Using Lexical Analysis Software to Understand Student Knowledge Transfer between Chemistry and Biology

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Chemistry of Biology

- Evaluate students' understanding of basic chemistry that may be related to conceptual problems students have in cellular and molecular biology
- Introductory Cell and Molecules Biology
- Focus on two topics: Free energy and acid/base chemistry

Research Questions

- Do students use chemistry concepts in response to biological chemistry problems?

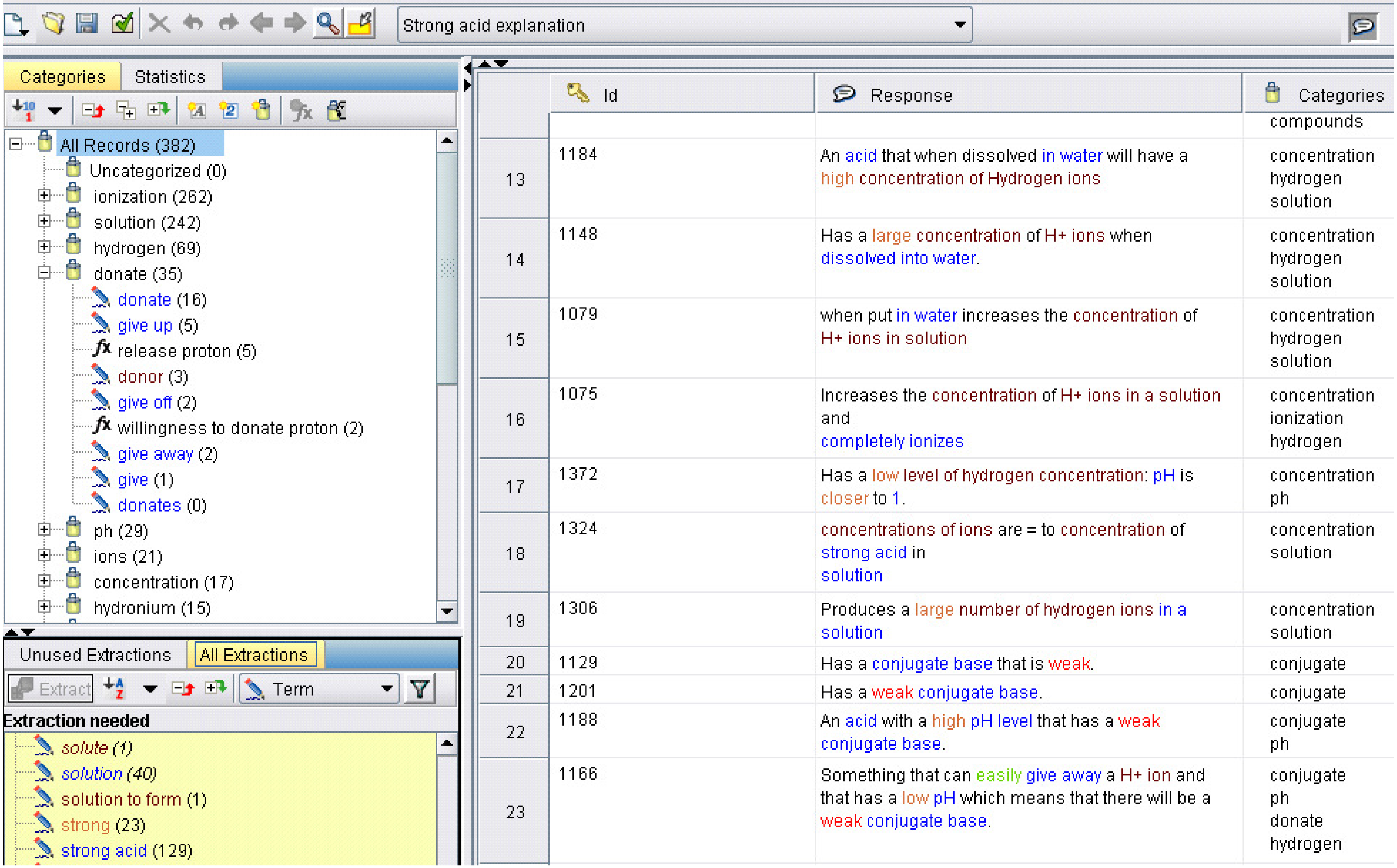
- Can lexical analysis extract and categorize chemistry terms from student responses?
- Are these categories meaningful?

