Assessing student biological understanding using text analysis and machine learning

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Introduction

Written and other constructed response assessments:

- Allow students to represent their understanding in their own words (Keuchler and Simpkin, 2010)
- Give faculty greater insight into student thinking compared to multiple choice assessments (Birenbaum and Tatsuoka, 1987)
- Influence students' study habits (Stanger-Hall, 2012)
- But can be time consuming and difficult to grade and provide feedback

Therefore, new methods such as computer assisted analyses are critical to support written assessment as a common classroom practice in large enrollment science courses.

Research Objectives

Compare the performance of text analysis and machine learning methods to analyze student writing about matter and energy within an ecosystem.

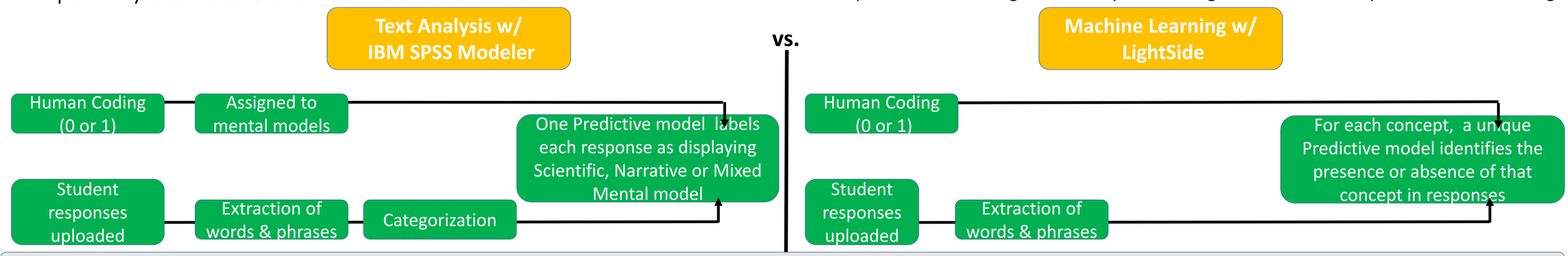
Methods

170 students in an introductory biology course at a large southeastern public university responded to the prompt:

"Explain why food webs tend to have five or fewer levels"

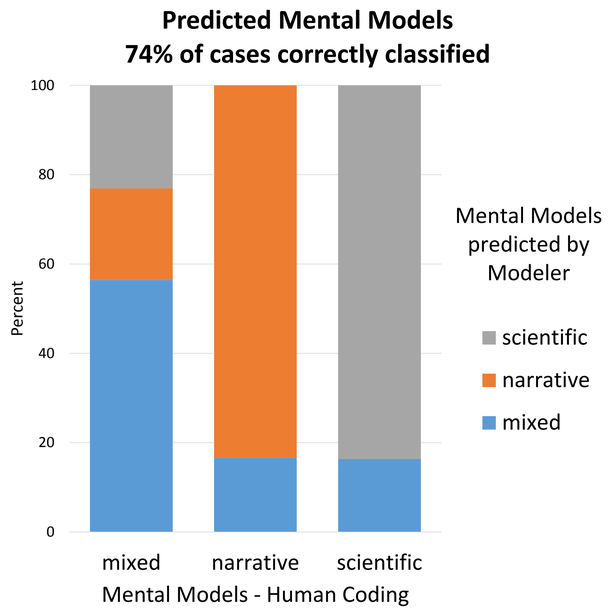
Responses were coded by 3 researchers using a grounded theory approach and achieved Interrater Reliability of 0 .7 or greater (Cronbach's alpha)

We compared human coding to two computer scoring methods: text analysis & machine learning



Results

Mental Model	Concept	% Student Responses
Scientific	Heat loss	
	2nd law of thermodynamics	40.6
Narrative	Description of consumption at the top trophic level	18.8
Mixed	Principled and Narrative Models	32.4
Naive	Energy converted into Matter or Vice Versa	
	Superficial Interpretation of Food Webs	8.2



"The second law of thermodynamics states that energy conservations are never one-hundred percent efficient, this meaning that some energy is lost along the way. In any transfer process this lost energy, which can do work, is lost in the form of heat."
Mental model - Scientific
Concept code - : heat loss; 2nd law of thermodynamics

"…a secondary consumer (higher up on the chain) needs to consume more than a primary consumer (lower on the chain) to gain the same amount of energy; this is because the secondary consumer's source is of energy is indirect (it isn't directly consuming a primary producer). ."
Mental model – Narrative
Concept codes: description of consumption at top level

Concept Code	% Student Responses	% Correctly Classified	Kappa Agreement
Energy transferred	62.4	91.8	0.83
Heat loss	43.5	95.3	0.91
Energy loss during transfer	42.9	89.4	0.79
Energy costs	31.2	83.5	0.60
2nd law of thermodynamics	19.8	99.4	0.98

"Food webs tent to have five or fewer levels because food webs can be so complex that it is hard to view it clearly. A food web can become so complex that it may be hard to view which species has impact on another species if there are so many levels to it."
Mental model- naïve
Concept codes surface interpretation

"…as you increase the trophic level you lose energy due to metabolism, heating or cooling processes, etc. Therefore if a 6th or 5th tropic level existed, a large sum of food would need to be eaten in order to survive. Also individuals tend to grow in size as you climb up the trophic levels."
Mental model - Mixed
Concept codes - energy loss; description of consumption at top level

Conclusions

- About one third of students showed mixed mental models, demonstrating the heterogeneity of student thinking that is often not captured using multiple-choice assessments in which students select a single correct or incorrect response.
- Machine Learning performed better for identifying scientific concepts. Both Machine Learning and Text Analysis predicted models with agreement similar to the agreement between human coders.

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