Opportunities in Statistics Education Research

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Who am I?

- Undergraduate math major
- PhD Operations Research
  - Minor in Education
  - *Behavior Characterization and Estimation for General Hierarchical Multivariate Linear Regression Models*
- Mathematics department, University of the Pacific
- Statistics department, Cal Poly – SLO (1999)

Overview

- What can we learn from the history of statistics education research?
- What kind of research is being done?
  - Classroom based research
  - Qualitative research
- Examples
- Resources/Advice

What can we learn from the "history" of stat ed research?

Beginnings of Stat Ed Research

- Psychology research, Educational psychology, Cognitive science
- Mathematics education
  - International group for the psychology of mathematics education
  - ICME: International congress of mathematics education
  - *JRME: Journal of Research in Mathematics Education*
- Statistics education research
  - IASE: International association for statistical education
  - *SERJ*: *Statistics Education Research Journal*
  - ICOTS: International conference on teaching statistics (USCOTS)

Beginnings of Stat Ed Research

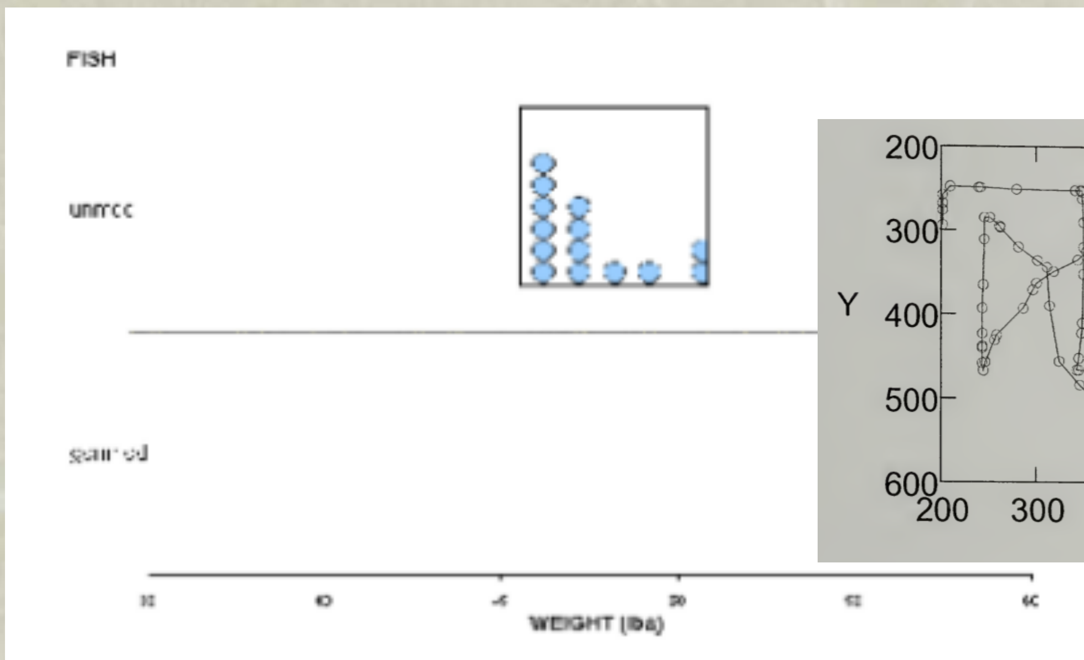
- Initially limited focus
  - Identification of misconceptions
  - Comparison of instructional modes
  - Prediction of achievement
- Rarely focused on statistical reasoning
- Still "straddling two worlds" a bit

