Beyond Multiple Choice: Heterogeneous Thinking About Photosynthesis is Revealed by Automated Analysis of Student Writing

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The Approach

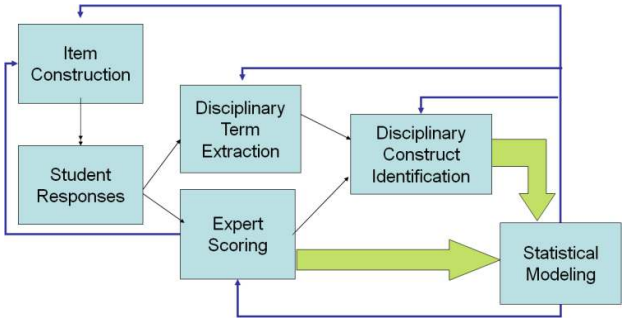

Figure 1. Workflow of item construction, analysis and statistical classification.

How do students think about photosynthesis?

- Crossover design: multiple choice and open-ended
- Open-ended responses: heterogeneous ideas about photosynthesis
- Text analysis uncovers student ideas not visible from multiple choice

Categorizing Student Ideas

- Relevant for an expert answer
- Computer extracts terms and manage categories
- Discover main ideas in students' writing
- Capture misconceptions

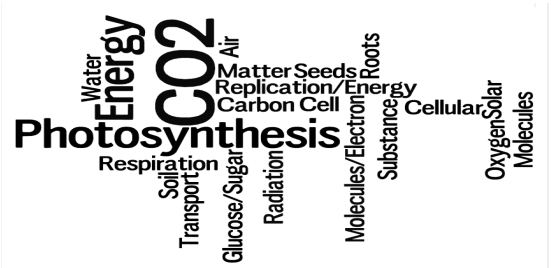

Figure 2. A wordle of the categories used for the project

Multiple Choice Data

(BS111, FS09, EX2, N=381)

A mature maple tree can have a mass of 1 ton or more (dry biomass, after removing water), yet it starts from a seed that weighs less than 1 gram. Which of the following contributes most to this huge increase in biomass?

7.7% A: Absorption of mineral substances from roots
12.7% B:Absorption of org. sub from soil via roots
59.4% *C:Incorporation of CO2 gas from atmosphere into molecules by green leaves*
7.7% D:Incorporation of H20 from soil into molecules by green leaves
12.7% E: Absorption of solar radiation into the leaf

Web Diagram

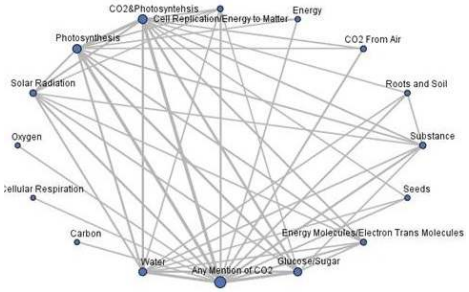

Figure 3. A web diagram showing the responses shared between categories (only responses that are grouped in the category "Any Mention of CO2" are included
Nodes: Category
Lines: Responses that used both categories

Category Distribution

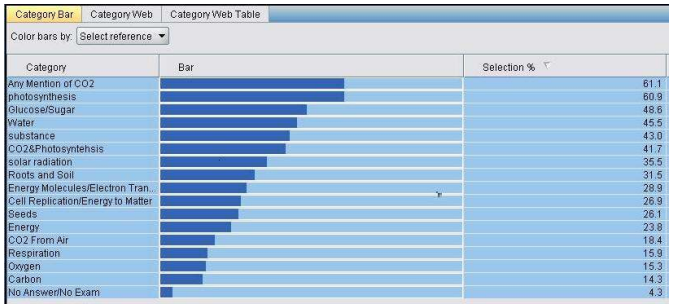

Figure 4. A bar graph showing the percentage of responses that were grouped into each category

Acknowledgements

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For more information, people involved or other projects visit the AACR group website at:
aacr.crcstl.msu.edu

How do the Categories Relate to Open-Ended Responses?

Substance
•Biomass is increased due to the absorption of organic substances from the soil
Roots and Soil
•The maple seeds have drawn nutrients from the ground, mainly organic, and used it as food to grow
CO2 and Photosynthesis
•This huge increase in biomass comes from photosynthesis. The carbon taken from CO2 is incorporated into the plant, increasing its biomass. Some minerals from the soil, taken in by the roots would account for a very small portion of the biomass increase.
Water
•The huge increase in the biomass of the corn comes from all that is involved in allowing the corn to grow. Water and nutrients are taken up and aid in the growth of the corn. The water and light energy allow for photosynthesis to occur in the plant and aids in the growth of the corn as well.
Solar Radiation
•The increase of biomass is because of the absorption of solar radiation into the leaf, which allows for photosynthesis to occur which in turn, allows the corn plants to yield energy to absorb nutrients from the soil and thrive.

Conclusions

- Students can pick an answer out of a group
- Students written answers lack confidence
- These assessments tell two very different stories
- Misconceptions prevalent
  - Often co-exist with correct ideas leading to heterogeneous answers

Moving Forward

- Develop an expert rater scoring rubric that will be informative to instructors
- Use the lexical analysis data to predict expert ratings
- Challenges:
  - Wording of the question
  - Trade-off between holistic scoring and heterogeneity of student responses