GAISE 2024 Proposal:
Three Introductory Statistics Courses

Abstract: To better meet the needs of today's college students, the 2024 GAISE update should acknowledge the need for and the teaching of three kinds of introductory statistics. College students can be classified into three groups: Those in non-quantitative majors (consumers), those in quantitative majors that don't need programming skills (analysts) and those in majors or courses that involve programming skills (producers). The idea that a single introductory statistics course can satisfy the quantitative needs of these three groups of students seems naively idealistic. By acknowledging these differences in student needs, the guidelines can make targeted recommendations.

Here is a proposal for the three different kinds of introductory statistics: Stat 100 Statistical Literacy, Stat 101 Traditional (Formulaic or "Normal") Statistics, and Stat 102 Data Science Statistics. Stat100 (Statistical Literacy) would focus on every-day (observational) statistics, multivariate thinking, confounding and "taking into account" using simple techniques as shown in the 2016 GAISE update. Stat 101(Traditional or "Normal Statistics") would focus on using analytic models to analyze random variation, confidence intervals, p-values and statistical significance. Stat 101 has been taught worldwide since the 1950s. Stat 102 (Data Science Statistics) would focus on using computers to produce, manipulate and summarize data, and on using simulation to generate statistical summaries and inference.

BACKGROUND:

The January draft of the 2024 GAISE update (Appendix A) noted that the final report will include:

- Student Learning Objectives for Intro Stats
- Student Learning Objectives for Intro Data Science

The recommendations are nicely broad and at a high level. Here are two good features.

1. Draft avoids making "multivariate thinking" a goal of all introductory statistics courses. There is very little room in teaching the standard statistics course to include multivariate thinking.
2. Draft proposes two kinds of introductory statistics: "Intro Stats" and "Intro Data Science." This is a major improvement. The idea of having "one size fits all" is long overdue.

This draft overview of the 2024 GAISE update raises several issues:

1. No mention of statistical literacy which was featured in the first and second GAISE reports.
2. No mention of multivariate thinking which was featured in the 2016 GAISE-2 report.
3. No mention of confounding which was featured in an appendix in the 2016 GAISE-2 report.

Appendix B provides some history on each of the first three issues.

The Introductory Statistic Course

The introductory statistics course has a dual mandate. One mandate is for the course to satisfy a requirement for those majoring or minoring in statistics. The other is to satisfy a mathematics requirement in the General Education curriculum. Some majors offer separate courses to untangle this overlap. For example single-mandate courses like music appreciation, astronomy, geology and mathematics for liberal arts satisfy a general education requirement, but do not satisfy a requirement for the major. Statistics uses the same introductory course to satisfy both mandates. In introductory statistics, the primary focus is usually on preparing students for future courses in statistics. Far less attention is given to the quantitative needs of the other students.

Quantitative Needs of College Students.

One way to design the introductory course is to present the ideas and content that are most fundamental to subsequent courses in statistics. Another way is to start with the quantitative needs of all college students.

Statistical educators tend to do the former. Given the diversity of college students, consider the latter.

What is the distribution of college students by math requirement? A survey like this cannot be located. However, the results can be estimated since many majors require a particular mathematics course for all their students. Figure 1 summarizes the data presented in Figure 3 in Appendix C.

50% are required to take Statistics	15% take Calculus*	**35% have no specific Math requirement**

* or Discrete or Finite Mathematics

Figure 1: Distribution of College Students by their Math Requirement

What is the distribution of college students by the type of statistical studies most commonly encountered? Again, there is no survey on this. These results can be estimated by subjectively assigning a primary and secondary type of study to each major or to various groups of majors. Figure 2 summarizes the data shown in Figure 6 in appendix C. Note that these numerical results are based on subjective estimates.

Observational Studies 50%	**Randomized Controlled Trials (RCT) 30%**	**Quasi-Experiment 20%**

Figure 2: Distribution of College Students by Most Common Type of Study Encountered

Note that surveys and sampling are not shown as a separate category. These are methods for gathering data. They can be used by every kind of study: experimental or observational. The traditional Stat 101 course with its focus on random sampling covers the population inference need of all students. And by introducing randomized controlled trials, the traditional Stat101 course satisfies the causal inference needs of 30% of college students, but not the statistical needs of the other 70%.

