Beyond Multiple Choice:

Automated analysis of student writing reveals heterogeneous student thinking in STEM

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Automated Analysis of Constructed Response (AACR) research group

Outline

- Theoretic Framework and Research Objectives
- Automated Analysis Approach
- Results: Chemistry of Biology

Constructed Response Assessment

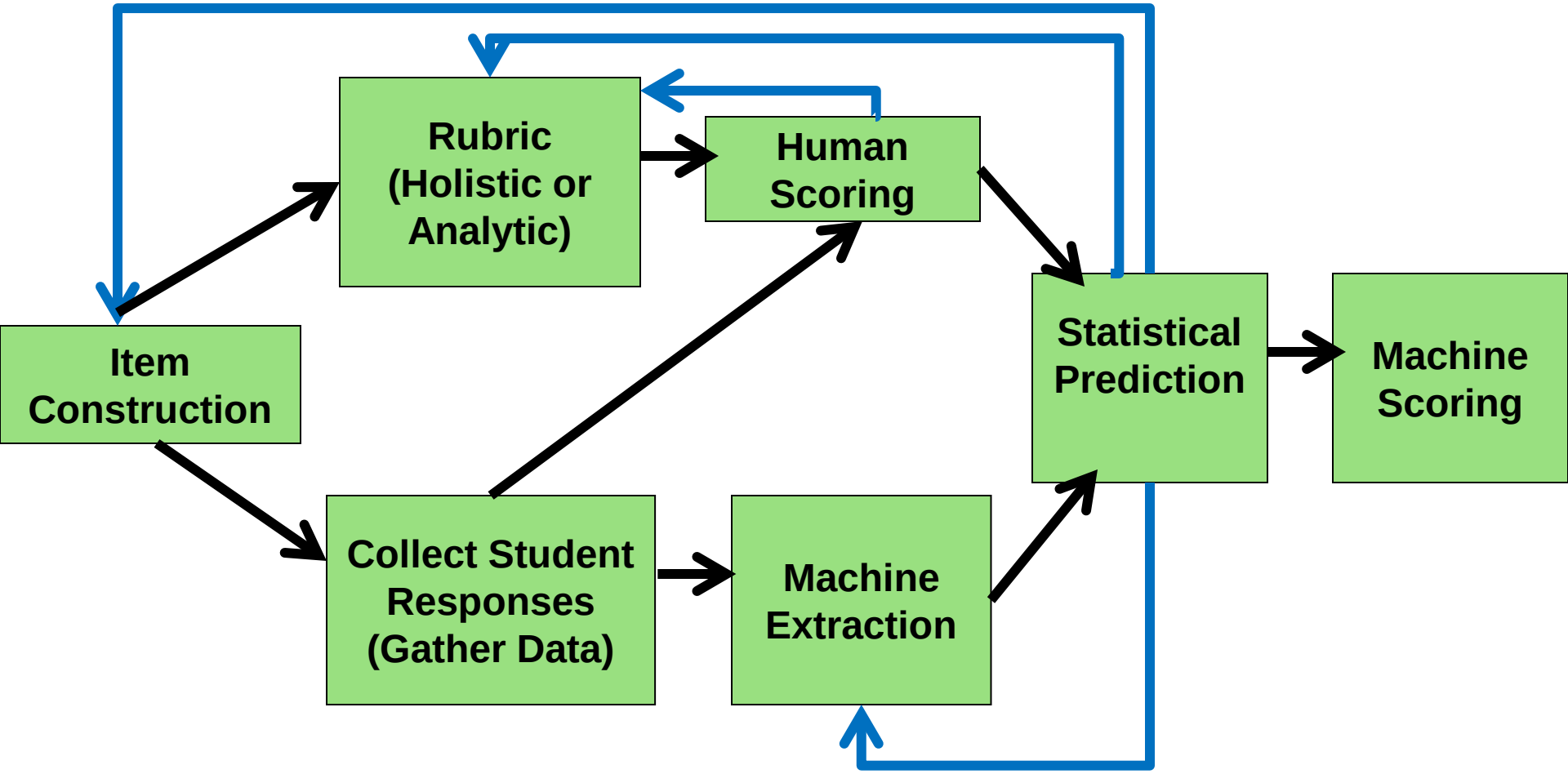
- Students learn by constructing knowledge
- Assessment should allow students to represent their knowledge in their own language
- Large enrollment courses prohibit the use of constructed responses assessments

