, the Engineering Council sets some standards (http://www.engc.org.uk/documents/CEng_IEng_Standard.pdf). In Europe, two *applied* statistics societies: ISBIS (http://www.isbis.org/) and ENBIS (http://www.enbis.org/), contribute to statistics education of engineers. Many of these professional societies target (and are directed by) applied statisticians, and not only engineers.

Some pure engineering societies also hold sporadic statistically-oriented presentations, short courses and training. A survey (http://lcs.syr.edu/faculty/romeu/Surv2.pdf) of the Tech Alliance of Central New York (TACNY, http://tacny.org/) showed how few of their member engineering societies developed statistical activities. These were poorly attended and would greatly benefit from being jointly sponsored and better advertised

In addition, professional organizations conduct most activities for their members' benefit and even compete for membership. Outsiders may not always have access to their activities or documents, may remain unaware of the existence of useful information, or find their location is difficult or impossible to obtain. *Free* documentation often addresses specific problems and is not sequenced, making it difficult to digest by readers without the proper background. For example, reading DOE without first knowing how to conduct a simple paired t-test can be a difficult task.

Tutorial materials are intended to be used by average practitioners as self-learning tools, to help them improve their statistics level. However, many journal and conference papers are beyond the stats level of the *average* engineer, who would benefit from their classification and sequencing. Hence, more efficient methods are needed so that more practitioners can fully benefit from such excellent and already existing materials, and can better use them to increase their statistics knowledge.

Summarizing, current education efforts of the professional associations are dispersed and uncoordinated, and are geared to solving specific problems of their members, as they arise. Hence, they do not contribute to *systematically* create a real *knowledge base*.

4. Research Centers

Another source of learning materials are the research and development centers, created and supported by Industry, Academe, and government and private agencies. However, these centers generally address *basic research*, or *as needed professional training and consulting*, thus providing limited help to practicing engineers interested in *systematically learning* statistics by themselves, in their own time, using the Internet, to create a strong Knowledge Base. We overview several examples of such centers, below.

The National Science Foundation has a program to support Engineering Research Centers (NSF, http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5502&org=NSF). EPA, the Environmental Protection Agency, supports the National Center for Environmental Research, (NCER, http://epa.gov/ncer/). These centers advertise for, and describe, some particularly successful NSF and EPA research programs (http://www.erc-assoc.org/). But they provide few, if any, statistics education materials. That is not their objective.

Applied center examples include The Center for Quality and Productivity Improvement of the University of Wisconsin, (CQPI, http://cqpi.engr.wisc.edu/research); The Institute for Advanced Analytics, of the North Carolina State U. (IAA, http://analytics.ncsu.edu/); Hromi Center for Quality and Applied Statistics of Rochester Institute of Technology (CQAS, http://www.rit.edu/kgcoe/cqas/); and HWP Center for Engineering Education. and Practice, U. of Michigan, (http://www.engin.umd.umich.edu/HPCEEP/). All of them address specific problems in engineering statistics, generated by consulting or research stemming from their operations. They produce excellent reports and tutorials addressing such issues, often but not always available to the general public. But their work remains widely unknown to the average practicing engineer, who may not even be aware of the existence of such centers, unless they are somehow directly related to them.

Theoretically oriented research centers address *Basic Research* work. Some examples include the joint Rutgers-Arizona State U., Quality and Reliabiity Engineering Center, http://www.engr.rutgers.edu/~ie/sub_navi/centers_labs/qre/index.html, Risk and Decision Analysis Center http://www.rci.rutgers.edu/~carda/; and the University of Maryland Center for Advanced Lifecycle Engineering (CALCE, http://www.calce.umd.edu/). Their products (research reports, papers, courses, etc.) are beyond the statistics level of the average practicing engineers. Their research problems are also outside of the daily issues that impact the average practitioner.

Professional societies also sponsor Centers for Statistical Education that research how students learn at different levels, including lifelong learning, and produces training materials: ASA's (http://www.amstat.org/education/index.cfm?fuseaction=main). RSS's (http://www.rsscse.org.uk/), IASE (http://www.stat.auckland.ac.nz/~iase/) and ASQ's Learning Institute (http://www.asq.org/learninginstitute/) are examples.

