

The Theory Behind the Statistical Thinking Approach

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Beyond the Formula – August 2004

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The Theory Behind the BYU Experience

Some important facts:

- The BYU experience was not the result of random “hit or miss” innovation.
- Gale did not “get lucky”.
- This course design was guided by current educational and behavioral research.
- Traditional statistical education violates most principles of such research.

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The Theory Behind the BYU Experience

Some principles of educational and behavioral research:

- Education, and especially training, should always be based on achieving a specific, relevant, purpose.
- Introductory courses cannot cover the details of an entire discipline in one or two semesters. Rather, such courses should focus on the fundamental concepts and methods of a discipline, leaving the details to subsequent courses.
- The sequence in which topics are covered is very important to students’ comprehension.
- People learn in different ways. Therefore, over reliance on one mode of learning, e.g., lecture, will typically not suffice. Many people learn best by actually doing something, preferably by doing it repeatedly with feedback.

We don’t have to invent theory here, just use it! ³

The Theory Behind the BYU Experience

Four relevant areas of educational and behavioral research:

- Purpose
- Content
- Sequence
- Learning Methods

Each area must be considered to improve statistical education.

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The Theory Behind the BYU Experience

Why most traditional courses fail:

- There is generally no stated purpose.
- The unstated purpose drives a content focused on presenting as many techniques as possible, with emphasis on the math versus conceptual understanding.
- The sequence of topics is often haphazard, or a “bottoms-up” approach, which is known to be a poor sequence.
- The teaching method is typically: lecture-memorize-regurgitate-forget. Students become good at this.

The revised courses have made noteworthy improvements in the second and fourth areas.

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The Theory Behind the BYU Experience

What type of purpose makes sense?

- What do employers in business and industry want from intro course graduates?
 - Have a continuous improvement mindset
 - Can study and improve processes
 - Understand variation and can apply the concept
 - Can effectively use graphical analysis techniques
 - Believe in data based decision making
- What skills do students need for future courses?
 - Understand statistical lingo and concepts
 - Can handle more advanced statistical material

The purpose should be to develop this knowledge, skill, and attitude.

The Theory Behind the BYU Experience

What content would achieve this purpose?

- Content focused on developing understanding of key statistical concepts:
 - Any activity can be studied, and the results improved (“All work is a process”)
 - Appropriate data help us “study and improve”
 - Variation exists in all data and activities (“Variation happens”)
 - In many cases, reducing variation is the key to improvement, even when the objective is to move the average (i.e., in golf)
- Many people call this stuff “Statistical Thinking”.
- Content must also develop tangible skills in basic tools, and provide a basic theoretical background (not formulas).

These concepts go beyond the data analysis concepts in “revised” courses.

The Theory Behind the BYU Experience

Some important concepts missed even in the revised courses:

- Statistical thinking can be applied by anyone to everyday situations – it is not a “spectator sport”.
- Real applications are iterative – not “one shot studies”. Therefore, practitioners must integrate several individual tools into overall approaches to improvement.
- Statistics as a discipline only works if it is well integrated with subject matter knowledge. This integration process can be taught (deduction – induction cycle of GEPP).
- Most real applications involve sampling from dynamic processes, not static populations. This requires a process orientation to statistics (all work is a process).

We are only aware of one text that emphasizes these concepts.

The Theory Behind the BYU Experience

What does current research say about sequencing topics?

- Educational and behavioral research (Mager 1988, Forester 1990) suggests that learning is easiest when instruction flows:
 - From the big picture to the details (whole to parts), also called “top-down” instruction
 - From applications to theory (tangible to abstract)
 - From developing gross conceptual understanding to developing fine, tangible skills (gross to fine)
- The typical drivers’ education course is one example which follows this research.

Introductory statistical education is typically sequenced just the opposite.

The Theory Behind the BYU Experience

One practical approach to utilizing the research:

- Why should I care? (gross conceptual understanding)
 - Explain the context and relevance of the topic
- What is it? (big picture)
 - Sequential case studies (tangible whole)
 - Conceptual high-level model (abstract whole)
- How do I do it? (details of parts – fine skills)
 - Detailed instruction on how to use the tools
- The text, BYU course, and this workshop all followed this sequence

This sequence is very logical and is consistent with research recommendations.

The Theory Behind the BYU Experience

What learning methods should be used to reach everyone?

