Statistics for All: Nearer Our Destination or Slip Sliding Away?

- Dick Scheaffer

Statisticks

An inquiry into the state of a country for the purpose of ascertaining the quantum of happiness enjoyed by its inhabitants, and the means of its future improvement

Sir John Sinclair, Scotland, Late 1700s

BEYOND THE INTRODUCTORY COURSE

The Transition: AP Statistics

Success in terms of numbers and growth!

Advanced Placement Statistics: Numbers of Students Taking the Exam

Year	1997	1998	1999	2000	2001	2002	2003	2004
Exams	7667	15,488	25,240	34,118	41,609	49,824	58,230	65,878
% Increase		102	63	35	22	20	17	13

Success in terms of impact on undergraduate programs?

- **In 2000, around 1000 students received statistics department credit for an introductory course (2% of the intro stats enrollment).**
- **Around 18, 000 students scored 3 or better on the AP exam that year. Where did they go?**
- **About 80% of statistics departments give bachelors degrees; 32% of them have seen an increase in the number of majors between 1997 and 2000.**

More About the Undergraduate Major

Bachelors Degrees in Mathematics and Statistics Departments at Four-Year Colleges and Universities

Major	1989-90	1994-95	1999-2000
Mathematics	13,303	12,456	10,759 (992)
Statistics	618	1031	502 (68)
Actuarial Mathematics and Statistics	245	620	425 (90)
Mathematics and Statistics	124	188	196 (101)

Curriculum Guidelines for Undergraduate Programs in Statistical Science

Skills needed:

Statistical

- **Statistical reasoning**
- **Design of studies**
- **Exploratory analysis of data**
- **Formal inference procedures**

Mathematical

- **Foundation for statistical theory**

Computational

- Use of standard statistical software
- Data management
- Algorithmic problem solving

Non-Mathematical Skills

- Communication
- Teamwork
- Project organization and management

Substantive Area

- Depth in an area of application

What About the Non-Majors Who Need Statistics?

Estimates of Fall Enrollment in Statistics & Calculus I by Year; Four-Year Colleges & Universities (1000s)

	Mathematics Departments			Statistics Departments		
	1990	1995	2000	1990	1995	2000
Elementary Statistics	87	115	136	30	49	54
Upper Level Statistics	38	28	35	14	16	20
Calculus (all)	647	538	570			
Advanced Math	119	96	102			

Upper Level Course Enrollments in Statistics (Math and Stat Depts.) (1000s)

Courses	1980	1985	1990	1995	2000
Math Stat	16	24	17	16	18
Probability	13	15	13	10	17
Applied Stat	8	11	10	9	6
Design Exps	2	1	1	1	2
Regression	1	1	2	1	2
Biostatistics	na	na	na	na	2
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Total	43	53	52	44	55

- Enrollments are flat over two decades, which implies a downward trend in percentage of students taking upper level courses.
- Math stat and probability courses do not produce statistical thinkers who can apply or teach statistical concepts and methodology tothose with broad interests.

Turning the trend …

will require sustained, coordinated and creative effort in reaching out to other disciplines.

- **Biological sciences – modeling, data mining**
  (See BIO 2010, NRC)
- **Business – regression, time series**
  (See MSMESB, www.msmesb.org/)
- **Social Sciences – sampling, categorical data**
  (See AAU, S4S, www.s4s.org/)
- **Engineering – design of experiments**
  (See Six Sigma)
- **Law – uses and misuses of quantitative argument, statistical thinking**
  (See *Chance*)
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Prospective teachers need special help!

- Only 4% of the statistics departments offer a special course for prospective teachers.
- About 68% of statistics departments say that prospective teachers are likely to take a standard elementary statistics course.

Teachers (continued)

- Teachers need to learn about good materials for use in K-12 teaching of statistics.
- Teachers need specialized courses in statistical thinking and statistical methods beyond the introductory course.
- Research on what, when and how to teach must go from fledgling to soaring eagle.

BUT...

Prospective secondary mathematics teachers are "owned" by mathematics departments, and therein lies a broader message…

Do Not Divorce Statistics from Mathematics: Statistics is not Mathematics, but the Two Must Work Together

Mathematical Thinking:

Where's the proof (logic)?
- **Logical reasoning (abstract)**
- **Optimization**
- **Number**
- **Algebra (Functions)**
- **Geometry**

Statistical Thinking:

Where's the data (experience)?
- **Answering the question (context)**
- **Variables and cases**
- **Distribution and variation**
- **Exploration and confirmation**
- **Purposeful design of studies (randomness)**

From the Father of Data Analysis

"Statistics is a science in my opinion, and it is no more a branch of mathematics than are physics, chemistry and economics; for if its methods fail the test of experience - not the test of logic - they are discarded."

(John Tukey, 1962, *Annals of Mathematical Statistics*)

And mathematicians agree...

"Using data to make decisions is rather different from the science of numbers and shapes."

(Alfred B. Manaster as quoted in Steen, 2001, *Mathematics and Democracy: The Case for Quantitative Literacy*)

In short …
- Statistics is a mathematical science.
- If statistics is to have a home in the K-12 curriculum, it will be in mathematics. (Case in point: Advanced Placement Statistics)
- Home life could be strengthened if the two did not divorce at the college level.
- Statistics and math must seek to understand their differences as well as the strengths that can come from a continued union.

A word from the wise:

- The gradual distancing of statistics from mathematics, …, carries risks for both disciplines.
- Statistics risks dissipating back into the many fields from which it coalesced or being swallowed by broader information technology.
- Mathematics risks following academic philosophy into irrelevant profundity.

- Statistics has cultural strengths that might greatly assist mathematics, while mathematics has organizational strengths that can provide shelter for academic statistics."

(George Cobb and David Moore, *American Mathematical Monthly*, 2000, pp. 615-630)

Examples on the positive side:

- **Katherine Halvorsen (and others) working with the College Board**
- **Mathematics Education of Teachers report of CBMS (www.cbmsweb.org)**
- **CUPM report of MAA (www.maa.org)**

More from CUPM

C.1. Develop mathematical thinking and communication skills

Courses designed for mathematical sciences majors should ensure that students

- --
- Gain experience in careful analysis of data;
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C.2. Develop skill with a variety of technological tools

- All majors should have experiences with a variety of technological tools, such as computer algebra systems, visualization software, statistical packages, and computer programming languages.

D.1. Majors preparing to be secondary school (9–12) teachers

- Mathematical sciences majors preparing to teach secondary mathematics should fulfill the requirements for a mathematics major by including topics from abstract algebra and number theory, analysis, discrete mathematics, geometry, and statistics and probability with an emphasis on data analysis;

To Keep from Slip Sliding Away:

1. **Pay attention to state guidelines and assessments**
2. **Support AP Statistics and the "graduates" thereof**
3. **Promote undergraduate programs, both majors and minors**

4. **Develop modern, creative, and flexible upper level courses by working constructively with other disciplines, especially**
   - **Education, with prospective teachers in mind**
   - **Mathematics, with understanding of differences as one goal**

Why?

Be<u>CAUSE</u> it is essential for a strong democracy in a quantitative world!

"I see you brought the pie charts."