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POGIL-style Activities Introducing Students to Bayes Theorem

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Abstract

While technology advancements have allowed Bayesian statistics in undergraduate classrooms to become more accessible, to grasp Bayesian methodology significant base knowledge is still required of students. In summer 2023 we attended a one-week Bayes-BATS (BAyesian Thinking in STEM) workshop and during fall 2023 developed several POGIL-style Bayesian activities: "Developing Bayes Theorem" and "Applying Bayes Theorem." POGIL refers to Process Oriented Guided Inquiry Learning and activities are designed to have student teams be self guided through the content with the instructor acting as facilitator. The first activity builds from a base knowledge of probability, to using conditional proportions, and finally to developing Bayes Theorem. The second activity was created to follow directly after the first and reviews Bayes Theorem before leading students to apply the formula. Both activities could fit within an introductory statistics course, an undergraduate probability course, or in a STEM course with a quantitative focus. The first activity was piloted in three classrooms during fall 2023: Mathematics in Society (seven private R2 Gen Ed non-STEM students); Elementary Statistics (30 private liberal arts Gen Ed non-STEM students); Biostatistics course (25 private liberal arts Biology students). Additional pilot runs are planned for spring 2024. Feedback indicated that students better understood conditional probabilities and were able to see the motivation for the Bayesian approach, but we need to work on the length of the activities and question wording. We believe these activities offer instructors one option for introducing Bayesian statistics into undergraduate classrooms.

References

For Bayesian textbooks online:

Albert, J. and J. Hu. 2020. Probability and Bayesian Modeling. (available online: https://bayesball.github.io/BOOK/probability-a-measurement-of-uncertainty.html) (See also print version: Chapman and Hall/CRC Press. ISBN 9781138492561)

Johnson, A., M. Ott, and M. Dogucu. 2021. Bayes Rules! An introduction to Applied Bayesian Modeling. (available online: https://www.bayesrulesbook.com/) (See also print version: Chapman and Hall/CRC Press. ISBN 9780367255398)

For ideas and/or resources used in Activities 1 and 2:

Kahneman, D. 2011. Thinking, Fast and Slow. Farrar, Straus, and Giroux.

Kunin, D. Seeing Theory: A visual introduction to probability and statistics. http://seeingtheory.io

Rossman, A. Ask Good Questions. https://askgoodquestions.blog/2019/09/09/10-my-favorite-theorem/

Sanderson, G. and J. Pullen. Bayes' Theorem. https://www.3blue1brown.com/lessons/bayes-theorem

Summarized Instructor Perspectives gleaned from Student Feedback on Activity 1 (from both Katie and Angela):

1. Overall students really enjoyed completing the activity - had fun getting to actively problem solve with their peers.
2. Some students even mentioned the activity in end-of-course evals (over a month later) and said they would have enjoyed more activities like this for other course topics.
3. At first students said they didn't think the formalized group roles were necessary - felt unnatural and commented that group roles would maybe be more appropriate/effective for more difficult/involved activities or in a lab setting. After sharing observations about how well the groups were collaborating, upon reflection students tended to agree that the POGIL roles were beneficial. They then articulated that even though it wasn't their natural/organic working dynamic, it did help get everyone engaged and shifted the focus more towards learning/understanding for each person rather than just 1-2 people leading the way to "get through" the assignment. That being said, some students indicated a preference for smaller group sizes (working as partners in groups of 2 rather than in groups of 3-4).
4. Most students seemed to think the activity was fast-paced but straightforward and interesting/engaging. Some students definitely felt rushed.
5. While some students appreciated the step-by-step approach which made the activity work well for a group, others were confused by some of the question wording and also where answers/numbers were supposed to come from.
6. Many students expressed appreciation of the “real world” application of the health context.
7. For the larger classes (20+ students), it was harder to get through all of the activity – which meant some groups did not get the satisfaction of seeing Bayes’ Theorem being used (and thus likely missed out on the goal of the activity).
8. Some students suggested that a class-wide discussion after the activity would help overall understanding (which would mean that the activity definitely needs to be shortened). One student suggested removing the relatively simple Model 1 (review of probability using cards) to allow for more time to focus on Model 2 and 3.