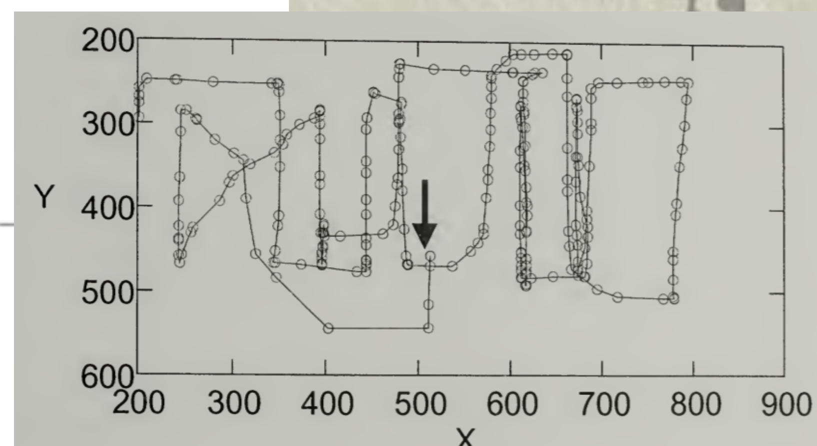
Measurement

- Standardized exams, Final exams, Student ratings
  - Students who earn good grades on final exams often demonstrate poor statistical reasoning skills (Hawkins, Joliffe, & Glickman, 1992)
  - Most existing high-impact standardized exams are poorly aligned with national standards for instruction and assessment (Lesh & Lovitts, 2000)
  - Traditional exams too often emphasize final answer over the process" Garfield (1993)
- If goals change, so must assessment strategies

New kinds of "data"

- Cliff Konold, "The virtues of building on sand", plenary presentation, ICOTS 8, 2010





Research Techniques

- Randomized comparative experiments
  - *Using statistics effectively in mathematics education research* (Scheaffer et al., 2007)
- Cautions
  - long vs. short-term
  - confounding variables
  - realism
  - time delays
  - ethical issues
  - external perspective

Qualitative Research

- *SERJ* special issue: Qualitative approaches in statistics education research (Nov. 2010)
- Standards
  - Validity
  - Generalizability
  - Reliability
  - Objectivity
- Consistent, Replicable, Well-documented, Fair and equitable

Classroom-Based Research

- "Teachers researching their own practice of teaching."
  - Feldman & Minstrell in Kelly & Lesh (2000)
- "It is most simply defined as ongoing and cumulative intellectual inquiry by classroom teachers into the nature of teaching and learning in their own classrooms."
  - Cross and Steadman (1986)

Classroom-Based Research

- Narrows gap between theory and practice
  - direct link to classroom environment
- Further insight into classroom, students
  - combined with nonparticipant viewpoint
- Dynamic
- Open to alternative student interpretations
- Focus on process

To Experiment or Not to Experiment?

- Variety of tools should be employed
  - "Different techniques generate different types of information, and it is often the case that a single technique will not provide the breadth of information necessary to answer unequivocally the research questions under investigation." – Mestre (2000)
  - qualitative and quantitative data
  - observe before manipulate

Human Subjects

- Talk to your institution's Institutional Review Board (IRB)
  - Exemption

Best Practices

- *Handbook of Research Design in Mathematics and Science Education*
  - – Kelly and Lesh, Eds. (2000)
- *International Handbook of Research in Statistics Education*
  - – Ben-Zvi, Makar, and Garfield, Eds. (2018)
- Research agenda/Instruments and Methods

Examples

- 1. Tools for Teaching, Assignment Statistical Inference Project
  - 5-year collaboration with Joan Garfield and Bob delMas
    - Diverse background/perspective
    - Diverse institutions
  - Developed new instructional technology
  - Developed new assessment tools (visual), student interviews

Examples

- 2. Simulation-Based Inference Project
  - 10-year collaboration with Tintle, Cobb, Rossman, Roy, Swanson, VanderStoep
  - Developed new instructional materials
  - Developed new instructional technology (applets)
  - Cross-institutional assessment (pre/post)
  - Workshops for teachers