- Lecture – learn by hearing
 - Still appropriate, but used less often
- Case study review – learn by example
 - Allows students to see application of concepts
- Reading assignments – learn by reading
 - Students can go at their own pace
- Conceptual model review – learn by seeing
 - “A picture is worth a thousand words”
- Open discussion – learn by interacting
 - Sharing of ideas often helps clarify concepts
- Experiential exercises – learn by participating
 - I hear, I forget; I see, I remember; I do, I understand
- Course project – learn by doing (for real)
 - Real projects, real issues

Only lecture and experiential exercises (revised courses) have been typically used.

Your turn:

What do you think?

A Statistical Thinking Approach to Introductory Statistics: Theory and Practice

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A Statistical Thinking Approach

Why Focus the Intro Course on Statistical Thinking? (The Theory)

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Why Focus the Intro Course on Statistical Thinking?

The Problems

- Statistical thinking and methods
 - Not valued by students, and society in general
 - Gap exists between “Actual” and “Potential” use
- Feelings of many people
 - Statistics is complex, abstract, boring, not relevant
 - “I can never remember the formulas”
 - “I can never get the right answers”
- Bottom line -
 - There is general agreement that the introductory course is inadequate and needs to be replaced

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Why Focus the Intro Course on Statistical Thinking?

The Statistics Profession Responds

- Numerous improvements implemented
 - Focus on concepts versus formulas
 - Use of real data and examples versus “textbook problems”
 - Use of class exercises and other experiential learning
- Unfortunately, many problems remain
 - No underlying theory or clear course objectives to guide revisions
 - Statistics still depicted as something “others” do
 - Students still see a “collection of tools” – no unifying “big picture”
- Bottom line – Good start, but we have a long way to go!

Why Focus the Intro Course on Statistical Thinking?

How Do We Solve This Problem?

Use first 3 steps of our Problem Solving Model

- What’s the Problem?
- What are the Causes of the Problem
- What’s the Solution?

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Why Focus the Intro Course on Statistical Thinking?

Students Still Have Problems Seeing How Statistics is Relevant to Them

- Emphasis is on individual tools – how do they fit?
- Statistics is viewed as something “interesting” rather than something “useful”
 - Ex: Salk Polio Vaccine, Draft lottery, Drug efficacy
 - Statistics only proves what we already know
 - Students see themselves as “Consumers” of statistics rather than “Producers” of statistics
- Focus is on static populations rather than dynamic processes - which affect us all and need improvement
- Focus is on one-shot “tests” rather than sequential applications - which is our reality

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Why Focus the Intro Course on Statistical Thinking?		
<u>Key Differences Between Approaches</u>		
<u>Category</u>	<u>Reformed Approach</u>	<u>Transformed Approach</u>
<i>Course Goal</i>	Unstated, or exposure to numerous tools	Knowledge, skills, attitude
<i>Statistics conveyed as:</i>	Interesting (consumer role)	Useful (producer role)
<i>Context of Data</i>	Static populations	Dynamic processes (SMT*)
<i>Applications</i>	One-shot studies	Sequential, iterative cases
<i>Organization</i>	Bottom-up; individual tools first, tie together at end	Top-down; overall approaches first, then tools

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*SMT - Subject Matter Theory

Why Focus the Intro Course on Statistical Thinking?
<u>Our Suggestion for Your Consideration</u>
<ul style="list-style-type: none"> • Current unstated objective - making intro students “experts” in all statistical methods <ul style="list-style-type: none"> - Is not a realistic expectation • Business world does not need or expect this. • Business world wants people who <ul style="list-style-type: none"> - Have a continuous improvement mindset, - Can study and improve processes, - Understand variation and can apply the concept, - Can effectively use graphical analysis techniques, - Believe in data based decision making.

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Why Focus the Intro Course on Statistical Thinking?
<u>Suggestion (cont'd)</u>
<ul style="list-style-type: none"> • Appropriate objectives that emphasize understanding of, and ability to apply, key concepts, would better: <ul style="list-style-type: none"> - Satisfy business customers, and - Set the stage for future, more advanced courses taught by academic customers. • Benefit - Students would: <ul style="list-style-type: none"> - Understand why they are learning a technique, - What it actually does, and - When it would be appropriate to use it. • These benefits are typically glossed over or totally missed in the traditional course focused on mechanics.

