Statistics Education in the Modern Era

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Michael A. Posner, PhD, PStat®, Villanova University
http://homepage.villanova.edu/michael.posner

Overview

- Statistics Today
- Modern Statistics Education
  - Guidelines for Assessment and Instruction
  - The Modern Curriculum
  - Cognitive Learning Theory and Statistics
  - Education in the 21st Century
- Statistics Education Research
  - Past, Present, and Future
- Questions and Discussion

Outline

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Statistics Today

- Video: Art Benjamin on calculus vs. statistics
- Google's Chief Economist, Hal Varian (2009):
  "I keep saying the sexy job in the next ten years will be statisticians. People think I'm joking, but who would've guessed that computer engineers would've been the sexy job of the 1990s?"
- McKinsey Report on Big Data (2011):
  "The US alone faces a shortage of 140,000 to 190,000 people with deep analytic skills as well as 1.5 million managers and analysts to analyze big data and make decisions based on their findings"
  See The Website
  NY Times article on February 11, 2012 about Big Data cites it
- The United Nations has declared 2013 as
  The International Year of Statistics (http://statistics2013.org)

Statistics Today II

- Computing has led to advances in
  - Statistical Genetics
  - Big Data and Analytics
  - High Dimensional Graphics
  - Educational Technology
- Samuel Wilks said
  - "Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write"
  - I think that day has come

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Knowledge Needed to Teach

Content Knowledge

Pedagogical Knowledge

Pedagogical Content Knowledge

Student Learning Outcomes

What are the needs of the student?

- Theory vs. application
- Computing or programming skills
- Consumer of statistics vs. producer of statistics
- Evaluate statistical reporting
- Data manipulation
- Dealing with large datasets or small datasets
- Is this course part of a sequence?

GAISE

Guidelines for Assessment and Instruction in Statistics Education – six recommendations

1. Emphasize statistical literacy and develop statistical thinking
2. Use real data (real > realistic > naked data)
3. Stress conceptual understanding, rather than mere knowledge of procedures
4. Foster active learning in the classroom
5. Use technology for developing conceptual understanding and analyzing data
6. Use assessments to improve and evaluate student learning

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The Modern Curriculum

- Some old topics are optional (one semester)
  - Most of probability, normal approximation to binomial, Central Limit Theorem, tables of distributions
- Some new topics may be necessary
  - Simulations, complex correlations, multiple imputation, statistical learning
- Order course by type of analysis
- Big data – unstructured, data mining
- Graphical displays – Rosling, McCandless
- Randomization-based curriculum

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Pedagogical Knowledge

- What if we trained airline pilots like we trained teachers? (Laboy-Rush, 2012)
- Assessment of Learning (Summative) vs. Assessment for Learning (Formative)

Cognitive Learning Theory

- Webb's Depth of Knowledge/Bloom's Taxonomy
- Common themes in successful international mathematics education (Stigler)
  - Time on task / practice
  - Making connections
  - Struggle
- "Applying Cognitive Theory to Statistics Instruction" (Lovett & Greenhouse)
  - Time on task / practice
  - Knowledge is context-specific and learning must integrate new knowledge with existing beliefs
  - Real-time feedback promotes efficient learning
  - Learning decreases as mental load increases

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Education in the 21st Century

- Applets to promote understanding
- Access to statistical computing (R)
- E-learning
  - Online learning, blended and flipped classes, and MOOCs
- Analytics-based adaptive testing

Think About…Course Design

- Don't just ask what do we want to cover
- Ask what do I want them to know
- …what will they be able to do
- …what is the best way to convey material
- …how do I know what they know

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Statistics Education Research

- Past
  - Statistics education research is young, ~1990s
  - Univ of Minnesota is only graduate program in statistics education, started in 2002
- Present
  - Growing interest in evidence-based practice in stat ed
  - Many varieties of assessment instruments being used
  - Connecting Research to Practice Report
- Future
  - Integration with disciplines
  - Valuable outcomes measured (long-term retention, employment)
  - New methods of delivery

Connecting Research to Practice

Connecting Research to Practice Report

1. Cognitive Outcomes

   "… the nature of knowledge and learning are suggestive of instructional approaches we should stress (and others we should de-emphasize) if we want to affect how students think (as opposed to how they respond on exams)."

   (Konold, 1995)
2. Affective Constructs

   "…students' feelings about statistics education, and the effects of these feelings on resulting learning, knowledge and further interest in statistics, should occupy a more central role in the minds of statistics educators."