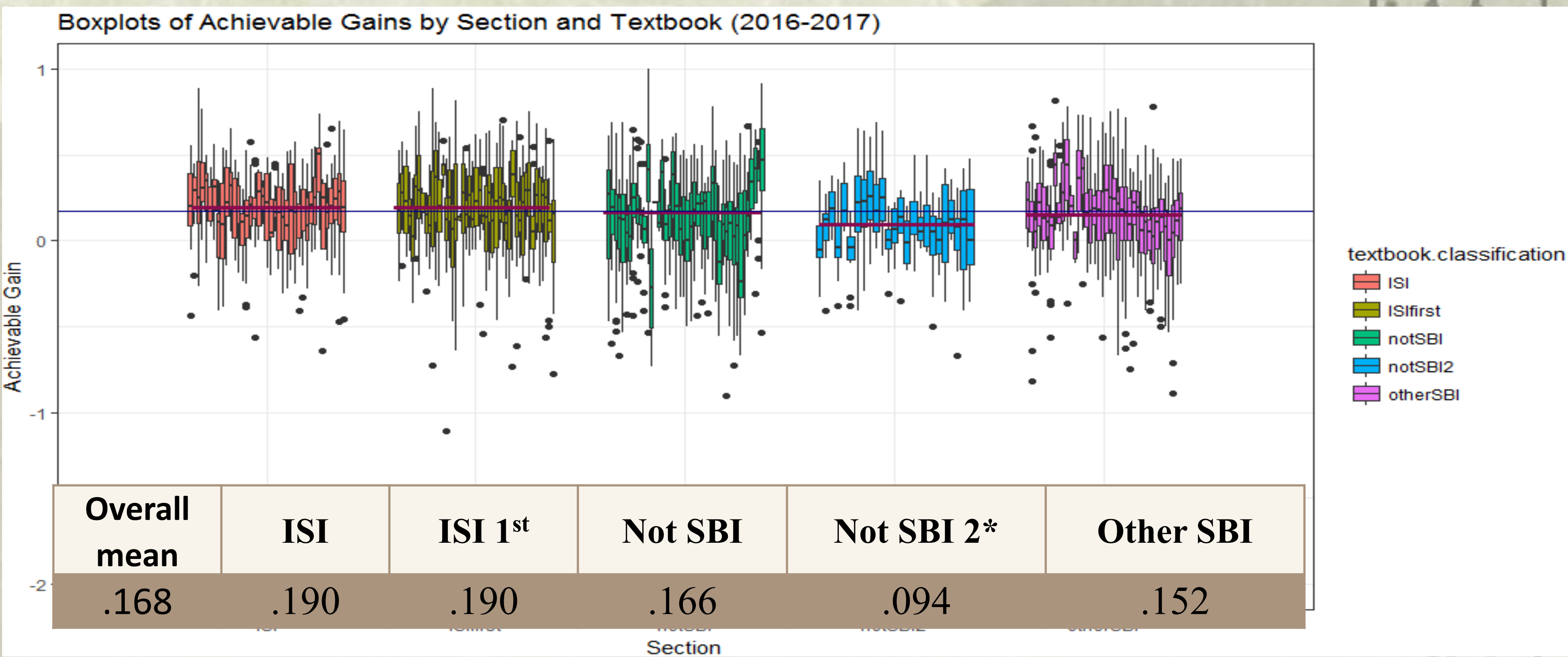
NSF Grants

- CCLI #0633349: *Concepts of Statistical Inference: A Randomization-Based Curriculum,*
- *NSF TUES* Type I Project, Award #1140629: *Developing an Innovative Randomization-based Introductory Statistics Curriculum*
- NSF/TUES/DUE- Phase II, Award #1323210: *Broadening the impact and evaluating the effectiveness of randomization-based curricula for introductory statistics*
- NSF/IUSE/HER #1612201: *Developing and Assessing a Conceptual Approach to an Algebra-based Second Course in Statistics*
- RCN-UBE #1730668: *Statistical Thinking in Undergraduate Biology (STUB) Network: A network for coordinating the teaching and assessment of statistical thinking in introductory biology*