But these excellent efforts do not fill all statistical needs of practitioners, who deal with uncertainty on a daily basis in their work. They address specific problems in uncoordinated ways, which improves the situation. But such method creates a statistics Knowledge Quilt, instead of a Knowledge Base, which is created through a systematic, coordinated education effort. This problem has been recognized by the NSF and some programs have been created to address it (http://www.nsf.gov/div/index.jsp?div=EEC).

Finally, some professional (ASQ, IEEE, MFE, IIE, SIAM, UK Engineering Council) and statistical (ASA, RSS) societies define requirements and standards, grant certifications, teach and examine candidates in specific areas (e.g. reliability, quality, six sigma) to help bridge the gap between college statistics, and real world needs, as reflected by the certification requirements. However, such programs, given the differences between the topics covered in college statistics and in certification curriculums, are insufficient.

5. Government and Other Organizations

Professional education and training is developed by several government organizations. For it is in the best interest of government agencies to increase the statistics level of its employees and contractors. This author worked for years at the. Reliability Informatin Analysis Center (**RIAC**, http://TheRiac.org) and at the Rome Air Development Center (**RADC**), now part of the Air Force Research Labs (http://www.wpafb.af.mil/AFRL/). There, dozens of excellent reports and tutorials were written on reliability, quality, maintainability etc. Other Armed Forces branches also have similar operations. Two examples of such Department of Defense efforts are the Office of Naval Research (**ONR**, http://www.onr.navy.mil/) and **DTIC-IAC** programs (http://iac.dtic.mil/).

Many products (web tutorials, reports, computer programs etc.) are freely available in their web pages, and others are sold at cost. However, our experience is that these remain widely unknown to the average engineer working outside the contracting companies.

One of the best statistics education materials is freely available in the web page of the National Institute for Standards and Technology (**NIST**, http://www.itl.nist.gov/div898/). It consists of an excellent and comprehensive web-based statistics textbook, plus several statistics computer programs, tutorials with developed examples etc. This author uses this material constantly in his graduate and undergraduate statistics courses.

The NSF-funded National Science Digital Library **NSDL,** http://nsdl.org also includes stats tutorials. However, its excellent materials are mostly geared to statistics faculty (course syllabuses, examples, exercises etc.), and not to address the problems of the average practicing engineer, looking to solve their daily problems.

The International Statistics Literacy Program, sponsored by the International Association for Statistics Education **(ISLP,** http://www.stat.auckland.ac.nz/~iase/islp/training) links to many statistics education training programs and materials created by others. But it does not provide links to numerical tutorials, geared to practicing engineers.

The ASA Q&P Section has a *Webinar Training program* for its members, found in http://www.amstat.org/sections/qp/webinar.cfm; The Smith Institute for Industrial Math and Systems Engineering, in the UK, (http://www.smithinst.co.uk/) also teaches stats for industry. There is a comprehensive library of statistics reports is in the Center for Quality and Productivity Improvement (**CQPI** http://cqpi.engr.wisc.edu/technical_reports) of the U. of Wisconsin Finally, The RIAC has several dozen industrial statistics tutorials, developed as part of its training mission. Some of them are catalogued and sequenced in: http://web.cortland.edu/romeu/urlstats.html.

Another type of organization interested in the statistical education of practicing engineers are the consultants, who provide many of the available training materials and services to practicing engineers. Private examples include QSI (http://quanterion.com) a small group.

Technomath (http://www.lkl.ac.uk/research/technomaths/) is a (UK) government-sponsored (http://www.esrc.ac.uk/ESRCInfoCentre/index.aspx) literacy program example (http://www.tlrp.org/). Other industrial education centers include **KTN** http://maths.globalwatchonline.com/epicentric_portal/site/IMS/home/?mode=0 and **WLE** http://www.wlecentre.ac.uk/cms/index.php?option=com_content&task=view&id=2&Itemid=2) They develop statistics training develop technical reports and materials for the industrial workplace, on an as-needed, case basis. They also demonstrate a proactive government effort to help practicing professionals in their lifelong education.

Finally, the National Academy of Engineering http://www.nae.edu/ has produced studies such as *Educating the Engineer of 2020* (**NAS**, 2005), and *The Bridge: Linking Engineering and Society* (2006). Such studies are aimed at understanding and, eventually at solving the problems discussed, with an eye in the future.

However, many times the average practitioner is unaware of such excellent material, or is unable to use them because they are not assessed, sequenced, or they are unavailable. Below we show two tables, summarizing this discussion.

