Integrating Sustainability into the Mathematics Curriculum

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Sustainability[1]

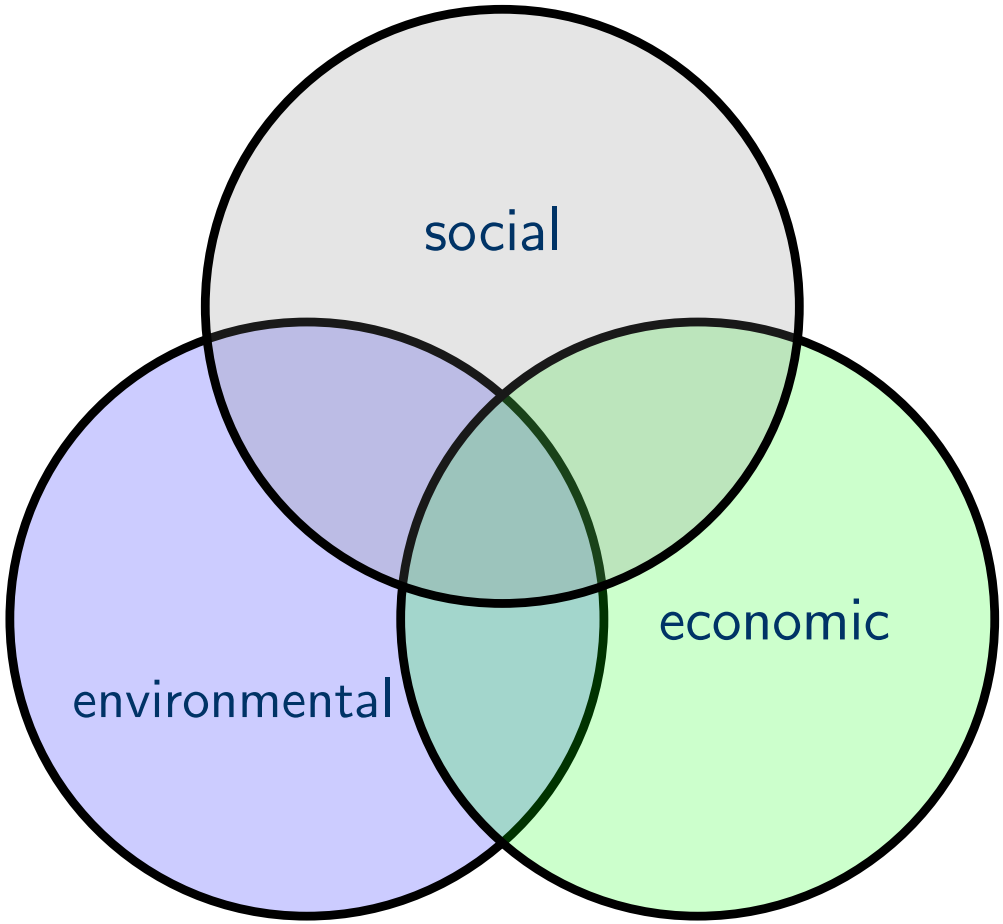
Sustainability refers to a process in which human societies adapt to live within the earth's finite limits in ways that:

- restore healthy ecosystems and reduce harm to water, air, forests, soils, and biodiversity;
- support secure livelihoods and vibrant local economies and redress poverty and inequality;
- create resilient cultural and natural systems and empowered communities;
- and meet the needs of the present without compromising the ability of future generations to meet their own needs.

[1] Definition of Sustainability Created by Emory Faculty (2013). This definition of sustainability was adopted by the Emory College Sustainability Minor Steering Committee 9-27-13

Sustainability

Sustainability includes economic, environmental and social dimensions, including equity and diversity goals.



Motivation

The [sustainability] crisis cannot be solved by
the same kind of education that helped create the problems.
-David Orr

THE AMERICAN STATISTICIAN
2016, VOL. 70, NO. 2, 129–133
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EDITORIAL

The ASA's Statement on *p*-Values: Context, Process, and Purpose

In February 2014, George Cobb, Professor Emeritus of Mathematics and Statistics at Mount Holyoke College, posed these questions to an ASA discussion forum:

> Q: Why do so many colleges and grad schools teach $p = 0.05$?
> A: Because that's still what the scientific community and journal editors use.
> Q: Why do so many people still use $p = 0.05$?
> A: Because that's what they were taught in college or grad school.

Cobb's concern was a long-worrisome circularity in the sociology of science based on the use of bright lines such as $p < 0.05$: "We teach it because it's what we do; we do it because it's what we teach." This concern was brought to the attention of the ASA Board.

