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LAST WORD

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TWO SIDES OF A COIN

Future engineers need to learn both probability and statistics. Now, few can.

Most engineering curricula require a course on probability or statistics, seldom both. Probability is often taught by electrical engineering faculty engaged in signal processing or communications research. Introductory applied statistics is more likely to be offered by the industrial or systems engineering department. Neither is usually a prerequisite for any other required undergraduate course.

This is a flawed approach. Engineering students would be better served by a rigorous course in probability and statistics housed in the department of mathematics, its natural home. What's more, textbooks should be redesigned to include important engineering applications of both. Here's why:

Probability and statistics are two sides of the same coin. The theory of probability helps to predict the outcome of experiments when the underlying phenomena obey a model with known probabilities. Statistics shows how to estimate probabilities from the outcome of experiments. The fundamental notions of probability and statistics were developed simultaneously from observations of gambling, errors in astronomical measurements, epidemiology, and demographics. The notions taught in current introductory courses were formalized by the Bernoulli family, Laplace, Fermat, Graunt, Quetelet, and Bayes soon after the development of the necessary mathematical apparatus by Gauss and Leibniz. *The Drunkard's Walk* by Leonard Mlodinow, physicist at the California Institute of Technology, presents striking examples of how intuition often leads to wrong conclusions about uncertain phenomena.

Every engineering discipline makes use of both probability and statistics just as it makes use of both differential and integral calculus. Students in curricula that require only probability lack exposure to statistics beyond the notions of the sample average, standard deviation, and linear least squares fit. Important topics that never receive class time are the design of experiments, descriptive statistics, confidence intervals, hypothesis tests, multivariable regression, sufficient statistics, parameter estimation, and the analysis of variance. Students fail to gain any appreciation of the role of sample size. They don't learn to distinguish random error from systematic error. They are not coached in the subtleties of sampling strategies and the pitfalls of statistical analysis.

Students who take only statistics seldom learn transformations or functions of a random variable, transform methods, and multivariate distributions. They usually have only a brief exposure to expectations, particularly conditional expectations and the expected value of a derived random variable.

For our students to get the instruction they need, authors and publishers need to provide more appropriate textbooks that address the needs of engineering. Most authors of texts on probability are aware of the importance of statistics and are loath to skip it entirely. Yet they strain to keep concrete observations from intruding upon probabilistic abstraction. Likewise, authors of introductory statistics books certainly understand probability, but they shy away from emphasizing its axiomatic foundations. They typically refrain from exploring what can be learned from appropriate probabilistic models after estimating their relevant parameters from actual data.

Students are missing out on the rich interplay between these math subjects.

Academic publishers offer dozens of texts on probability for engineers but only a few with both statistics and engineering in the title. The probability texts are often plain vanilla, with remarkably few illustrative examples relevant to engineers. Most of the examples are based on coin tosses, dice, urns, and a layman's view of the telephone, Internet, weather, or highway traffic. Transform methods and signal processing are discussed only in chapters meant to support a follow-up course on stochastic processes or queuing theory. Most introductory statistics texts could be intended just as much for social or natural science students as for engineers. Their examples also require little depth in engineering.

Texts written to include both statistics and probability could offer engineering students much more, revealing the magnificent composite structure and rich interplay of the two subjects.

Many, if not most, engineering graduates will be called upon to make decisions in a nondeterministic framework. By not teaching them both statistics and probability, we send them into the field insufficiently prepared.

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