Math 497: The New Frontier of Math & Statistics[1]

Topic: Generative AI, Formal Reasoning, and Adaptive Statistical Interventions

Part 1: The "AlphaGo Moment" for Mathematics

Reference: New Scientist – AI Achieves Gold at IMO 2025

In July 2025, AI systems from Google DeepMind and OpenAI achieved a gold-medal score at the IMO. This is a paradigm shift because IMO problems are not "calculable"—they require **creative leaps** and **logical synthesis**.

Key Concepts for Discussion:

- **Natural Language vs. Formal Proofs:** Unlike previous systems that required "Lean" (a formal coding language for math), the 2025 models generated proofs in natural language.
  - *Discussion Point:* Does a proof's "readability" by humans matter if the logic is verified by a machine?
- **The "Problem 6" Wall:** Both AI models failed the same complex combinatorics problem.
  - *Discussion Point:* Is there a specific "type" of mathematical intuition—perhaps spatial or highly abstract—that remains uniquely human?
- **The Death of "Brute Force":** These models didn't just guess; they used "Deep Think" reasoning loops to explore tree-based paths of logic.

Part 2: Statistics in the Age of Autonomy

Reference: Dr. Susan Murphy (Harvard) – JSM 2025 Interview

Dr. Susan Murphy argues that we are moving from "static" statistics to **Just-In-Time Adaptive Interventions (JITAIs)**. This moves the statistician from an analyst of the past to a designer of real-time, autonomous systems.

The Reinforcement Learning (RL) Framework

In Murphy's work, the "Treatment" is no longer a fixed dose, but a dynamic policy.

Key Concepts for Discussion:

- **Causal Inference in Real-Time:** How do we maintain statistical rigor when the "experiment" is constantly changing based on the participant's current state?

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[1] This document was partially constructed using AI.

- **The Ethics of Engagement:** Dr. Murphy warns that corporate AI often optimizes for "clicks" or "engagement."
  - *Discussion Point:* As statisticians, how do we define a "Reward Function" R_t that prioritizes long-term human wellness over short-term data points?
- **The "Self-Driving" Health System:** If an algorithm is making health decisions (e.g., when to prompt a patient to exercise), what is the role of the human clinician?

Part 3: Synthesis & Group Discussion

"The boundary between statistical modeling and algorithmic modeling is dissolving." — *Dr. Susan Murphy*

Breakout Questions:

1. **Reasoning vs. Estimation:** The IMO video focuses on **deductive reasoning** (proofs), while Dr. Murphy focuses on **probabilistic estimation** (RL). Where do these two intersect in a modern AI model like Gemini or GPT-5?
2. **Verification:** If an AI produces a gold-medal math proof, we can verify it. If an AI produces a personalized health intervention, how do we "verify" that it was the optimal choice?
3. **The Career Path:** Given these breakthroughs, should a Senior Math/Stats major focus more on learning **coding/architecture** or **foundational theory**? Is the "foundational theory" now more important because the AI can handle the "coding"?