I. Characteristics of the Sources

- Many are unknown to practitioners
  - Or unaccesible to non-members
- Mostly concerned with consulting, training
  - Or with basic research in narrow areas
- Reports and tutorials are uncoordinated
  - Unsequenced and unassessed
  - Missing basic pre-requisites
  - Slanted to the researcher or educator

II. Characteristics of Materials

- Web material, more and more relevant, but:
  - need for creating data base of existing ones
  - need for cataloguing and assessing them
  - need for sequencing such reading material
  - need for developing more/filling the "holes"
- Short Courses are widely used, but:
  - Single topic, poor inter-relationships, uneven
  - Student body is also very heterogeneous
  - Background and assumptions often missing

6. Our Proposed Institute

To help practicing engineers *bridge the gap* between the statistics learned in college and the statistics required by certification *Body of Knowledge* (BOKs), and to help them develop a statistics *knowledge base* instead of a statistics *knowledge quilt*, Romeu (2007) has proposed the creation of local *Institutes*. In addition, Institutes provide a feasible procedure for those engineers who, due to family and budgetary considerations, cannot enroll in graduate school, to advance their careers via Lifelong learning activities.

Such Institutes will *coordinate* access to appropriate, rated and sequenced web-based *statistics material*, so practitioners can study on their own, in their time, raising college level statistics (estimation, testing and basic regression and ANOVA) to certification levels (e.g. advanced regression, DOE, SPC, reliability).

Different to others, said *institutes* will act as *clearinghouses*, assessing and sequencing existing web tutorials and materials, created to support professional certifications. In addition, institutes will *develop* new tutorials and support material, to fill holes among the existing ones, and to complete more complex, or inadequately covered statistics topics.

Institutes will use consultants and existing organizations such as community colleges, to develop forums, conferences and *mentoring activities*. They will create and nurture a *community of statistics learners*. Institutes will then network, both across geographical regions as well as across areas of scientific interests and specialization. This activity will foster a network of specialists from different (but complementary) areas, enhancing synergistic applications of science. We can summarize all of this in the table below:

<u>The Proposed Institute</u>

- Partnerships: Government-Industry-Professional Organizations-Academe
- Supported entirely by grants/donors
- To Coordinate, support and provide
- Comprehensive Knowledge Base
- To Practicing STEM Professionals

As engineers improve their statistics backgrounds, especially statistical thinking, they will be able to read more of the excellent papers and reports already in journals and web sites, and to attend more stat conferences, that would benefit from larger participation. Learners would use, with added proficiency, existing challenging methods currently unused or misused. For example, some Six Sigma Black Belts implement DOEs and Fractional Factorials, while ignoring basic assumptions of two-sample t-tests. Ill-understood, incomplete or simply erroneous knowledge of statistical procedures, can only lead to bad practice and help discredit statistics as an analysis tool.

Professional societies and statistics consultants will become active partners, supporters and mentors of such *institutes*. They will provide direction, oversight and structure, as well as tutorials and other learning materials. They will also provide the instructors that will teach well-structured short courses and workshops, and lead forums and panels. In short, Institutes will become *the place* where societies, colleges and consultants will meet to work together.

Institutes will use engineering students as interns in revising/completing the existing web tutorials, and in statistical work, for low and mid size organizations who cannot afford consultants. In addition, Institutes will provide statistical workshops and presentations for High School teachers and students, to entice future generations of STEM professionals. We summarize all these activities in the following table:

<u>Some Institute Activities</u>

- Coordinate efforts of existing organizations
- Assess, sequence, write new web tutorials
- Develop talks, workshops, & short courses
    - Foster and nurture *user community* at QR&CII
- Develop Statistics Assessments
    - Using college engineering students as Interns

- Develop presentations and talks for H.S. students

Finally, Institutes will become a reality and succeed, only if they become a complement and unifying thread for already existing organizations, consultants and societies, who are currently providing such education services. They will surely fail if, instead, Institutes become just another competitor, fighting to take away a piece of the action from those others already in the education market.

7. Conclusions

Work already exists to help practicing professionals, and engineers in particular, to bridge the gap between statistics learned in college, and the one they need to function.