Measurements

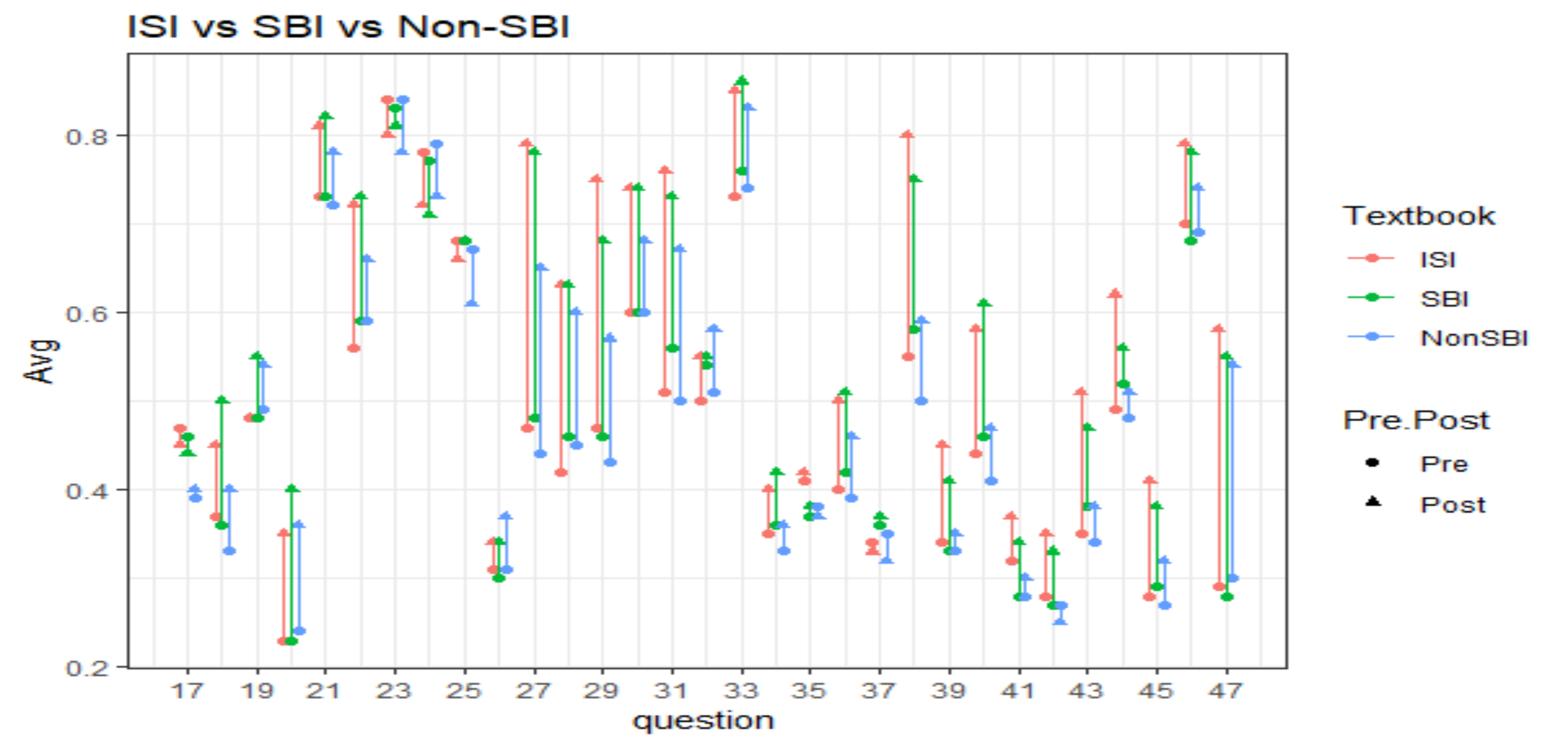
- Multi-institutional assessment pre/post
  - Concept inventory adapted from CAOS
    - Comprehensive Assessment of Outcomes in first Statistics course (see also GOALS)
    - ~35 questions (24 “sets”)
    - National comparison data
  - SATS = Students Attitudes Toward Statistics (Schau, 2003; see *SERJ* special issue – Nov 2012)
    - 6 Subscales (e.g., Affect, Difficulty, Effort, Cognitive competence, Value, Interest)
  - Demographic data

Multilevel Models!



Overall mean	ISI	ISI 1st	Not SBI	Not SBI 2*	Other SBI
.168	.190	.190	.166	.094	.152

Data Visualization



Where to begin?

Key Principles – How students learn statistics

- Garfield (1995), Garfield & Ben-Zvi (2007)
  - Students learn by constructing knowledge
  - Students learn by active involvement in learning activities
    - *Active learning increases student performance in science, engineering, and mathematics*, Freeman et al (*PNAS,* 2014)
  - Students learn to do well only what they practice doing
  - Do not underestimate student difficulty

Key Principles – How students learn statistics

- Garfield (1995), Garfield & Ben-Zvi (2007)
  - Students need to become aware of and confront their errors in reasoning
  - Use technology to visualize and explore
  - Consistent and helpful feedback on their performance
  - Students learn to value what they know will be assessed