   (Gal & Ginsburg, 1994)
3. Curriculum

   "The need for curricular resources in statistics is acute, arguably more acute (at the college level) than in any other subject. The reason: Of all subjects taught as often as statistics, surely no other subject is so often taught by faculty with so little formal training in the subject." (Cobb, 1993)

Connecting Research to Practice

Connecting Research to Practice Report

4. Teaching Practice

   "Shorn of all subtlety and led naked out of the protective fold of educational research literature, there comes a sheepish little fact: lectures don't work nearly as well as many of us would like to think." (Cobb, 1992)
5. Teacher Development

   ***"…**good teachers of statistics need to be **developed**, as opposed to being **trained**."* (Garfield & Everson, 2009)
6. Technology

   "It is hard to imagine teaching statistics today without using some form of technology. However, just 20 years ago that was very common" (Garfield & Ben-Zvi, 2008)
7. Assessment

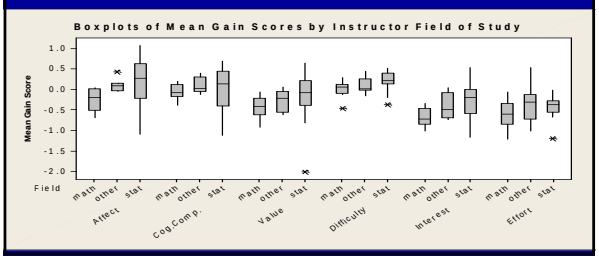
   "In reality it is through classroom assessment that attitudes, skills, knowledge and thinking are fostered, nurtured and accelerated – or stifled" (Hynes, 1991)

My Stat Ed Research

- Student attitudes
  - Relation with instructor characteristics
  - Impact of first day
  - Relationship with content
  - Long-term retention (future)
- Hybrid assessment / flipped classroom
- Fun – video intervention, games, etc.
- PARLO (standards-based grading)
- Grading paradox

Attitudes: Instructor Characteristics

- Data from a warehouse of student attitudes towards statistics
- 2,184 students in 121 courses from 31 instructors
- Analyzed with HLM. All factors, except difficulty, were significant



Attitudes: Impact of First Day

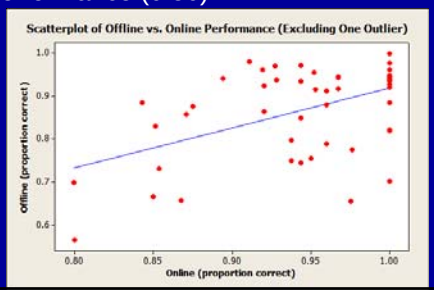
- Randomized study of 32 sections of intro stats
- Half student got SATS before first class and half got it afterwards
- Affect, cognitive competence, and difficulty were higher after first class
- If our results (including mean increase and additional variance component) were applied to six existing research studies, four would have reported different results (in terms of statistical significance)

Hybrid Assessment

- Two courses in Statistical Methods…
  - Majors (2012), 2nd course for non-majors (2011)
- Homework
  - Online (Mixed)
  - Offline
    - Mixed (when both online and offline were given)
    - Only Offline (when no online homework was given)
    - Total Offline (combining previous two)
- Final Exam (Z-score)
- Survey of Attitudes Towards Statistics (2012)
- One outlier excluded

Results – Online/Offline

- Correlation between online and offline performance (0.50)



Results – Predicting Final Exam

	Online	Offline	Both
Online	5.75**		2.46
Offline		4.23****	3.56**
Intercept	-5.42	-3.66	-5.40
R-sq	11%	20%	21%

** p<0.05, **** p<=0.001

Models including gender, course, and interactions were examined but not included here, since these factors were not significant

Results – Attitudes

		Affect	Cogn Comp	Value	Difficulty	Interest	Effort
Online Model	Online	6.9*	7.9**	-3.2	3.4	0.7	3.8
	Pre	0.5***	0.4*	0.4*	0.1	0.5**	0.2
	Intercept	-4.0	-4.3	6.1	0.5	1.7	1.3
	R-squared	31%	23%	18%	4%	17%	3%
Offline Model	Offline	4.1**	2.9	-1.6	0.4	0.3	4.4*
	Pre	0.6***	0.3	0.4*	0.1	0.5**	0.3
	Intercept	-1.6	1.1	4.6	3.5	2.1	0.4
	R-squared	34%	15%	17%	1%	17%	13%