(Bransford, 2000; Von Glasersfeld, 1994)

Objectives

- Evaluate students' understanding of scientific concepts
  - Create models of student thinking
- Use lexical and statistical analysis to analyze students' writing
  - Develop resources - libraries and categories
  - Validate by predicting expert ratings

Automated Analysis Approach



Functional Groups: Multiple Choice

Consider two small organic molecules in the cytoplasm of a cell, one with a hydroxyl group (-OH)

and the other with an amino group ($-NH_2$).

Which of these small molecules (either or both) is most likely to have an impact on the cytoplasmic pH?

33% A. Compound with amino group
49% B. Compound with hydroxyl group
12% C. Both
6% D. Neither

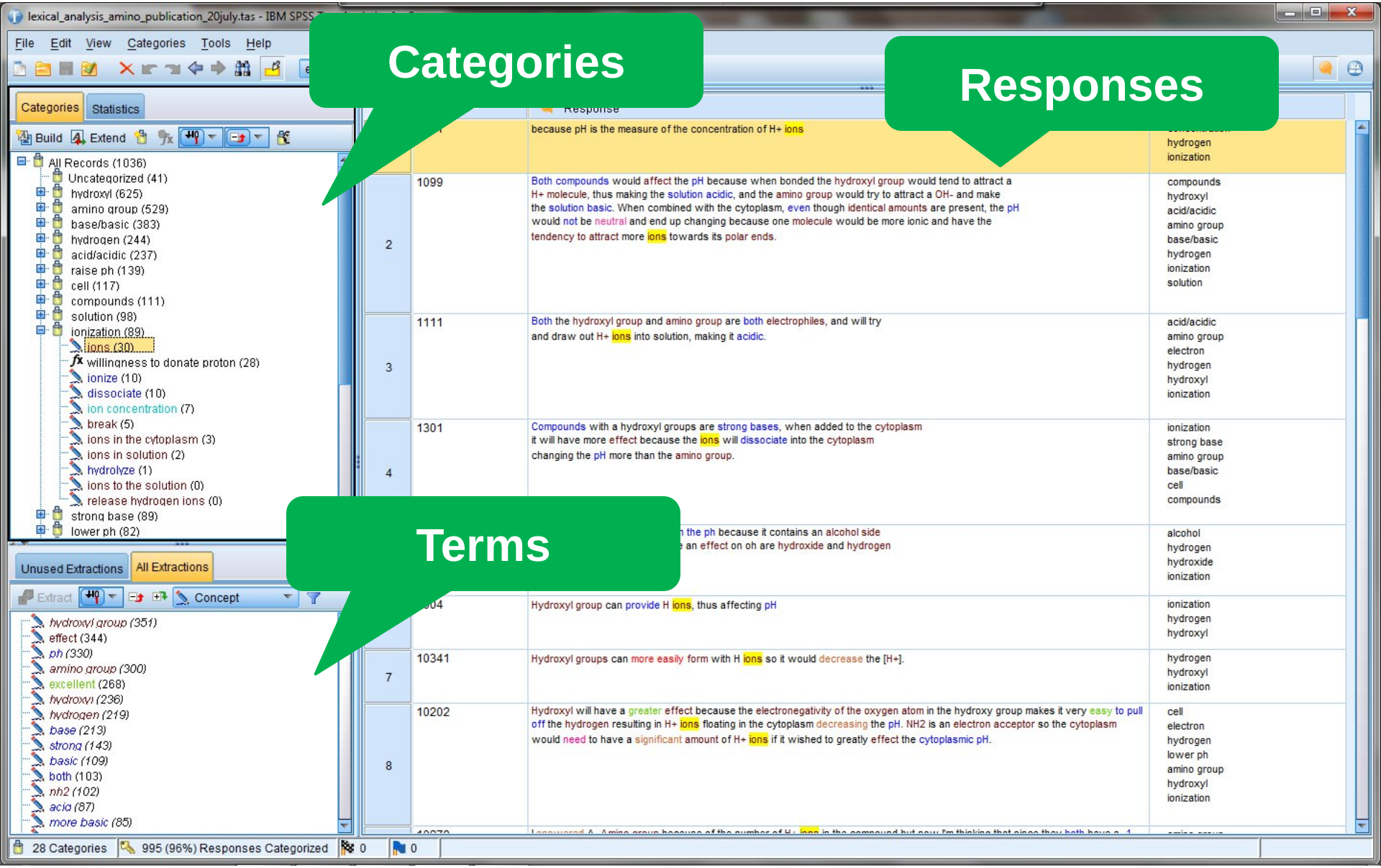
Explain your answer

Haudek, K., Prevost, L., Moscarella, R. B. A., Merrill, J. E., & Urban-Lurain, M. (In Revision). What are they thinking? Automated analysis of student writing about acid/base chemistry in introductory biology. *CBE - Life Sciences Education.*