Some work is institutional. For example, the 1983 NSF report *A Nation at Risk* provided a wake-up call (http://www.ed.gov/pubs/NatAtRisk/index.html). Another recent NSF report, *Moving Forward to Improve Engineering Education*, shows ways to implement innovations in engineering education, in student recruitment, and in student retention (http://www.nsf.gov/pubs/2007/nsb07122/nsb07122.pdf).

Most *existing efforts* emphasize piecewise implementations. This paper *identifies the main problem*: the *huge gap beetween* statistics *knowledge and professional need*. It diagnoses its *root-cause*: *insuficient* statistics *training in college*, due to lack of space in the busy curriculum (which may also be true for many other college subjects). Finally, it proposes *a new systematic approach* to solve the problem: Lifelong learning *Institutes*.

We *propose a comprehensive solution*: (1) to teach *descriptive stats* and elementary probs in grade school; (2) teach *statistical thinking* and elementary inference and modeling in college. Finally, (3) leave more in-depth and specialized training for *life-long learning* when practicing engineers, our target population, can study in their own times, at their pace, *using sequenced tutorials* and other web-based support material, *self-training and mentoring of societies, colleges and consultants. Institutes* will constitute *the vehicle* for developing and organzing such education materials.

Summarizing, our proposed institutes will coordinate the existing, dispersed education efforts and materials, assessing and sequencing them. Insititutes will use consultants and faculty as course and material developers, and as short course instructors and mentors. Insititutes will use engineering students as interns. Institutes will also develop special activities and materials for High School teachers and students. As a result Insititutes will be attacking the complete problem cycle, by providing training to practicing engineers (past), hands-on experience to college students (present), and enticing high school students to pursue science and engineering careers, thus fostering a new (future) generation of scientists.

References

Bakker, A., Hoyles, C., Kent, P., & Noss, R. (2006). "Improving work processes by making the invisible visible," *Journal of Education and Work*, 19, 4, 343-361.

Bisgaard, S. (1991). Teaching Statistics to Engineers. *The American Statistician*. Vol. 45. p. 274-83

Hoadley, A. and J. Kettenring. (1990). Communication Between Statisticians and Engineers and Physical Scientists. *Technometrics*. Vol.. 32, No. 3.

Hogg, R et al. (1985). Statistics Education for Engineers: an initial Task Force report. *The American Statistician*. Vol. 39, pp. 168-175.

Jeske, D; Lesch, S. and H. Deng. (2007). The Merging of Statistics Education, Consulting and Research: a case study. *Journal of Statistical Education (JSE*). Vol. 15, No. 3.

Kettenring, J. (1995). What Industry Needs. *The American Statistician*. Vol. 49, pp. 2-4.

National Academies of Engineering, *The Bridge: Linking Engineering and Society*. Vol. 36, No. 2 (Washington, DC. NAE. Summer 2006).

National Academies of Engineering, *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* (Washington, DC. NAS Press, 2005).

Romeu, J. L. (2005). A Quality and Reliability Institute at Syracuse University. Research Proposal to NYSTAR.. Dept. Mech. & Aerosp. Eng. (MAE). Syracuse University.

Romeu, J. L. (2006). Teaching Engineering Statistics to Practicing Engineers. *Proceedings of International Conference of Teaching Statistics, ICOTS-7*. Salvador, Brasil. http://www.stat.auckland.ac.nz/~iase/publications/17/4A1_ROME.pdf

Romeu, J. L. (2007). Enhancing the Statistical Education of Practicing Engineers. *Fall Technical Conference*. JAX, FL. http://web.cortland.edu/romeu/FTCPaper07.pdf

Romeu, J. L. (2010). Practicing Engineers and the Learning of Statistics After College. An NSF Proposal. Dept. MAE, Syracuse University.

Rose, D. (2007). The Teaching of Corrosion at Colleges and Universities. Proceedings of the Materials Forum, NCR/NAS, PP. 8-9.

Romero, R; Ferrer, A; Capilla, C; Zunica, L; Balasch, S; Serra, V. and R. Alcover. (1995). Teaching Statistics to Engineers: an innovative pedagogical experience. *JSE*. Vol. 3, No. 1.

Snee, R. D. (1993). What's Missing in Statistical Education. *The American Statistician*. Vol. 47. pp. 149-154.

Spedding, T. (1998). Teaching Statistics to Engineers: towards developing a multi-media teaching environment. *Proceedings of ED MEDIA and ED TELECOM-98*, pp. 1333-1338.