How Well Do Required Statistics Courses Prepare Students for Higher Level Science?

The Undergraduate Statistical Education Study

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INTRODUCTION

Statistical Literacy:

- Defined by Wallman (1993) as "ability to understand and evaluate statistical results that permeate everyday life"
  - Considered key component of modern citizenship
  - Becomes increasingly important over time
- Is the basic minimum threshold for understanding and interpreting results of scientific experiments.
  - Is that threshold enough?

Undergraduate Science Majors

- Need to have a higher level of statistical fluency
  - English Majors don't *just* meet literacy requirements in English
  - Ability to go beyond comprehension and analyze
- Ben-Zvi & Garfield (2004): Levels of Statistical Literacy Framework
  - Statistical Literacy: Understanding statistical results presented
  - Statistical Reasoning: Effectively using statistics to communicate
  - Statistical Thinking: Understanding how/why to conduct analyses

Introductory Statistics Courses

- Required to major in most physical, social, and computing sciences
- Offered in multiple formats across departments
  - Common content considered "essential"
- Assessed at the Statistical Literacy Level
  - Lecture content does go to higher levels
  - But to students internalize higher level skils?
  - Do the skills generalize?

PARTICIPANTS & PROCEDURE

Participants

- 136 Students recruited from STT 211 & STT 212 class
  - Collection continues in remaining classes
- Student Demographics:
  - 45% Male
  - 71% Native English Speakers
  - Status: 10% Freshman; 56% Sophomore; 20% Junior; 14% Senior
  - Majors: 40% Economics/Business; 33% Physical Sciences; 15% Social Sciences

Procedure

- Optional review session given within 1 week of exam covering the same topics
  - Recruitment Incentives: Extra credit for attending review
  - Students assessed when they're maximally familiar with material
- Session format:
  - Review gave assessment questions and then reviewed them with class
  - Interested participants were able to opt into the research study
  - Declining participants left ID field & demographics blank (packets destroyed)
- Assessment of interested participants then linked to their exam scores

Measures

- Questions representing 3 content areas:
  1. Categorical differences (Chi-Square)
  2. Group Differences (t-tests)
  3. Principles of Hypothesis Testing (Interpreting *p-values & significance)*
- For each content area, 3 questions were asked:
  a) Application Qs: Literacy questions from old exam nested in language from an actual current article.
  b) Reasoning Qs: Retrieved from ARTIST inventory (Garfield et al., 2005)
  c) Thinking Qs: Retrieved from ARTIST inventory (Garfield et al., 2005)
- Questions selected to minimize calculation

Scoring Criteria

- Grading criteria designed after holistic reading of all responses by first author (DC)
  - Points granted for specific desired features of answer (e.g., One point for each axis of requested table)
- Validation: Each criterion individually correlated with students' exam averages
  - Dropped any criterion where $r < .1$ (uncorrelated with exam performance)
  - Questions with no remaining criteria excluded from present analyses
    - 2/9 questions dropped this way
    - Still 2 or more questions for each type & content category
- Criteria averaged within each question *type* to identify % of possible points earned

RESULTS

Identifying Predictors of Exam Performance

- Uncorrelated: Native English, Major, & HS Statistics Exposure
- SAT, Class year, & Hours Studying do not significantly predict exam scores in multiple regression **when controlling for current GPA**
- Therefore: GPA the only relevant covariate

Means and Correlations of Variables in the Analysis

Variables	Mean	GPA	Exam	Reason	Thinking
GPA	**3.44**				
Exam Grade (Literacy)	**90%**	**.596****			
Reasoning Questions	**67%**	**.327****	**.344****		
Thinking Questions	**31%**	**.269****	**.151**	**.142**	
Application Questions	**41%**	**.127**	**.259****	**.388****	**.080**

Note. * = p<.05; ** = p<.01

GPA & Exam Scores Predicting Performance by Type

Predictors	Application	Reasoning	Thinking
GPA	-.043	.189	**.278***
Exam Grade	**.284***	**.231†**	-.014
R^2	.07	.14	.07

Note. **† = p<.10; * = p<.01**

CONCLUSIONS

Do statistical literacy skills generalize into applied contexts?

- **YES!** Exam scores positively correlated with performance on application questions
  - Indicates development of literacy in class prepares students to read articles
- **HOWEVER:** Performance on application questions was 41%
  - Suggests that while literacy-in-context utilizes same skills, it is more difficult
- IMPLICATIONS: Students need to develop familiarity with field-specific language
  - A reasonable amount of practice will likely bridge this gap
  - Practice could occur simply by participating in upper-level science courses

Do statistical literacy skills generalize into statistical reasoning skills?

- **SORT OF:** Exam scores positively correlated with performance on reasoning q
  - Correlation diminishes when controlling for prior academic achievement
- **RELATIVELY STRONG:** Students earned 66% possible points
  - Students DO complete reasoning tasks during the semester (HW)
  - Professors DO describe reasoning problems during class (Class Examples)
- IMPLICATIONS: Reasoning skills emphasized; students are not held accountable
  - High achievers commit to learning, studying, retaining information
  - Other students may neglect material that "Won't be on the final"
  - Assessing, diagnosing, and addressing difficulties might close the gap

Do statistical literacy skills generalize into statistical thinking skills?

- **NO:** Exam scores uncorrelated with performance on thinking questions
  - Only predictor of thinking question performance is prior achievement
- **POOR PERFORMANCE:** Students earned 31% possible points
  - Common comment: I can use *p*-values, but I don't ***know*** what they are
  - Statistical thinking described in lecture, but not in interactive ways
- IMPLICATIONS: Thinking skills are underemphasized
  - Prior academic achievement above/beyond class score predicts statistical thinking abilities
  - Suggests students are developing thinking skills outside of the classroom
  - If statistical thinking is expected in higher level courses, students need:
    1. Required higher level stats classes
    2. Stats focused research methods classes
    3. Stats review & explicit discussion in higher level content courses

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