Text Analysis

- Software
  - SPSS Text Analysis for Surveys
  - SPSS Modeler – Text Mining

- Procedure
  - Library Construction
  - Extraction
  - Categorization

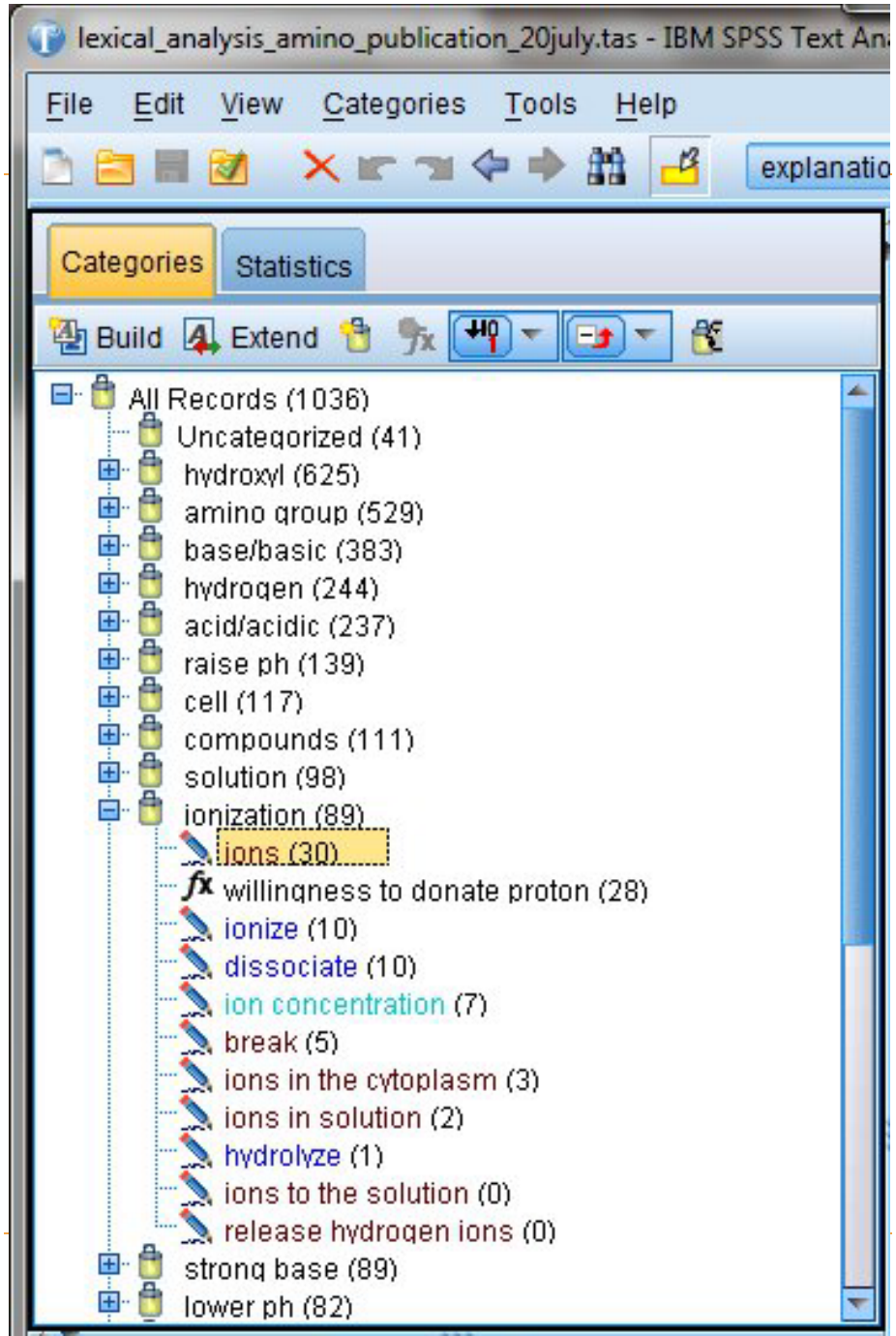

lexical_analysis_amino_publication_20july.tas - IBM SPSS
File Edit View Categories Tools Help
Categories
Responses
Terms
Categories Statistics
Build Extend
All Records (1036)
Uncategorized (41)
hydroxyl (625)
amino group (529)
base/basic (383)
hydrogen (244)
acid/acidic (237)
raise ph (139)
cell (117)
compounds (111)
solution (98)
ionization (89)
ions (30)
willingness to donate proton (28)
ionize (10)
dissociate (10)
ion concentration (7)
break (5)
ions in the cytoplasm (3)
ions in solution (2)
hydrolyze (1)
ions to the solution (0)
release hydrogen ions (0)
strong base (89)
lower ph (82)
Unused Extractions All Extractions
Extract Concept
hydroxyl group (351)
effect (344)
ph (330)
amino group (300)
excellent (268)
hydroxyl (236)
hydrogen (219)
base (213)
strong (143)
basic (109)
both (103)
nh2 (102)
acid (87)
more basic (85)
Response
because pH is the measure of the concentration of H+ ions
hydrogen
ionization
2
1099
Both compounds would affect the pH because when bonded the hydroxyl group would tend to attract a H+ molecule, thus making the solution acidic, and the amino group would try to attract a OH- and make the solution basic. When combined with the cytoplasm, even though identical amounts are present, the pH would not be neutral and end up changing because one molecule would be more ionic and have the tendency to attract more ions towards its polar ends.
