Assessing Writing about Matter and Energy: Comparing Text Analysis and Machine Learning

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Introduction

•Students struggle with grasping concepts of matter and energy, often interconverting these main principles (Carlsson, 2002)
•Written assessments allow students to demonstrate their knowledge of the material by letting the student respond in their own words. (Kuechler and Simkin, 2010)
•Written assessments also allow faculty to better understand student thinking and influences how students study (Birenbaum &Tatsuoka 1987; Stanger-Hall 2012)
•Computer assisted analysis can facilitate the use of written assessments

Research Goal

The research goal was to analyze student writing about to matter and energy flow by comparing machine learning and text analysis.

Methods

• We asked 170 students from an Introductory Biology course at a southeastern university to write a response to a matter and energy related question:

A tropical rainforest is an example of an ecosystem. Which of the following statements about matter and energy in a tropical rainforest is the most accurate?

Please choose ONE answer that you think is best.

A) Energy is recycled, but matter is not recycled.
B) Matter is recycled, but energy is not recycled.
C) Both matter and energy are recycled.
D) Neither matter nor energy is recycled.

Explain your answer.

• Three biologists coded student responses and checked for interrater reliability of 0.7 (Cronbach's alpha)
• We performed Text Analysis and Machine Learning:
  •For Text Analysis we used IBM SPSS Modeler. Words and phrases were extracted and placed into categories. To create one predictive model, we used the human coding of the four nominal mental models [scientific, narrative, naïve, and mixed]
  •For Machine Learning we used LightSide to create a predictive model for each code. The model extracted words and phrases and predicted the presence and absence of each concept

Results

Student Responses

"Matter is recycled through decomposition. When leaves fall of a tree or animals die, they decompose and turn into nutrients and soil. Animal remains and excrement essentially turn into plant food."

[Mental Model: *Narrative* Concept: *heat loss; energy from the sun; An example of how matter is recycled*]

"The second law of thermodynamics states that energy conversions are never 100% efficient… Thus energy isn't recycled because it has been lost as heat"

[Mental Model: *Principled Reasoning* Concept*: heat loss, biogeochemical cycles*].

"Energy comes from matter, and it is matter that produces energy. Therefore, it is matter that is recycled."

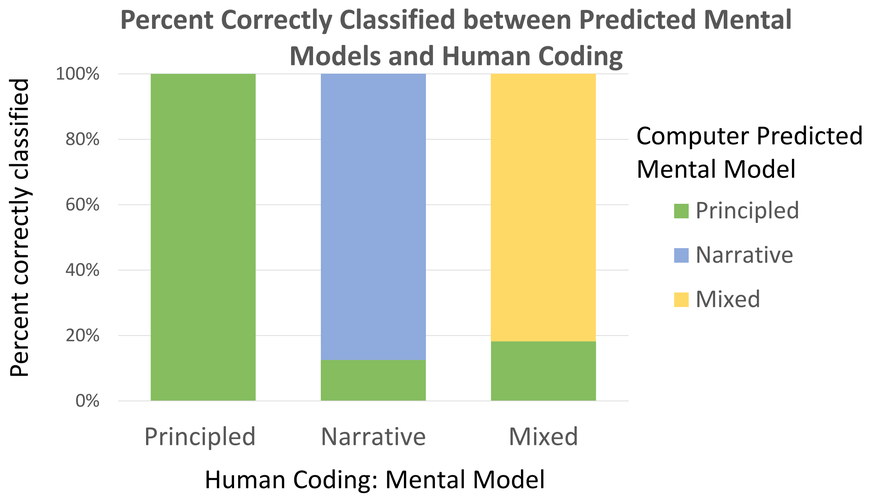
[Mental Model: *Naïve Concepts: Matter and energy interconverted*]

"Energy is not recycled, but is constantly being received by Earth in the form of sunlight. Once this energy is dissipated as heat, it cannot be recycled again. For example, in a tropical rainforest, a plant may harvest sunlight energy and use it to produce biomass"

[Mental Model: *Mixed* Concepts: *Heat loss, biogeochemical cycles, energy from the sun*]

Text Analysis

Mental Model	Concept	% Student Responses
Principled reasoning	Heat loss	27.0
	Biogeochemical cycling	
Narrative	Description of matter moving through food chain	36.5
	Trophic groups	
Naive	Energy converted into Matter	1.8
	Matter converted into Energy	
Mixed	Naïve, Principled and/or Narrative	34.7



Machine Learning

Concept	% Student Responses	% Correctly Classified	Kappa
Heat Loss	64.3	89.4	0.77
Biogeochemical cycling	26.3	90.0	0.73
Law conservation of matter	17.0	92.4	0.71
Energy from the sun	24.0	92.9	0.80
An example of how matter is recycled	36.3	76.4	0.49
Example of trophic level	28.7	80.6	0.47

Conclusion

•34.7% of students had mixed responses, which would not be observed using the multiple choice format
•Text analysis correctly predicted mental models over 80% of the time
•Machine learning is more accurate at identifying principled reasoning concepts
•By using student writing and the machine coding we can obtain a more detailed picture of their reasoning

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