A Practical Guide for Incorporating Ethical Reasoning into Mathematics Courses through Modeling Problems

Feryal Alayont [1]   Korana Burke [2]   Erin Griesenauer [3]
Jeremy Shaw [4]   Rohit Thomas [2]

[1] Grand Valley State University

[2] University of California, Davis

[3] Eckerd College

[4] Oregon State University-Cascades

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Outline

- What are you hoping to get out of this webinar?
- What do we mean by ethical reasoning?
- Why should we include ethical reasoning?
- Goals of our framework
- General description of our framework
- Framework applied to specific problems (differential equations, precalculus, multivariable examples)
- Reflections
- Takeaways

Your Expectations

Questions:

1. What are you hoping to get out of this webinar?
2. Which classes do you teach?
3. How big are your classes?

Ethical Reasoning in Math

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Idea: ~~Add ethical reasoning questions to existing mathematical modeling activities or problems.~~ Put back the ethical reasoning questions that people asked before creating the mathematical model into the problems we ask.

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From a more philosophical perspective:
"Mathematics teachers share the obligation to consider the ethical consequences of different pedagogies, and selections of content and representations of content." – Ernest, *The ethical obligations of the mathematics teacher*, 2019.

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- Bonus: Helps with teaching math by making math more relevant.
- Bonus: Helps with teaching critical thinking.

Why a Framework Format?

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- Consistency creates routines

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Mathematical modeling problems involve various tasks.

- **Background and context:** Analyzing the model and its components in context.
- **Mathematical solution of the model:** Solve the problem using mathematical techniques.
- **Reflection:** Evaluating the results of the mathematical work.

Differential Equations Example[2]

According to Newton's law of cooling, if an object at temperature T is immersed in a medium having the constant temperature M, then the rate of change of T is proportional to the difference of temperature $M - T$. This gives the differential equation

$$\frac{dT}{dt} = k(M - T).$$

ⓐ Solve the differential equation for T.

ⓑ A thermometer reading $100°$ F is placed in a medium having a constant temperature of $70°$ F. After 6 minutes, the thermometer reads $80°$ F. What is the reading after 20 minutes?

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[2]From *Fundamentals of Differential Equations*, 9th edition, by Nagle, Saff, and Snider

Example Problem: Analyzing Model & Components

- To what real-life contexts that you care about can this model be applied? What are possible questions that could be answered that would have an important impact in this context?
- How would you test the accuracy of this model?
- Do you think the model is reliable in its predictions?
- Are there reasons to suspect that the rate parameter might not be constant?
- What challenges do you foresee in the process of estimating the model parameters? What potential trade-offs might be made when estimating these numbers?
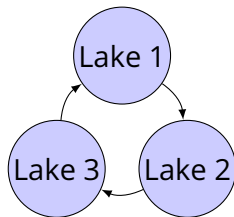
Example Problem: Reflection

- List at least two different Business, Industry, Non-profit, or Government organizations who might use this model. For each, list at least one question they might be trying to answer.
- What are possible consequences if this model is inaccurate? What entities might be affected?
- What kinds of policy decisions might be made using your results? What entities might be affected by these decisions?
- From the perspective of an organization using this model, is it better to overestimate or underestimate risks? (What risks are there to think about?) How would you revise your model in order to do this?
- What further questions could you investigate with this model? What are some potential benefits and harms that could come from this model?

Transport of Environmental Pollutants[3]

Suppose three lakes of equal volume V are interconnected. All the water flow occurs at the same rate r. A shipping accident releases 300,000 kg of a chemical pollutant into Lake 1. Assume that each lake is well mixed and none of the pollutant settles out.

- Write down a set of differential equations describing the amount of pollutant in each lake.
- Using the fact that the total amount of pollutant is constant reduce the size of the system.
- Determine the stability of the equilibrium.

- Find the solution for the IVP. What happens as $t \to \infty$?

[3]From *Biocalculus: Calculus, Probability, and Statistics for the Life Sciences*, 1st edition, by Stewart and Day

Example Problem: Analyzing Model & Components

- Which assumptions does the model make that might not be valid in real life?
- How could you improve the model?
- Which measurements would you make to test the validity of your new model?