compounds
hydroxyl
acid/acidic
amino group
base/basic
hydrogen
ionization
solution
3
1111
Both the hydroxyl group and amino group are both electrophiles, and will try and draw out H+ ions into solution, making it acidic.
acid/acidic
amino group
electron
hydrogen
hydroxyl
ionization
4
1301
Compounds with a hydroxyl groups are strong bases, when added to the cytoplasm it will have more effect because the ions will dissociate into the cytoplasm changing the pH more than the amino group.
ionization
strong base
amino group
base/basic
cell
compounds
alcohol
hydrogen
hydroxide
ionization
Hydroxyl group can provide H ions, thus affecting pH
ionization
hydrogen
hydroxyl
7
10341
Hydroxyl groups can more easily form with H ions so it would decrease the [H+].
hydrogen
hydroxyl
ionization
8
10202
Hydroxyl will have a greater effect because the electronegativity of the oxygen atom in the hydroxy group makes it very easy to pull off the hydrogen resulting in H+ ions floating in the cytoplasm decreasing the pH. NH2 is an electron acceptor so the cytoplasm would need to have a significant amount of H+ ions if it wished to greatly effect the cytoplasmic pH.
cell
electron
hydrogen
lower ph
amino group
hydroxyl
ionization
28 Categories
995 (96%) Responses Categorized
0
0