2014) and a statement on risk-limiting post-election audits (American Statistical Association 2010). However, these were truly policy-related statements. The VAM statement addressed a key educational policy issue, acknowledging the complexity of the issues involved, citing limitations of VAMs as effective performance models, and urging that they be developed and interpreted with the involvement of statisticians. The statement on election auditing was also in response to a major but specific policy issue (close elections in 2008), and said that statistically based election audits should become a routine part of election processes.

By contrast, the Board envisioned that the ASA statement on *p*-values and statistical significance would shed light on an

The Piedmont Project

Emory's Piedmont Project brings together faculty from across the university to support new courses or course modules that strengthen curricular engagement with issues of sustainability, environmental awareness, and urgent societal challenges.

Figure: Peggy Barlett, Goodrich C. White Professor of Anthropology

- 2 day workshop in May
- prepare course materials over the summer
- a half-day fieldtrip in August
- No prior experience with sustainability or environmental issues in the classroom or in research is necessary
- $1000 stipend

Infusing existing courses with new content

Mathematical Statistics II with Writing

Fundamentals of statistical inference: estimation, properties of estimators, methods for comparing estimators, confidence intervals, hypothesis testing, regression, and analysis of variance.This course is an extension of MATH 362 which includes a writing lab. Students take a writing lab and learn how to articulate why the statistical methods they use are applicable, discuss what their results show and make recommendations for future studies.

Mathematical Statistics II with Writing

Throughout the semester students analyze Emory's Sustainability Literacy Survey. They will learn how to articulate why the statistical methods they use are applicable, discuss what their results show (and don't show), and make recommendations for future studies based on their findings. In addition to the analysis, students develop an intuition on what statistics measure and understand the difference between statistical significance and practical significance.

Emory's Sustainability Literacy Survey

1. Your Sustainability-Related Behaviors
2. About You
3. Knowledge of Sustainability Issues
4. Student information
5. Demographic information

The Sustainability Tracking, Assessment & Rating System
(STARS) is a transparent, self-reporting framework for colleges and universities to measure their sustainability performance.

The Association for the Advancement of Sustainability in Higher Education

Schedule: Below is a week-by-week listing of the topics to be covered in class. **Please note that this schedule is tentative**. It may be necessary to make changes to the topics and to the test dates. The sections refer to the text *An Introduction to Mathematical Statistics and Its Applications*. Additional materials are may be given out in class when needed.

17 Jan: Snow Day

19 Jan: Lab 1: Sustainability and LaTeX
Discussion: What is Sustainability? What are some examples of Sustainability efforts at Emory? Introduction to LaTeX.

22/24 Jan: Maximum Likelihood Estimation, Method of Moments, Interval Estimation, Margin of Error & Sample Size [§5.1-5.3]

26 Jan: Lab 2: Emory's Sustainability Literacy Survey and R-studio
Discussion: Look at the Survey. What types of answer do we expect? How much variation do we expect? Introduction to R and R-studio. Load the data to look at it.

29/31 Jan: Properties of Estimators, Minimum Variance Estimators, Sufficient Estimation & Consistency [§5.4-5.7]

2 Feb: Lab 3: Data Exploration in R
Discussion: Common Visualization Tools. How to visualize your proposal?

5/7 Feb: Bayesian Estimation [§5.8]

9 Feb: Lab 4: What can you conclude? Common misconceptions and overreaches.
Discussion: This lab will be a group work lab with several actives with pictures and statements where the students need to judge if the statements are true based on the picture.

12/14 Feb: Hypothesis Testing, Decision Rule & Testing Binomial Data [§6.1-6.3]

16 Feb: Lab 5: Project Presentations
Discussion: Each student will prepare a brief presentation of what they would like to find in the data. Students will give feedback and discuss. Students will form groups for a collaborative final paper.

19/21 Feb: Type I and Type II Errors & Generalized Likelihood Ratio Test [§6.4-6.5]

23 Feb: Lab 6: Formatting a Paper in LaTeX
Discussion: During this lab students will integrate their Writing Assignments 1-3 into a paper. Students will learn how to use BibTeX for their bibliography as well as a style file for the appropriate formatting.

26 Feb: Review for Midterm 1

Midterm 1 : Wednesday 28 February – Chapters 5 & 6

2 Mar: Lab 7: Choosing the Correct Method
Discussion: What method should you use to test your hypothesis about the data? Are all the assumptions of the test satisfied? Would it be okay to abuse some of the assumptions?

5/7 March: Inferences based on the normal distribution, T-Distribution & Drawing Inferences About μ & σ [§7.1-7.5]

9 Mar: Lab 8: Test your Hypothesis
Discussion: Use R to test your hypothesis. Is there statistical significance? Does the data reflect what you had hoped?