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Why Focus the Intro Course on Statistical Thinking?
<u>Suggestion (cont'd)</u>
<ul style="list-style-type: none"> • So what are the key changes in the students’ “view of the world” that we should be creating in the intro course? <ul style="list-style-type: none"> - All work is a process - any activity can be studied, and the results improved. - “Variation happens” - variation exists in all activities and all data. - Appropriate data help us “study and improve”. - In many cases, reducing variation is the key to improvement, even when the objective is to move the process average (i.e., in golf). • Many people call this stuff “Statistical Thinking”.

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Why Focus the Intro Course on Statistical Thinking?
<u>An Example of Such a Mindset Change</u>
<p>“ I was introduced to Statistical Thinking in October, 1988 when I attended Heero Hacquebord’s course on “Statistical Thinking for Leaders”. I went into the course thinking that I already knew everything I needed to know about SPC. I came out of the course with a whole new perspective on statistics, looking upon SPC and other statistical applications more as a way of thinking about processes so we can learn how to improve them. I also found that I could never again be satisfied with looking at numbers without graphical analysis”.</p> <p style="text-align: right;">Tom Pohlen (Chemist at 3M)</p>

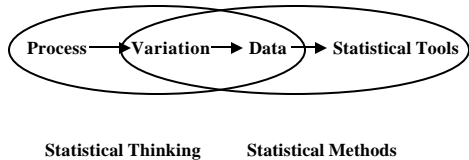
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Why Focus the Intro Course on Statistical Thinking?
<u>What is Statistical Thinking?</u>
<p>Statistical Thinking is a philosophy of learning and action based on the following fundamental principles:</p> <ul style="list-style-type: none"> •All work occurs in a system of interconnected processes •Variation exists in all processes, and •Understanding and reducing variation are keys to success

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Source: Glossary of Statistical Terms, ASQ Quality Press

Why Focus the Intro Course on Statistical Thinking?

Relation Between Statistical Thinking and Methods



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Why Focus the Intro Course on Statistical Thinking?

Value of Using Statistical Thinking

- Process focus provides the context and relevancy for using statistical methods
 - How we do our work for our customers
- Results in broader and more effective use of statistical methods
 - All parts of the organization
 - Manage and improve processes
 - Guide strategic and managerial action
 - Provides “suction” for statistical methods

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Why Focus the Intro Course on Statistical Thinking?

Summary

- *Problem*
 - Lack of value for statistical thinking and methods
 - Missed opportunities for students and employers
- *Causes* - Introductory statistics courses
 - Do not match the needs of today
 - Are not taught in an interesting way
- *Solution*
 - Focus content on Statistical Thinking
 - Improve the delivery of the course

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An Introductory Course in Statistical Thinking
at Brigham Young University

- What is different?
- Student Reactions
- Student demographics
- Course structure
- Lectures and labs
- Term project
- More Student Reactions

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What is different?

- Typical Introductory Statistics Approach
 - Numerical and Graphical Summaries
 - Probability and Distributions
 - Inference- Tests and Confidence Intervals
 - Simple Linear Regression
 - One-Way ANOVA
 - “Plug and Chug”

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What is different?

- The Statistical Thinking approach
 - Focus on process
 - Broad concepts before specifics
 - Case studies
 - Complete, not one shot
 - Wide variety of applications and tools
 - Focus on applications, not computations
 - Plus all the normal concepts using statistical software.

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In-Class Essays

This essay will not be graded.
You are not required to put your name
on your paper.

Please write a short essay on your thoughts
and feelings concerning your experience in
this course. Anything is fair game, the
approach, the book, the instructor, the labs,
or anything else you think of.

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Comments From Essays

- I came into this class thinking that statistics is just plug-and-chug math. I did not realize that it is really a way of thinking and learning.
- We didn't spend excessive amounts of time learning and memorizing formulas that we'll forget anyway.
- It's one of the few classes that I've taken that seem relevant to my everyday life. It makes me look at everyday situations in a different light.