Responses

alytics for Surveys

	Id	Response	Categories
1	2331	because pH is the measure of the concentration of H+ ions	concentration hydrogen ionization
2	1099	Both compounds would affect the pH because when bonded the hydroxyl group would tend to attract a H+ molecule, thus making the solution acidic, and the amino group would try to attract a OH- and make the solution basic. When combined with the cytoplasm, even though identical amounts are present, the pH would not be neutral and end up changing because one molecule would be more ionic and have the tendency to attract more ions towards its polar ends.	compounds hydroxyl acid/acidic amino group base/basic hydrogen ionization solution
3	1111	Both the hydroxyl group and amino group are both electrophiles, and will try and draw out H+ ions into solution, making it acidic.	acid/acidic amino group electron hydrogen hydroxyl ionization
4	1301	Compounds with a hydroxyl groups are strong bases, when added to the cytoplasm it will have more effect because the ions will dissociate into the cytoplasm changing the pH more than the amino group.	ionization strong base amino group base/basic cell compounds

Categories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File
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lower ph (82)

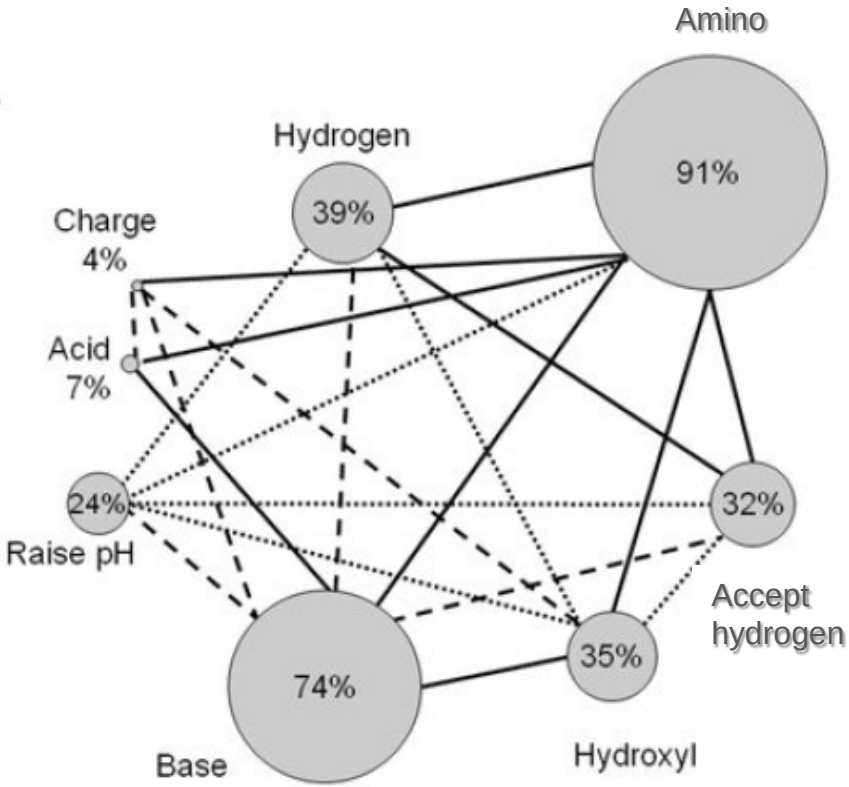
Example Holistic Rubric: Expert Ratings of Explanations