Some Current Efforts

- Service learning (e.g., Doehler; Nordmoe; Hydorn; Phelps), Experiential learning (e.g., Morris)
- Context-driven statistics (e.g., Dierker, ProCivicStats, Strengthening Data Literacy across the Curriculum)
- Beyond the first course (e.g., Kuiper; Tintle et al.; Chihara & Hesterberg; Nolan)
- Connections to research (e.g., Son & Stigler)
- Assessment, Adaptive testing (e.g., Beckman; Sabbag; Broaddus; Cheng)
- Interdisciplinary collaboration (e.g., STUB)

Some Current Questions

- Expert vs. Novice
- Student experience vs. instructor demonstration
- Large classes
- Analyzing student interaction with technology
- Preparation of future teachers
- Retention
- Student attitudes
- Statistics vs. Data Science

Advice – Designing a Lesson

- What are the learning goals?
  - What are common student difficulties
- How will I assess whether students have met those goals?
- How does it connect to content before/after this lesson?
- What is an engaging context?
- How/when do I actively engage the students
  - Directly confront student difficulties
- Will technology be helpful?

Advice – Designing a Research Question

- What is my audience?
- What are the learning goals?
  - What are common student difficulties
- What do I plan to do differently?
  - What are my preconceptions?
- How does it connect to prior research?
- How will I assess whether students have met those goals/whether it works?

Advice – Designing a Research Study (Grant)

- Familiarize yourself with the research, assessment tools
  - NSF Award Search
- Connect with others (e.g., causeweb.org)
  - Across institutions
  - Across disciplines
  - New and "Old" folks
- Talk with program officer
- Be open to alternative research methodologies
  - Synergy with your "real" research

e.g., NSF grant funding

- The IUSE program (formerly TUES) at the National Science Foundation supports curricular innovation, experimentation, and implementation

Track	Level
Engaged student learning	Level 1/Level 2/Level 3
Institutional and community transformation	Capacity building/Level 1/Level 2

Summary

- Look to history
- Importance of collaboration
- Student involvement
- Not all randomized experiments
  - Qualitative research, Think-aloud protocols, Learning trajectories, Classroom-based research
- New measurement tools
- Not only about students
  - Teacher preparation
  - Role of technology in teaching
  - Integration with data science, other disciplines

Any Questions?

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1. Tools for Teaching, Assessing Statistical Inference Project (Garfield, delMas, Chance)

- Can interaction with simulation program improve student reasoning about sampling distributions?
  - how to best integrate technology into instruction
  - why particular techniques more effective
  - how student understanding evolves

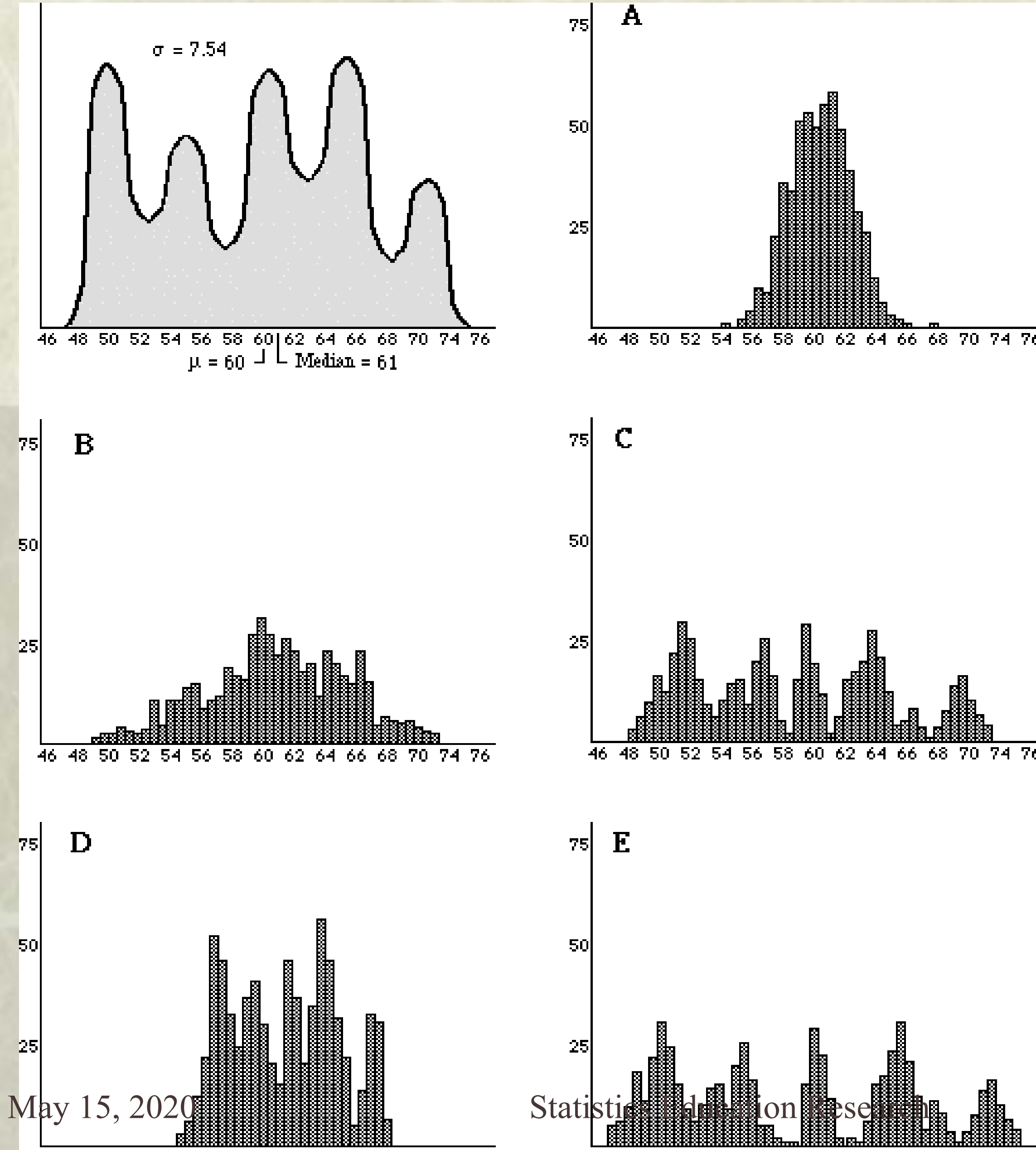
This project was supported, in part, by the National Science Foundation, DUE-9752523