Outcome is post SATS subscale
* p<0.10, ** p<0.05, *** p<0.01

Results – Open Ended

- "Dr. Posner posted multiple choice questions that were due for homework, which allowed us to submit answers until we got the question right. This took the emphasis of "grades" off of us as students and more on our understanding of the questions and how to answer them properly."
- "I liked how the HW was split up into two sections."
- "Sometimes the lengths of the homeworks was excessive."
- Course Evaluations – "Graded work fairly": 4.7 / 5 (compared to 4.3 the last two times I taught this class)

Challenges

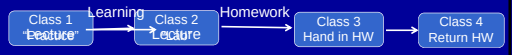
- Learning the system
  - Setting tolerance levels for answers
  - Writing open-ended questions
  - Establishing a database of questions
- Differences between book and my teaching
  - Notation: π and p vs. p and p-hat
  - z vs. t test
- No partial credit

Further Thoughts

- Computerized summary of problems (% correct) was helpful (for Flipped or JITT)
- Monitor student engagement
  - Who did them early
- Only worthwhile when teaching multiple times
- Need a larger and better designed study

Flipped Classroom

- Statistical Methods for Majors
- Each module designed around two classes



- Weekly quizzes during lab (repeated testing)
- How does this impact student attitudes, learning, and course evaluations? (ongoing research)
- Benefits
  - More time spent on real-world applications
  - Addresses heterogeneity of class
  - Allows (but relies on) student ownership of learning

The PARLO System

Proficiency-based Assessment
and
Reassessment
of
Learning Outcomes

Standards-based Grading
Mastery Learning

Success in High Schools

- *Young Women's Leadership Charter School of Chicago (www.ywlcs.org)*
  - Specific learning objectives for each course
  - Proficiency grading
    - Not Yet Prof (N), Proficient (P), High Performance (H)
  - Unlimited resubmissions allowed
  - Success!
    - Highest grad rate of non-selective public schools
    - >95% of graduates admitted to college
    - >85% of initial cohort still in college in 2005-2006
    - Transformed summer school format
- Quakertown Community School District
  - Increased score on statewide assessments

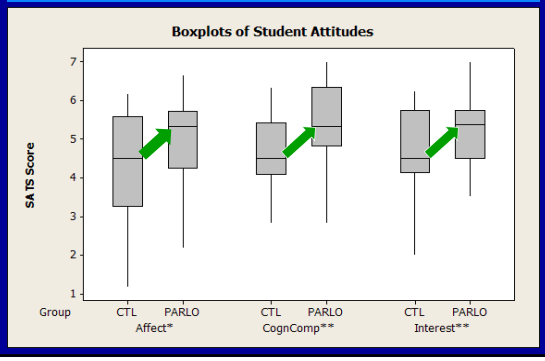
Villanova PARLO Study (VPS)

What are the
impacts on student attitudes and performance
of offering a
PARLO Assessment System?

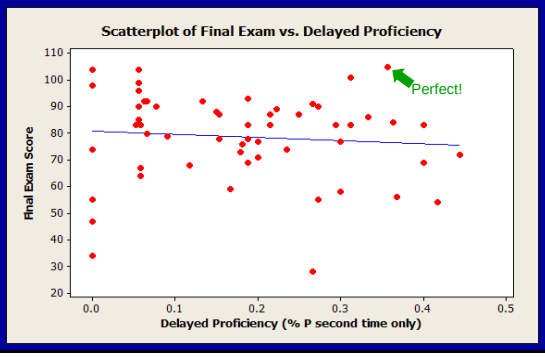
VPS Methods

- Two sections of intro statistics (for non-majors)
  - Same instructor, same material
  - Back-to-back class times (1:30 / 3 pm on Mon & Wed)
  - Control group
    - Numeric grading on each homework
    - No resubmission allowed
  - PARLO group
    - Proficiency grading on each learning outcome
    - Assignment resubmission (once)
  - Cross-over design (two years)
  - Outcomes: Common Final Exam, CAOS, SATS

VPS Results - Attitudes



VPS Results - "2nd Class Learner"?