- Two experts rated explanations from correct answers using 3-bin rubric
  - 37% Bin 1: Correct explanations of functional group chemistry (may include correct supporting reasoning)
  - 10% Bin 2: Partly correct explanations with errors in facts or reasoning
  - 53% Bin 3: Totally incorrect/irrelevant response

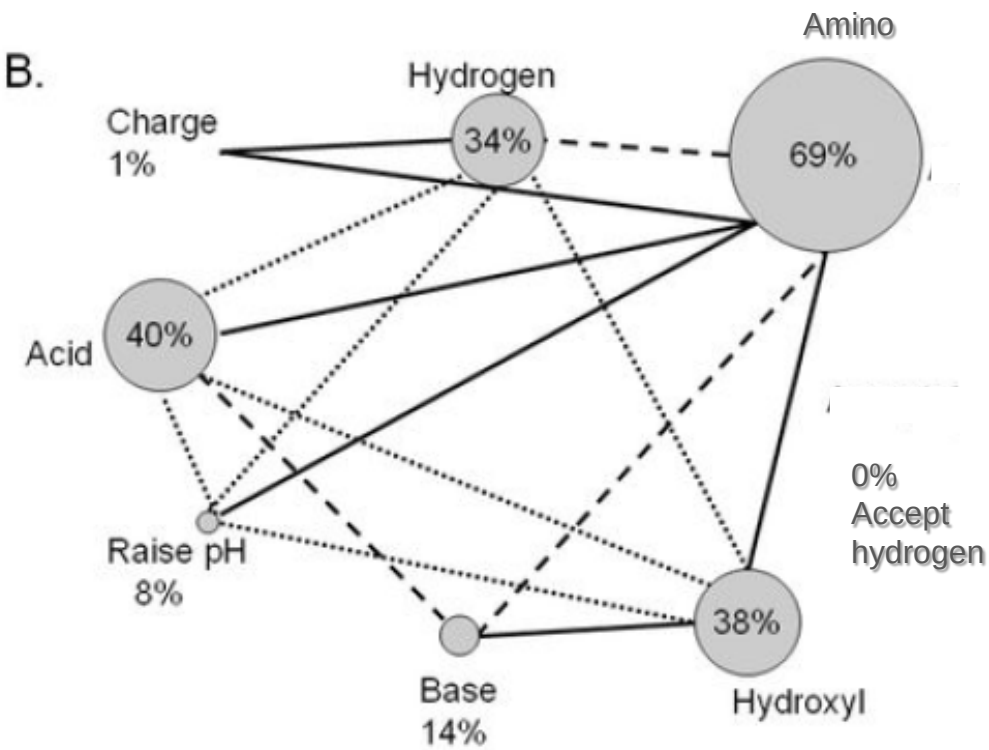
Inter-rater reliability = .90

Web Diagrams: Connections among categories

Bin 1: Correct



Bin 3: Incorrect



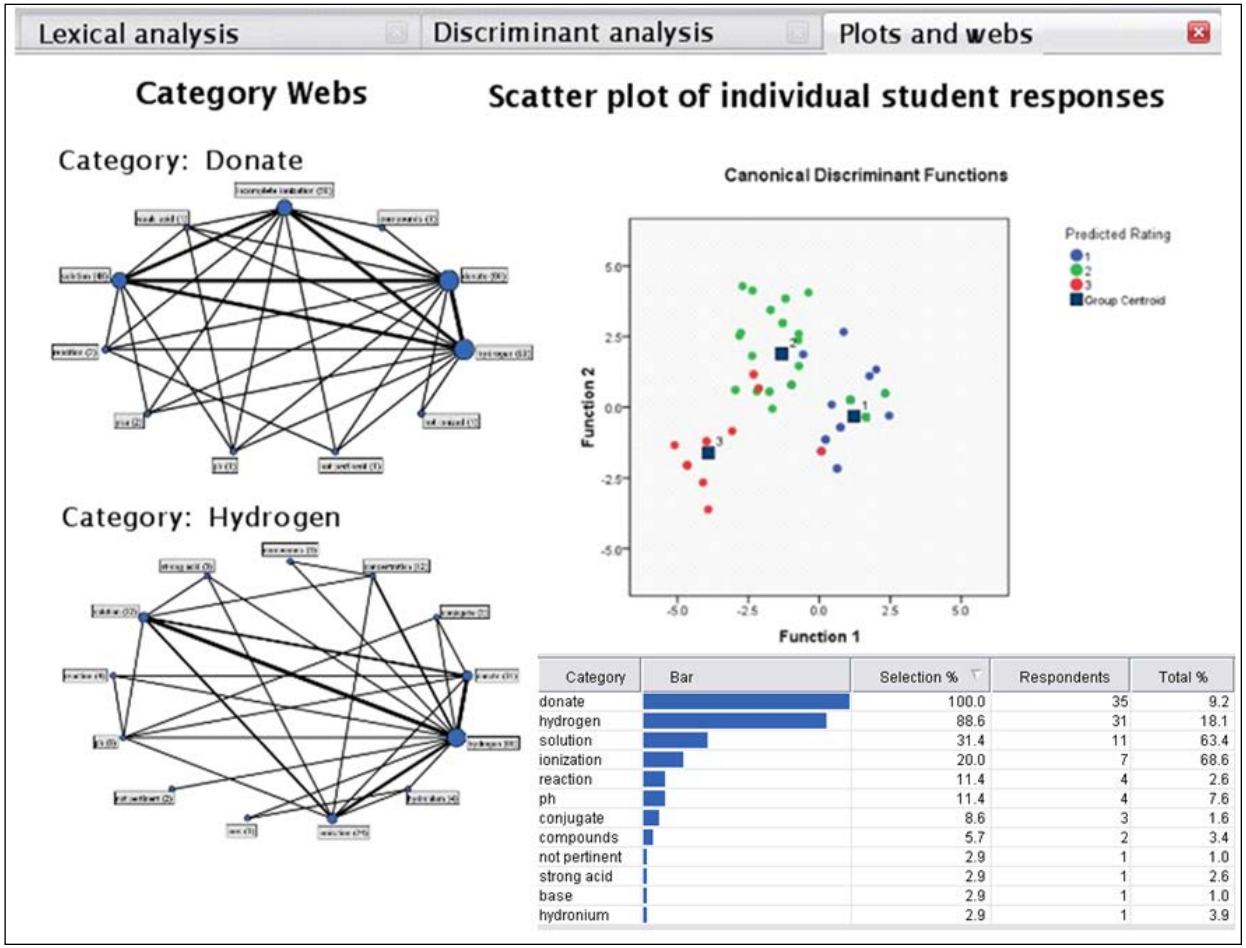
lines represent the % shared responses between categories

- 25 -49%;
- 50-74;
- ≥ 75%

Summary

- Automated Text Analysis can facilitate constructed responses assessments
- Lexical analysis provides a whole-class picture of term / concept usage
- Statistical analysis can help identify categories of importance
- Heterogeneity of student ideas is captured in categories and the connections among categories

Future Work – Web Portal



Category	Bar	Selection %	Respondents	Total %
donate		100.0	35	9.2
hydrogen		88.6	31	18.1
solution		31.4	11	63.4
ionization		20.0	7	68.6
reaction		11.4	4	2.6
ph		11.4	4	7.6
conjugate		8.6	3	1.6
compounds		5.7	2	3.4
not pertinent		2.9	1	1.0
strong acid		2.9	1	2.6
base		2.9	1	1.0
hydronium		2.9	1	3.9

AACR Research Group

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aacr.crcstl.msu.edu