What quantitative courses are available for the 70% who are unlikely to deal with statistical research or clinical trials?

Those students generally have two choices: traditional introductory statistics, or math for liberal arts. Both require algebra or higher and don't address the quantitative needs of the 70% of all college students.

In some colleges they will have three choices: those two and quantitative literacy. Depending on the quantitative literacy course, it may be more helpful than the other two. But none of these address the statistical needs of the 70% who deal primarily with observational studies or quasi-experiments.

Stated differently, 70% of college students graduate without having their statistical needs fully addressed in introductory statistics.

Based on this analysis, here are two recommendations:

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Recommendation #1: Offer Three Introductory Courses

To maintain continuity with the two previous GAISE reports, to better describe the growing methodological spread within statistics (analytic vs. simulation), and to better meet the diverse needs of all college students, the 2024 GAISE-3 update should support three kinds of the introductory course:

- Stat 102: Data Science Statistics. For data producers: data acquisition, manipulation, summarization, resampling and simulation. For students in data science majors.
- Stat 101: Classic/analytic statistics. For professional consumers/analysts. Focus on analytic population inference with univariate & bivariate data (two-group or two-factor data.) May also use or include resampling. Supports the statistical needs of client department.
- Stat 100: Statistical Literacy. For consumers. Big ideas: correlation-causation, randomness and confounding as major obstacles in using statistical correlations as evidence of causal connections. Effect size and study design as techniques that control confounding. Describing and comparing percentages and rates (conditional probabilities) in tables and graphs along with the confusion of the inverse. The influence of randomness: margin of error and statistical significance. For students in non-quantitative majors. May be useful for sociology majors and for business students in management and marketing. Software is optional. An MAA survey indicated that about 20% of colleges reporting were teaching some form for statistical literacy. (Schield, 2010).

Textbooks are available for each of these three kinds of introductory statistics.

Stat 102 textbooks.

- *Practical Statistics for Data Scientists: 50+ Essential Concepts Using R and Python* 2nd Edition by Bruce, Bruce and Gedeck
- *Statistics for Data Science: Leverage the power of statistics for Data Analysis, Classification, Regression, Machine Learning, and Neural Networks* by Miller
- *Foundations of Statistics for Data Scientists: With R and Python* (Chapman & Hall/CRC Texts in Statistical Science) by Agresti and Kateri

Stat 101: The vast majority of introductory statistics textbooks.

Stat 100 textbooks:

- *Statistics* by Freedman, Pisani and Purves:
- *Concepts and Controversies* by Moore (early editions) and Notz (current editions)
- *Seeing Through Statistics* by Utts
- *Statistical Reasoning For Everyday Life* by Bennet, Briggs and Triola
- *Statistical Literacy* by Schield

A new textbook that may span all three areas is *Statistical Modelling: A Fresh Approach* by Kaplan.

If the 2024 GAISE update committee wanted to go further, here is a second recommendation.

Recommendation #2: Restate the #1 goal.

Goal: Teach statistical thinking about statistical inference

- Population inference and randomness
- Predictive (data) inference and multivariate modelling
- Causal inference, multivariable data and confounding

Multivariable thinking for causal inference is very different from multivariable thinking for predictive inference. In predictive inference, adding a new variable may change the size and direction of the existing predictors, but so long as it increases the adjusted R-squared, no one really cares. But, in causal inference, multivariate analysis is needed to separate the influence of measured confounders. Changing the size or direction of an existing predictor can be a very big deal (c.f., Simpson's paradox).

Confounding is almost irrelevant in predictive inference; confounding is central in causal inference. Statistical educators must recognize that while the idea of confounding (confusing) is quite old, the idea of a confounder (a confuser) in the public media is quite new. See Appendix D.

This classification of the three kinds of statistical inference ties out nicely with the three kinds of introductory statistics that were previously presented.