VPS - Other Results

- Common Final Exam
  - PARLO group didn't perform better on common final
  - Controlling for Math SAT didn't change results
  - A gender-PARLO effect (males did worse)
- 92% strongly satisfied with grading system
  - none dissatisfied
- Students in the PARLO group thought the course was graded more fairly (4.45 vs. 4.0, $p<0.05$ (t-test and J-T))
- More PARLO students came to office hours
- Improved instruction and assessment by focusing on learning outcomes

VPS - One More Result…

- The following did NOT occur…

NSF PARLO Study

- Evidence-based STEM education on national agenda


- Five year, $2.4mil RCT of 32 high schools
- Use PARLO in 9th grade mathematics to improve attitudes, engagement and achievement
- Includes professional development and professional learning communities for teachers
- Currently in third year of implementation
- Results forthcoming

The Power of Choice

- Four sections of MBA classes at two universities from two instructors (cross-over design)
- Student given choice in allocating percentages for grades

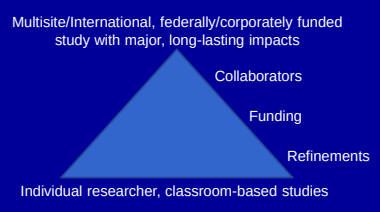
	Model 1 Triggered Situational Interest: Satisfaction with the Course		Model 2 Maintained Situational Interest: Take A Similar Course in the Future	
	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Intercept	5.71 ***	0.36	4.92 ***	0.57
Control variables				
Gender	-0.05	0.20	-0.48	0.32
University (dummy variable)	0.17	0.20	0.46	0.31
Experimental Condition	0.50 *	0.21	0.82 *	0.32
R-square	0.08		0.10	
Adjusted R-square	0.04		0.06	

Note. $n = 81$.
* $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Scholarship of Teaching/Learning

- SoTL as an evidence-based way for continuous improvement of teaching and learning is not a passing fad in research or pedagogy. It is a form of research that creates a "sustained culture of inquiry about teaching and learning" and an increased awareness of the nature, role and potential of SoTL for improved learning.
- Teaching can always become more effective and learning more significant and enduring. Growth in students and their learning is the life-juice of being a teacher. SoTL can stimulate those juices to flow in innovative, effective, and reflective ways.
- SoTL is not only the engagement by individuals in vigorous research on teaching and making that research public in building a body of knowledge, but also an attitude and a way of thinking about teaching. SoTL emphasizes that teaching is serious intellectual activity that can be both deeply personal and highly collegial. SoTL, as understood in an expansive sense, is perhaps the best way to improve teaching for student understanding. That is a lofty claim, yet one not only possible, but when done well, probable.

Pyramid of Classroom-based Research



Think About…Research Design

- What is the goal? Is it succinct and evaluable?
- Identify the control/comparison
- How are you measuring success? Is there a validated instrument out there already?
- Get IRB approval
- All the same principles you apply to your scientific investigations

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References - Articles

- GAISE Guidelines (2007,2010). http://www.amstat.org/education/gaise/
- Using Statistics Effectively in Mathematics Education Research. American Statistical Association, 2007. http://www.amstat.org/education/pdfs/UsingStatisticsEffectivelyinMathEdResearch.pdf
- Lovett, M. and Greenhouse, J (2000). Applying Cognitive Theory to Statistics Instruction. *The American Statistician*; 54(3), 1-11.
- Pearl, D.K., et. al. (2012) Connecting Research to Practice in a Culture of Assessment for Introductory College-level Statistics. http://www.causeweb.org/research/guidelines/ResearchReport_Dec_2012.pdf
- What If We Trained Airline Pilots Like We Train Teachers? Portland Wiz Kid Blog. Diana Laboy-Rush, 2012.
- Dobrow, S.R., Smith, W.K., Posner, M.A. (2011). Managing the Grading Paradox: Leveraging the Power of Choice in the Classroom. http://www.bnet.fordham.edu/dobrow/docs/GradingParadox.pdf
- Posner, M. (2011). The Impact of a Proficiency-based Assessment and Reassessment of Learning Objectives System on Student Achievement and Attitudes. *Statistics Education Research Journal*; 10(1); 3-14. http://www.stat.auckland.ac.nz/~iase/seri/SERJ10%281%29_Posner.pdf

References - Websites

- CAUSE. http://www.causeweb.org
- Stat-Attic. A compilation of statistics applets. http://sapphire.indstate.edu/~stat-attic/index.php
- Rossman Chance applets. http://www.rossmanchance.com/applets/
- The PARLO Project. http://www.parloproject.org