A General Framework for Incorporating Ethical Reasoning into Mathematical Modeling

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Outline

Ethical Reasoning in Math

Idea: Add ethical reasoning questions to existing mathematical modeling activities or problems.

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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 critical thinking.

Why a Framework Format?

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The Framework

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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.

Example of a Modeling Problem

Whooping cranes are an endangered species. Below are data[2] 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.

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

Example Problem: Analyzing Model & Components

- How would you test the accuracy of this model?
- Do you think the model is reliable in its predictions of the crane population over very short intervals?
- Are there reasons to suspect that the growth rate of the population might not be constant?
- What challenges do you foresee in the process of estimating the population numbers? What potential trade-offs might be made when estimating these numbers?
- Could you predict the number of cranes 10 years in the future? 100 years? Would you have confidence in these predictions?

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?

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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:

- 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 people/entities that might be affected positively/negatively by these assumptions.

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

Future Work

- Disseminate the fully developed framework to larger mathematics community: publication, presentations, curriculum materials.
- Include broader ethical reasoning dimensions beyond issue recognition such as developing and evaluating multiple perspectives and arguments.

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