Three different courses:

- Stat 101 Classical Statistics: Population inference
- Stat 102 Data Statistics: Predictive inference
- Stat 100 Statistical Literacy: Causal inference

However, this involves a narrowing of focus in the statistical literacy course. This is both good and bad. Good in that it clearly addresses the quantitative need of many – if not most – college students who see observationally-based statistics used as evidence for causal claims. Bad in that it eliminates most statistical literacy textbooks since it requires a major focus on observational studies, confounding, effect size, study design, 'taking into account' and the Cornfield conditions. Schield (2024a and 2024b)

Adopting this second recommendation would greatly advance the utility of introductory statistics for the majority of college students. Teaching students what it means to "take something into account" quantitatively is arguably more valuable that focusing on the difference between independent and dependent samples in a two-t test. Teaching students the difference between a "crude comparison" (a mixed-fruit comparison) and an "adjusted comparisons (an apples and apples comparison) is arguably more valuable than focusing on the influence of different levels of confidence in forming confidence intervals.

The 2024 GAISE update committee can take a major step forward by implementing recommendation #1.

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GAISE 2024 Draft:
College Recommendations

January 2024

Recommendations for Statistics and Data Science

1. Foster the learning of statistics and data science as a process of deriving information from data, leading to greater insights and better decisions.

2. Focus on key conceptual ideas while reducing the focus on algebraic manipulation and formulas.

3. Integrate real data with a context and purpose throughout the course. Where possible, select data that are meaningful and engaging to the students.

4. Implement evidence-based pedagogies that actively engage students in the learning process.

5. Incorporate statistical software/apps to explore concepts and analyze data.

6. Use a variety of formative and summative assessments to improve teaching and learning.

7. Focus teaching and learning on effectively and accurately communicating the scope and limitations of conclusions drawn from data.

8. Infuse course design and implementation with inclusive strategies that create a sense of belonging.

9. Incorporate ethics throughout the curriculum, as described in the ASA document Ethical Guidelines for Statistical Practice.

In addition to the draft Recommendations for Statistics and Data Science listed above, we anticipate that the final College GAISE report will also include the following:

- Student Learning Objectives for Intro Stats
- Student Learning Objectives for Intro Data Science

These will also be shared in draft form for feedback as they begin

Appendix B: History Statistical Literacy, Multivariate Thinking and Confounding

#1: STATISTICAL LITERACY

Statistical Literacy has been touted as a goal by statisticians for decades.

1951: ASA President, Helen Walker *the level of statistical literacy among the practitioners of the social sciences is appallingly low*; *the one-semester introductory course in which students learn a variety of computations will inevitably turn out a large number of semi-literates*.

1993 ASA President, Katherine Wallman. *my hope [is] that by enhancing statistical literacy, we may succeed in enriching our society. Statistical literacy is the ability to understand and critically evaluate statistical results that permeate our daily lives. As we endeavor to to enhance statistical literacy, I believe we will enrich both our professional society -- the American Statistical Association -- and the society in which we live.*

1997: RSS-SCE President Anne Hawkins *'Statistics for All' policies do not necessarily yield 'Statistical Literacy for All'. It seems that statistical literacy falls between a number of stools, and does not receive the widespread consideration that it should. A move towards statistical literacy for all should be accompanied by a move towards making statistical language intelligible to all.*

1998 ASA President David Moore. *Statistical literacy: what every educated person should know*

2001 Schield. W. M. Keck Foundation funds grant to "*support statistical literacy as an interdisciplinary curriculum in the liberal arts*".

2005 GAISE-1 College: *Emphasize statistical literacy and develop statistical thinking*

2005 GAISE-1 K-12: *The ultimate goal: Statistical Literacy*

2007 Alan Rossman: *Most students would be better served by Stat 100 than Stat 101*

2013 GAISE-2 College: *Teach statistical thinking*

2013 GAISE-2 PreK-12: *The ultimate goal: Statistical Literacy for all.*

2017 SERJ Statistical Literacy issue: *Statistical literacy: a pre-requisite for an informed democracy*

2017 Schield. *GAISE 2013 promotes statistical literacy.*

2020 Schield. *Statistical Literacy Approved for General Education at Univ. New Mexico.*

2024 International Statistical Literacy Project: International Day of Statistical Literacy.

#2: MULTIVARIATE THINKING

Multivariate thinking is a brand new goal in statistical education. It wasn't mentioned in McKenzie's (2004) list of the top 20 statistical concepts. It jumped from almost non-existing to being featured as a secondary goal in the 2013 GAISE-2 college recommendations.