Strong and weak acids: constructed response

- Students were asked to:
  - Give an explanation of a strong acid.
  - Give an explanation of a weak acid.

- 382 student responses collected from Fall 2008

Lexical analysis



Strong and weak acids: lexical analysis

- Each explanation was analyzed separately
- Lexical analysis resulted in a total of 27 categories

Strong acid

	% of responses
ionization	68.6
solution	63.4
hydrogen	18.1
donate	9.2
ph	7.6
ions	5.5
concentration	4.5
hydronium	3.9
compounds	3.4
reaction	2.6
strong acid	2.6
don't know	2.4
electrolytes	2.1
conjugate	1.6
bond	1.3
hydrolysis	1.3
not pertinent	1.0
base	1.0
not informative	1.0
not ionized	0.5
pka	0.5
equal	0.3
halogen	0.3

Weak acid

	% of responses
Incomplete ionization	59.9
solution	57.9
hydrogen	28.8
donate	18.1
not ionized	8.6
ph	6.3
ions	5.2
reaction	3.4
compounds	3.4
concentration	2.6
don't know	2.6
ionization	1.8
hydronium	1.6
electrolytes	1.6
conjugate	1.6
base	1.6
bond	1.6
hydrolysis	1.6
not pertinent	1.3
pka	1.3
weak acid	1.0
not informative	0.8
electron	0.5
strong acid	0.5

Strong and weak acids: expert scoring

- Two experts rated 150 responses using 4-bin rubric
  - Level 1: Correct explanations both strong and weak acids
  - Level 2: Mostly correct explanations with minor errors
  - Level 3: Mostly incorrect explanations OR one explanation completely correct; one explanation completely incorrect
  - Level 4: Totally incorrect explanations / irrelevant information

Strong and weak acids: expert rating

- Inter-rater reliability of two expert raters
  - Cronbach alpha > .97

LEVEL

1	2	3	4	TOTAL
91	9	18	18	136

Predicting expert score: Discriminant analysis

- Step-wise discriminant analysis
- Dependent Variable: Expert rating
- Independent Variables: Lexical categories

Strong and weak acids: discriminant analysis

Categories		Function 1	Function 2	Function 3
Strong acid explanation:	hydrolysis	-.111	.288	-.248
	donate	-.071	.143	.257
	solution	.323	.237	-.178
	hydrogen	-.062	.101	.187
	not pertinent	-.086	-.132	-.016
	conjugate	-.060	.156	-.134
	ionization	.446	.056	-.417
Weak acid explanation:	incomplete ionized	.624	-.094	.222
	not ionized	-.157	.354	.279
	solution	.294	.056	-.269
	not pertinent	-.122	.106	-.168
	electrolytes	.011	.031	.424

Function 1 accounts for 69.9% of variance

Function 2: 25.2%

Function 3: 5%

Strong and weak acids: cross-validation

- Cross-validation classification functions results in 83.8% of responses being correctly scored

	Computer Predicted Rating			
Expert Rating	1	2	3	4
1	**93.4**	3.3	3.3	0.0
2	33.3	**33.3**	22.2	11.1
3	5.6	5.6	**66.7**	33.3
4	11.1	0.0	11.1	**77.8**

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?
- **A. Compound with amino group (35%)**
- B. Compound with hydroxyl group (45%)
- C. Both (7%)
- D. Neither (13%)

Functional groups: constructed response

- "Explain your answer."
- 2 Experts rated 131 correct answers using 3-bin rubric
  - Level 1: Correct explanations of functional group chemistry (may include correct supporting reasoning)
  - Level 2: Partly correct explanations with errors in facts or reasoning
  - Level 3: Totally incorrect/irrelevant response