Methods

- Diverse tertiary environments
  - private liberal arts college, college of education, developmental education college
- Diverse student groups
- Researchers with diverse backgrounds
- Creation of desired learning environment
- Incorporation of existing theory
- Generating new models

Measurements

- Graphics-based test items
- Open-ended questions, justifications
- Multiple choice categorizations
- Pre-test vs. Post-test performance
- Post-test application problems
- Using assessment to create dissonance
- In-depth interviews and videotape analysis


σ = 7.54
46 48 50 52 54 56 58 60 62 64 66 68 70 74 76
μ = 60
Median = 61
A
B
C
D
E
75
50
25

n=1?

n=4?

n=16?

n=25?

Student interviews/Videos

"I'm going to go for C for n=4 and then 16 for … n=16 for A. And partially because … with n=4, I'm thinking you are going to have a larger range … yeah, a larger range for n=4 than that you would for n=16.

Student interviews/Videos

"Because before I was guessing and I thought that the standard deviation for a larger sample size would be closer to the original than the standard deviation for n=4."

Meeting the Standards

- Validity: prolonged investigation, immersion, triangulation, member checks
- Generalizability: extensive description, multi-site design
- Reliability: multiple perspectives, participant involvement
- Objectivity: documentation, dissemination
    - "acknowledged and controlled subjectivity"

Additional Benefits

- Narrows gap between theory and practice
  - direct link to classroom environment
- Further insight into classroom, students
  - combined with nonparticipant viewpoint
- Dynamic
- Open to alternative student interpretations
- Focus on process

1. Tools for Teaching, Assessing Statistical Inference Project (Garfield, delMas, Chance)

A model of classroom research in action: Developing simulation activities to improve students’ statistical reasoning

Article (PDF Available) *in* Journal of Statistics Education 7(3) · January 1999 *with* 396 Reads

2. Simulation-Based Inference Project (Tintle, Cobb, Rossman, Roy, Swanson, VanderStoep…)

- Does use of simulation-based inference in introductory statistics courses improve students' ability to learn statistics and/or students' attitudes towards statistics
  - Curriculum materials
  - Technology tools
  - Assessment
  - Dissemination
  - NSF grants:

Methods

- Web-based applets
- Textbooks
  - Process, Spiraling, Active learning, Assessment
- SBI Blog (www.causeweb.org/SBI)
- Workshops for teachers