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Student Demographics

- Statistics 221 –Principles of Statistics
- In 2002
 - 5 Females, 32 Males
 - Mostly Sophomores and Juniors
- A Variety of Majors

Major	Number	Enrolled
	2001	2002
Business (Pre-Mgt)	4	24
Sciences	11	1
Social Sciences	5	5
Open/Undeclared	4	7
Total	24	37

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Course Structure

- Lectures
 - 2001 -- 42 fifty minute lectures, MWF
 - 2002 – 28 eighty minute lectures, TTH
- One fifty minute lab period each week
- Three mid-term exams and a final exam
- Required term project
- Weekly homework assignments

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The Lectures

- Followed the textbook closely
 - Covered entire textbook
 - Most transparencies taken from the text
- Tied lab activities into lectures
- Primarily lecture/discussion
- Some in-class activities.

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The Labs

- Conducted by Teaching Assistants
 - Weekly preparation meetings
 - Detailed instructor's manual for each lab.
- Student Lab manual with exercises
- Data collection activities in 6 of 14 weeks
- Remaining labs used for:
 - Analysis of data from data collection activities
 - Instruction on the use of Minitab
 - Help on challenging homework exercises

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Data Collection Activities

- “Wordprint” Data Collection
- Deming’s Red Bead Exercise
- Measurement Variation
- Regression of Weight on Height
- Catapult Experiment
- Distributions

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The Term Project

- Required (20% of final grade)
- Proposals for projects required
- Work in teams or as individuals
- Project updates
 - About every two weeks
 - Required and graded each

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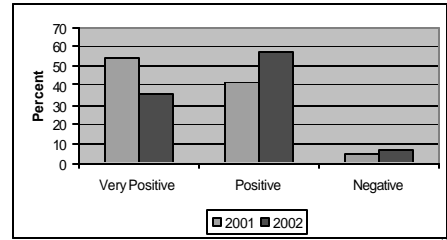
Comments From Student Reports

- I have been trained in my science classes to use the tradition OFAAT approach, and I am currently using it in a project that I have already started for my honors thesis. However, I never would have observed the interaction between garlic and bad oil if I had tested each factor independently of the others.
- I have found that I cannot simply make assumptions. I was surprised by some of the data. The busiest months and days were not the ones I would have guessed. In fact, everyone was a little surprised.

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Student Reactions from In-Class Essays

- Subjective Analysis of **Attitude about Statistical Thinking**



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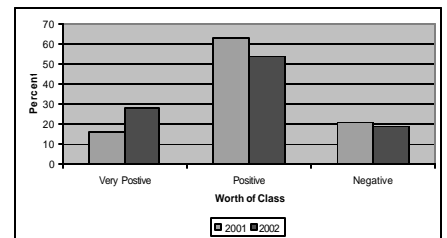
Comments from In-Class Essays

- **Very Positive**
 “I find myself using statistical thinking in areas that would have seemed ridiculous 10 weeks ago. Even though I still don’t plan on converting to ‘statisticandom’ I am thankful to have taken this course and I know that it will help me in many ways throughout my life!”
- **Positive**
 “I realized before the class that statistics would be useful in my career. Now I can actually envision using the principles myself. Before it was a concept, now it is a reality.”
- **Negative**
 “I am interested in using statistics in a different way. I want to increase understanding, not eliminate variation. I am interested in human subjects, not economic growth. The ideas in this course don’t seem to apply to me.”

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Student Reactions from In-Class Essays

- Subjective Analysis of Feelings about the **Worth of the Class**



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Student Reactions from In-Class Essays

- **Very Positive**

“I am truly disappointed that this is not a required course. I can easily compare it to the 7th grade life skills course; common sense is being taught to common people for use in common situations. If students were required to take this course, the world would be a better place.”

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Student Reactions from In-Class Essays

- **Positive**

“At the end of this course, my outlook on processes and ways to analyze these processes has changed tenfold. This course not only introduced the concepts, but also taught how to apply them.”

- **Negative**

“This has been my most frustrating and not-enjoyed class of my college career yet. I understand the importance of statistics, but it may be awhile before I ever consider another course.”

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Comments on the “Other” Stat 221

- Every one I have talked to has mentioned how miserable statistics is. Their memories of the class are painful more than anything. My reaction thus far is quite the opposite.
- I am somewhat familiar with the other Stat 221 course and I feel that in comparison Statistical Thinking 221 is more meaningful and applicable to life.
- I enjoy learning how statistical thinking can be applied directly to business processes. I have friends in other sections of Stat 221 and they complain to me that they are not learning anything.

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