2013 GAISE-2 College Recommendations:

1. Teach statistical thinking.

- *Teach statistics as an investigative process of problem-solving and decision-making.*
- *Give students experience with multivariable thinking*

2. Focus on conceptual understanding.
We live in a complex world in which the answer to a question often depends on many factors.

Closing Thoughts
Multivariable thinking is critical to make sense of the observational data around us.
1. learn to identify observational studies,
2. explain why randomized assignment to treatment improves the situation,
3. learn to be wary of cause-and-effect conclusions from observational studies,
4. learn to consider potential confounding factors and explain why they might be confounding factors,
5. use simple approaches (such as stratification) to address confounding.

Appendix B: History Statistical Literacy, Multivariate Thinking and Confounding

Multivariable models are necessary when we want to model many aspects of the world more realistically. The real world is complex and can't be described well by one or two variables. If students do not have exposure to simple tools for disentangling complex relationships, they may dismiss statistics as an old-school discipline only suitable for small sample inference of randomized studies.

Simple examples are valuable for introducing concepts, but when we don't demonstrate realistic models students are left with the impression that statistics is trivial and not really useful. This report recommends that students be introduced to multivariable thinking, preferably early in the introductory course and not as an afterthought at the end of the course.

2013 GAISE-2 PreK-12 Report.
Overview and Goals of GAISE II (Excerpts)

- Multivariable thinking throughout Levels A, B, and C

2024: The status of multivariate thinking is the subject of an eCOTS workshop by Tintle et al (2024):
Title: *Improving multivariable statistical thinking by teaching sources of variation*
Abstract: *In an increasingly data-centric world, where both consumers and creators of statistical information are required to understand the complex associations among the many variables that form the basis for good data-driven decisions, we pose the question: how can teachers of first and second courses of statistics introduce and build facility with multivariable thinking? The GAISE guidelines include multivariable thinking in the first course, and it's natural to assume that multivariable thinking also must be a focus of the second course.*

However, there is still a gap between what GAISE promotes and what instructors teach when trying to reach students that need pedagogically-sound, conceptually-based methods and visualizations to develop multivariable thinking. In this workshop we focus on how teaching sources of variation can be a key strand in developing multivariable thinking that cuts across the entirety of both the first and second algebra-based courses in statistics.

#3: CONFOUNDING

2013 GAISE 2 College Report: Simple methods such as stratification can allow students to think beyond two dimensions and reveal effects of confounding variables. Statistical thinking with an appreciation of Simpson's paradox would alert a student to look for the hidden confounding variables. The use of stratification by a potential confounder is easy to implement. It's important to have students look for possible confounding factors when the relationship isn't what they expect, but it is also important when the relationship is what is expected. It's not always possible to stratify by factors (particularly if important confounders are not collected).

2014 ASA Curriculum Guidelines for Undergraduate Programs*: Students obtain a clear understanding of principles of statistical design to … account for the possible impact of … confounding variables.*

2017: Tintle et al, *Confounding and variation are two major obstacles in analyzing data*

2017 Schield. Statistical literacy must include confounding and the ways confounders can be taken into account.

Appendix C: Distribution of Bachelor's degrees by Major

Students in the majors on the left (Statistically-based majors) are generally required to take introductory statistics. Students in the majors on the right (Calculus-based majors) are generally required to take Calculus or Discrete/Finite Math.

% of all	Degrees	Statistically-based Majors	% of All	Degrees	Calculus-based Majors
19.4%	391	Business	6.3%	127	Engineering
12.5%	251	Health Professions	4.4%	89	Computer/Info Science
8.0%	161	Social Science & History	2.6%	53	Military Tech. & Science
6.0%	121	Biological/Biomedical	1.5%	31	Physical Science
5.8%	117	Psychology	1.3%	26	Math & Stats
51.7%	**1,041**	**Subtotal (All = 2,013)**	**16.2%**	**326**	**Subtotal (All = 2,013)**

Number of degrees in 1,000 https://nces.ed.gov/programs/digest/d20/tables/dt20_322.10.asp

Figure 3: Bachelor's Degrees: Statistically-Based vs. Calculus-Based

However some on the left (Economics, Finance) may take calculus in place of statistics while others (History) may not be required to take a particular math course. Some of those on the right may not be required to take calculus.