Expert rating: Functional group open response

- Cronbach Alpha > .92

LEVEL			
1	2	3	TOTAL
41	14	58	113
36%	12%	51%	

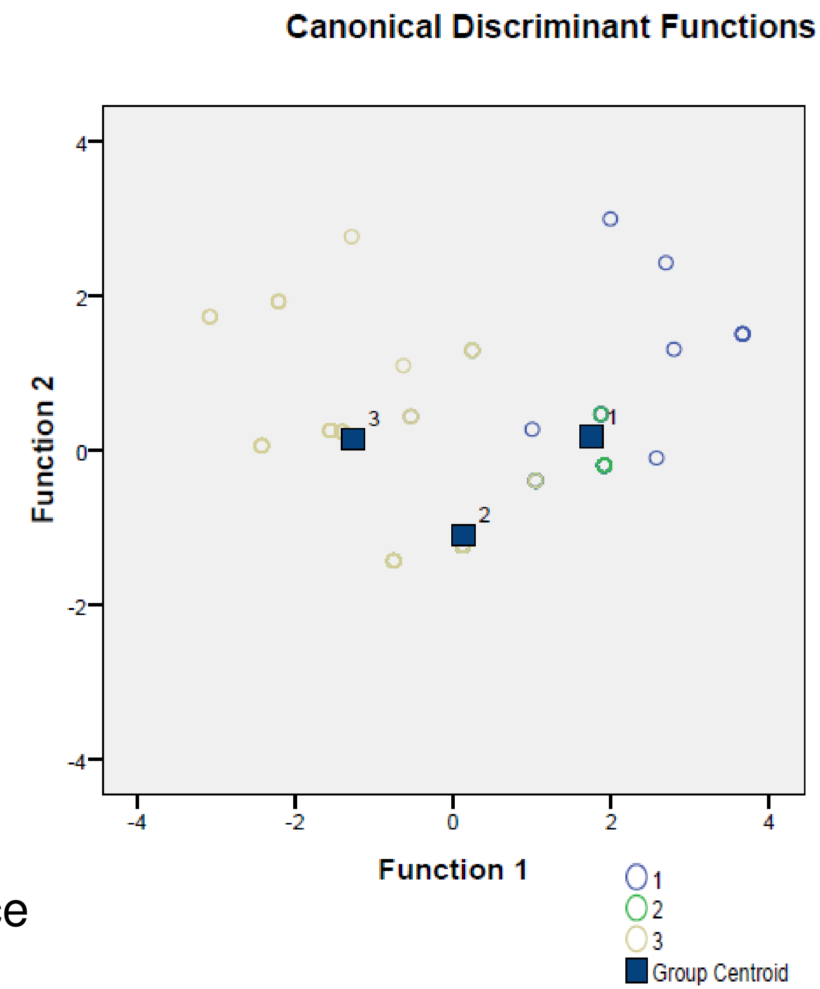
Lexical analysis: Functional groups

- Each foil analyzed separately
- For correct response: 28 categories
  - Ionization – 20
  - Accept hydrogen - 13

Functional group: Discriminant analysis

Category	Function 1	Function 2
base/basic	.517	.349
acid/acidic	-.378	.629
amino group	.280	.128
hydrogen	-.039	.605
charge	.121	.137
accept hydrogen	.345	.388

- Function 1 accounts for 91% of variance



Functional Groups: Computer predicted

- Cross-validation results in 77% of the cases scored correctly

	Computer Predicted Rating		
Expert Rating	1	2	3
1	**82.9**	12.2	4.9
2	21.4	**42.9**	35.7
3	6.9	12.1	**81.0**

- Expert/computer inter-rater reliability
  - Intraclass correlation = 0.835

Conclusions: Acid/base chemistry

- Students have difficulty describing activity of acid/base behavior of functional groups, but not in a general format.
- Important terms in student responses change between explanations.
- Inappropriate concept application revealed by lexical analysis.

Conclusions: Lexical and discriminant analyses

- Lexical analysis provides a whole-class picture of term / concept usage.
- Discriminant analysis can help identify categories of importance.
- Classification functions can be developed to accurately predict human scoring.
- Analysis can be done per rubric.

Future Directions

- Refinement of current analysis
  - Collection of more student responses
- Sequences and related constructed response items
- Expansion into other disciplines
  - Evolution and natural selection, geology, genetics
- Just in Time Teaching

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