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Population of Whooping Cranes

Whooping cranes are an endangered species. Below are data[4] on the number of wild whooping cranes each decade from 1940 to 2010.

Year	1940	1950	1960	1970	1980	1990	2000	2010
Cranes	26	32	37	58	79	146	180	283

a Make linear, log-log, and log-linear plots of the data.

b Determine which plot shows a relationship closest to linear. Find this best-fit line and use it to find the functional relationship between population and time.

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[4]Butler, Harris, & Strobel, *Biological Conservation*, 2013.

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"Wildlife protection organizations, conservationists, animal enthusiasts, ecologists, zoologists could all be interested in our predictions. If our predictions were too high, it could result in people overestimating the stability of crane populations and not allocating sufficient resources towards their preservation. However, if our predictions were too low, it could cause undue alarm over seemingly decreasing crane populations, which would result in resources being wasted on the preservation of cranes while they could be better put to use for animals that are actually in danger of disappearing."

An Easier Model

One part to be added to each modeling problem:

Part E for ethics:

> *Consider now the context of this problem (or a context of your choice). What assumptions are being made in this problem regarding the real-life context? How can we verify the reasonableness of these assumptions? List some parties that might be affected positively/negatively by these assumptions, and describe specifically how they might be affected.*

Heat Index[5]

Heat index $I(T, H)$, function of temperature T and humidity H.

$T \downarrow \backslash H \rightarrow$	70	75	80	85
90	106	109	112	115
92	112	115	119	123
94	118	122	127	132
96	125	130	135	141

- State the limit definition of the value $I_{TT}(94, 75)$. Then, estimate $I_{TT}(94, 75)$, and write one complete sentence that carefully explains the meaning of this value, including units.
- (Repeat for $I_{HH}(94, 75)$ and $I_{HT}(94, 75)$.)
- What are two assumptions being made in our solution regarding the context? Additionally, list at least two possible parties that might be affected positively/negatively by these assumptions and indicate how they might be affected.

[5]From *Active Calculus – Multivariable*, Schlicker, Keller, Long, 2023

Brainstorm in Breakout Rooms

Let's see how to apply the framework to some problems.

Go to `https://beav.es/cKB` and use the file for your breakout room. Instructions are in the file.

About: 15 mins

Group share outs

- Which contexts did you consider in your group for the first problem? For the second problem?
- What did you consider when deciding what prompts to add? How do you think your students will respond to the prompts?
- Anything else you noticed that was important to your group?

Student Response - Improvement in ER

In one calculus course involving weekly ethical reasoning questions using this framework, 81% of students completed pre and post surveys. Of these:

- "I am prepared to think about who my decisions will affect (and how)."
  - 94% of respondents agree!
  - Of these 94%,
    - 34% agreed *more* than at the beginning of the course,
    - 60% agreed the same amount, and
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- "In the future it will be important to think about who my decisions will affect (and how)."
  - 92% of respondents agree!
  - Of these 92%,
    - 36% agreed *more* than at the beginning of the course,
    - 61% agreed the same amount, and
    - 3% agreed *less*.

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In one calculus course where the simpler model was used with select questions throughout the course:

- More interest in these types of problems from students
- First ethical reasoning experience in math
- Improved analysis skills over time
- Significant improvement into the second semester (very small sample)

Takeaways

- Students need practice with ethical reasoning; group class discussions are ideal.
- These ethical reasoning questions work better with application type problems, or problems where students can add context.
- It is easy to weave ethics prompts into existing questions.
- After some practice students can be asked to contextualize existing problems and add ethical prompts.

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Thank You and the Materials

Thank you for your attention!

Link to the materials: `https://beav.es/cKB`

Other Ethics Assignments

- Analyzing a code of ethics of a professional society
- Case studies `http://persweb.wabash.edu/facstaff/westphac/ethics/EthicalCaseStudiesII.pdf`
- Responsible conduct of research training
- Reading assignments