For simplicity, an estimated 50% of today's college graduates will be required to take an introductory statistics course. While 15% of college graduates will be required to take Calculus or Discrete/Finite mathematics. The remainder (35%) have no specific mathematics requirement as part of their major.

50% are required to take Statistics	15% take Calculus*	**35% have no specific Math requirement**

* or Discrete or Finite Mathematics

Figure 4: College Students by Type of Mathematics Required

Figure 5 presents the kinds of studies commonly encountered by various majors. Studies are classified as observational (researcher is passive observer) or experimental (researcher or nature is active). Experiments are classified as ideal (laboratory), clinical trials (randomized controlled trials) or quasi-experiments. Quasi-experiments can involve researcher doing (price changes and sales/responses over time) or nature doing (COVID positives by state over time).

Computer and Information science majors are included since they can use computer simulations to conduct population inference. These majors were not included in Figure 3 since they may take Discrete or Finite Mathematics.

100%	Degrees	Statistically-based Majors	Statistical Studies Encountered*
35%	391	Business	Quasi-experiments & Obs.Studies
22%	251	Psychology	Clinical Trials (RCT)
14%	161	Health Professions	RCT & Observational Studies
11%	121	Biological/Biomedical	RCT & Observational Studies
10%	117	Social Science & History	Observational studies
8%	89	Computer/Info Science	Observational studies
Total	**1,130**	**Total: Including Data Science**	
2018-19	# in 1,000		*** All encounter sample-based surveys or studies**

Figure 5: Most Common Statistical Studies by Statistically-Based Majors.

Appendix C: Distribution of Bachelor's degrees by Major

The typical introductory statistics course focuses on random sampling (surveys) and randomized controlled trials (RCT). This matches the statistical needs of almost half (47%) of those taking statistics. These assignments are very crude. For example, psychologists encounter observational studies when random assignment is impossible or immoral, or when they are dealing with clinical or social psychology.

But, now consider the statistical needs of all college students. Those in non-quantitative majors see mostly statistics based on observational studies in the everyday media. Those in science and engineering are more likely to deal with ideal or laboratory experiments. This allows the maximum control by the researcher and they can typically be repeated to eliminate coincidence and most confounders. However, these science-engineering majors are most likely to see statistics from observational studies when they observe the everyday media as citizens. Figure 6 shows the results for all college students.

100%	Degrees	All Majors	Statistical Studies Encountered*
32%	*646*	*Non-quantitative majors*	*Observational.Studies*
20%	391	Business	Quasi-experiments & Obs.Studies
12%	251	Psychology	Clinical Trials (RCT)
8%	161	Health Professions	RCT & Observational Studies
6%	121	Biological/Biomedical	RCT & Observational Studies
6%	117	Social Science & History	Observational studies & Quasi Exp.
16%	326	*Science-engineering majors*	Observational studies, RCT
2018-19	**2,013**	**Total**	* All encounter sample-based surveys or studies
	# in 1,000	Non-quantitative & science see observational studies in media	

Figure 6: Statistical Studies Commonly Encountered by All Students.

Based on the primary kind of study encountered and summarize, 54% of all students deal primarily with observational studies, 26% deal primarily with clinical trials, and 20% deal primarily with quasi-experiments. Political science and education majors also deal with quasi-experimental studies. In order to simplify and avoid the perception of unjustified precision, the estimates shown in Figure 7 are used.

Observational Studies 50%	**Randomized Controlled Trials (RCT) 30%**	**Quasi-Experiment 20%**

Figure 7: Distribution of College Students by Most Common Study Encountered.

Although subjective and crude, these estimates give an empirical basis for deciding what should be taught in introductory statistics in order to meet the statistical needs of all college students.

Appendix D: nGrams of Confound

Figure 8 shows that some forms of confound are old: confounded, confounding, confound and confounds.