Spring Break : 12 – 16 March

19/21 March: Two-Sample Inferences & Confidence Intervals [§9.1-9.5]

23 Mar: Lab 9: Conclusions
Discussion: What do your results say? How could your results be improved? What questions would you like answered?

26/28 March: The F-test & Goodness of Fit Tests [§10.1-10.2]

30 Mar: Lab 10: How to Read and Review a Scientific Article.
Discussion: Summarize the Results, Explain the Approach, Critique the Analysis, Suggestions for the Author(s)

2/4 April: Goodness of Fit Tests & Contingency Tables [§10.3-10.5]

6 April: Lab 11: How to Respond to Review a Scientific Article.
Discussion: Address the readers concerns, and politely defend your approach

9 April: Review for Midterm 2

Midterm 2 : Wednesday 11 April – Chapters 7, 9, & 10

13 April: Lab 13: Proofread the paper and finalize your response
Discussion: read over the papers discuss what needs to be improved or removed

16/18 April: Regression, Linear Models, Covariance and Correlations [§11.1-11.4]

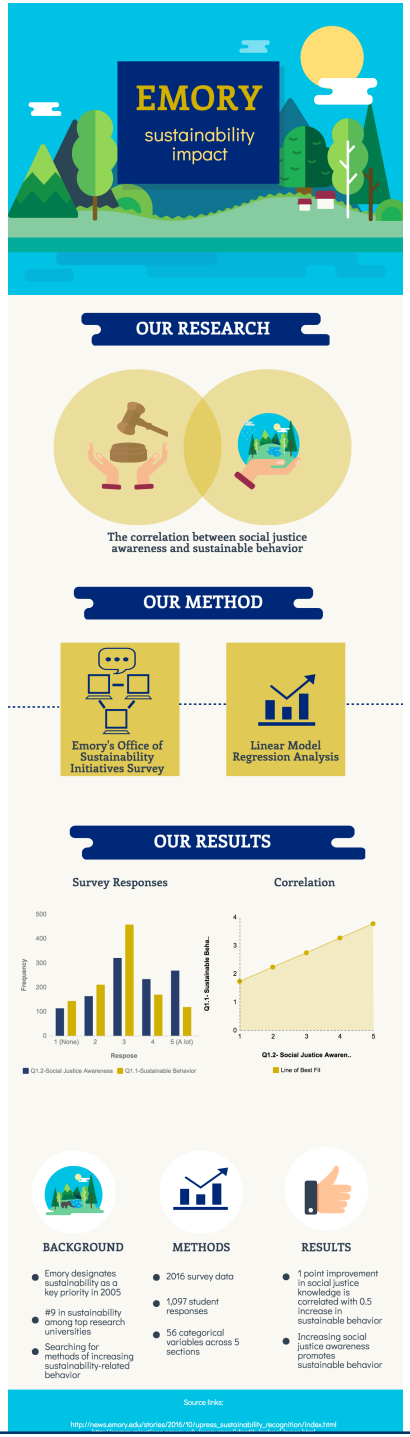
20 April: Lab 14: How to write a press release.
Discussion: Condense your result into a presentation and press release

23/25 April: The Bivariate Normal Distribution & ANOVA [§11.5-12.3]

27 April: Lab 15: Present
Discussion: Presentations of final projects

30 April: Review

Writing Portfolio Due : Thursday 3 May by 6 : 00 pm



Sustainability at Emory: An Analysis of the Impact of Knowledge of Social JusticeIssues on Sustainability-Related Behavior Changes

"As such, we can see in Figure 1 that the vast majority of students on campus have become more aware of social justice issues during their time at Emory. Through Figure 2, we can see that this increase in awareness of social justice (including sustainability-related issues) has in fact translated to increased involvement in initiatives related to those areas. This is apparent since a larger percentage of those students who answered 3, 4, or 5 on Q1.2 also answered a 3, 4, or 5 on Q1.1. However, there is still a significant number of students who have learned more about sustainability and other social justice-related issues without implementing this knowledge in their own lives. This is clear in the breakdown of responses to Q1.2; those who answered a 3 or above in Q1.2 did not all answer a 3 or above in Q1.1. As such, we can see that while an increase in knowledge does tend to lead to positive sustainability-related behavior changes, there is still more that can be done in sustainability education to encourage students to change their behavior."