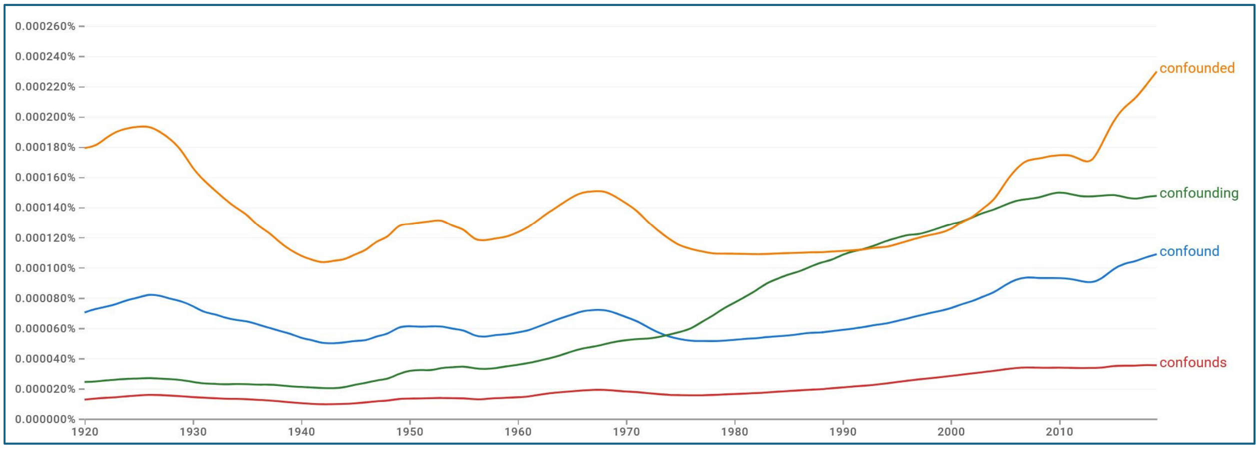

Figure 8: nGram Prevalence of Older Forms of Confound since 1920

Figure 9 shows that two forms of confound (confounder and confounders) are new and growing rapidly. Their combined prevalence has increased by a factor of 60 since 1970.

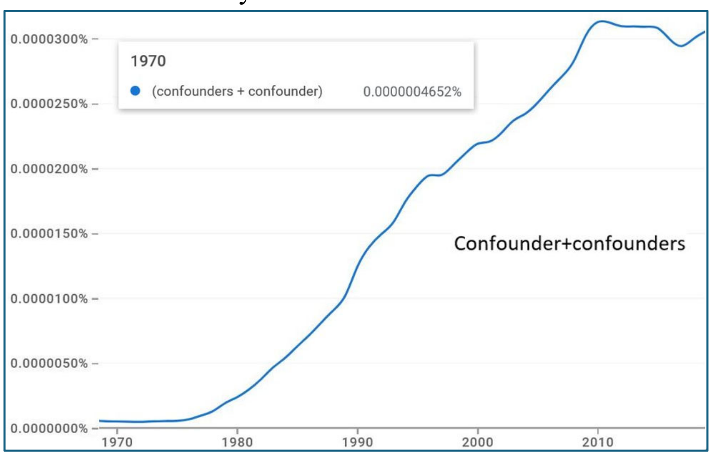

Figure 9: nGram Prevalence of *Confounders* and *Confounder* since 1970

Figure 10 shows that the new forms (confounders and confounder) are much less common than the old.

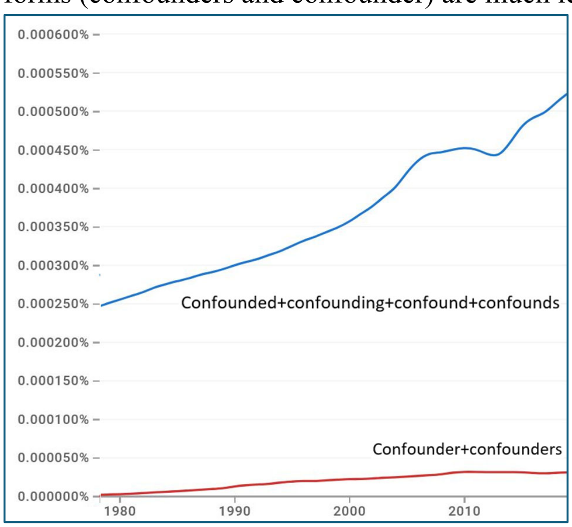

Figure 10: nGram Prevalence of Old and New Forms of Confound since 1980