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Additional Content: Statistical Analysis

1. Using R
2. Exploring Large Real Data Sets in R
3. Visual Representations of Data
4. Choosing a correct test to measure an effect (how appropriate is it to use the method with the given data)
5. What you can and cannot conclude from your results/plot

Writing: Learn to write a technical paper

1. Using LaTeX
2. Describing Data
3. Presenting (and giving a proof) of statistical tools
4. Peer Review
   - 4.1 Deconstructing other peoples' arguments
   - 4.2 Giving Constructive Criticism
5. Analyze results for both Mathematicians and Non-Mathematicians
6. Make valid recommendations based on results
7. Propose changes to current study to improve results or explore different questions

Hidden curriculum

1. Learn about Sustainability and Emory
2. Connect coursework with their community
3. Give context and investment to paper
4. Experiential learning

Some Paper Titles:

- *Knowledge and Behaviors: The Driving Force Toward Sustainability*
- *The Personalities of Sustainable Eaters*
- *Growing, eating, and composting at Emory*

PIC Math - Preparation for Industrial Careers in Mathematical Sciences[2] A spring semester research course will assemble teams of three to five students to work on messy real world problems. For more:
`https://www.maa.org/programs-and-communities/professional-development/pic-math`

PICMath

MAA
MATHEMATICAL ASSOCIATION OF AMERICA

[2] Support for this Mathematical Association of America (MAA) program is provided by the National Science Foundation (NSF grant DMS-1722275) and the National Security Agency (NSA).1345499

Choosing content

Fair Fight Georgia advocates for free and fair elections

- Students would analyze the rates of absentee ballot application requests and rejections by county over the last 8 election cycles to determine if any patterns exist (presidential vs non presidential/gubernatorial years, discrepancies by counties, by areas of the state, etc) and potential reasons for those patterns.

- The Secretary of State will be removing 4% of voters from the voter rolls (i.e. cancelling 4% of voter registrations) prior to the 2020 election. Students would matched the 2019 data to the Georgia voter file to create a more robust data set. Once a full data set is created, students would analyze the information to see if discrepancies exist in the types of voters who are placed on the list by reason. Additional analysis could also be done on the voters previously removed from the rolls between 2012 and 2019.

Atlanta Beltline a bike-path slash urban redevelopment program

- Students will use GIS data to identify *safe* routes to Atlanta Public Schools via the Beltline.

New assignment

Numerical Analysis Solution of linear and nonlinear systems of equations, interpolation, least-squares approximation, numerical integration, and differentiation.

1. integrated 3D printing and writing through a bottle design project
2. Topic: Univariate Minimization Determine the minimal the amount of material needed to create a bottle that holds 6.5 ounces of liquid with a wall thickness of 2 mm. Is the optimized bottle unique? Use what you know about the bottle that uses the least amount of resources to redesign your bottle to use fewer materials than your original design.

Student Reaction:

"I've been in countless classes that have involved minimization problems. The first being, of course, Calc I, involving "Fred"and his "desire to have the largest garden possible but only 20 ft of fence," and so on. However, I've never actually calculated the minimum of something in class and actually used it for something tangible. In fact, the only other time I used minimization techniques in the real world was when doing research and trying to find what particular value of resistance minimized feedback in a circuit. I think doing projects like this in class are crucial for students (at least those who want to become experimental physicists) because there can be a disconnect between what we learn in class and what we utilize when in the real world. Personally, I distinctly remember there being a disconnect between what I learned in class and what I first thought to apply when finding the minimum of that circuit mentioned above. I had never before applied my learning, so even a simple minimization problem tripped me up. This project is great because it gives students first hand experience in applying what we learn formally."

Eight Ways to Change Your Course:

Engaging Sustainability Issues in the Curriculum

1. Hidden curriculum
2. Paradigm shift; course strategy & goals
3. New content
4. New assignment
5. New unit or module
6. Guest speaker; team teaching
7. Engaged learning; community experience
8. New course

Development of New Courses

Topics in Mathematics: Math of Fairness We will explore three topics in mathematics related to fairness. In the first part of the course we will study the Apportionment Problem: how to fairly allocate N equally valuable resources to M entities of varying sizes, specifically in the context of assigning seats in a legislative body fairly among states or other political entities. Our second topic is Fair Division: the problem of dividing resources of varying worth among several equally deserving people so that each person believes they receive a fair share. Our third topic concerns Gerrymandering: the drawing up of political boundaries in order to give an unfair advantage in an election to one party or group. We will look at mathematical and statistical methods for detecting gerrymandering and methods for fairly drawing congressional districts.

Taught by Prof. Victoria Powers

Opportunities

- "Mathematics and Climate"by Hans Kaper and Hans Engler
- "Mathematics for Sustainability" by John Roe, Russ deForest, and Sara Jamshidi
- ODEs/PDEs
- Calculus (?)

Thank you!

"All models are wrong but some are useful" - George E.P. Box