



# Scientific Thinking and Conceptual Change:

---

## Revealing Student Thinking as a Foundation for Improving Learning Outcomes in STEM

Mark Urban-Lurain

Automated Analysis of Constructed Response Research Group

Division of Science and Mathematics Education

Michigan State University

# AACR Research Group

---

## Michigan State University

- Joseph Dauer
- Olga Eremina
- Emma Giese
- Laurissa Gulich
- Kevin Haudek
- Merle Heidemann
- Shauna Jones
- Jennifer Kaplan
- Julie C Libarkin
- Tammy Long
- Casey Lyons
- John Merrill
- Rosa Anna Moscarella
- Alan Munn
- Joyce Parker
- Brittany Shaffer
- Duncan Sibley
- Elena Bray Speth
- Mark Urban-Lurain
- Emily Geraghty Ward

## The Ohio State University

- Ross Nehm
- Judy Ridgway
- Hendrick Haertig
- Minsu Ha

## University of Colorado - Boulder

- Jennifer Knight

## University of Washington

- Michelle Smith

## Grand Valley State University

- Brittany Shaffer

## Western Michigan University

- Mary Anne Sydlik

# Acknowledgements

---



- National Science Foundation  
DUE-0736952, DUE-0243126,  
EHR-0314866, DUE-1022653
- Carnegie Corporation  
Grant #B7458
- The Vice Provost for Libraries,  
Computing and Technology,  
Michigan State University

Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the funding agencies.



# STEM Education Reform

---

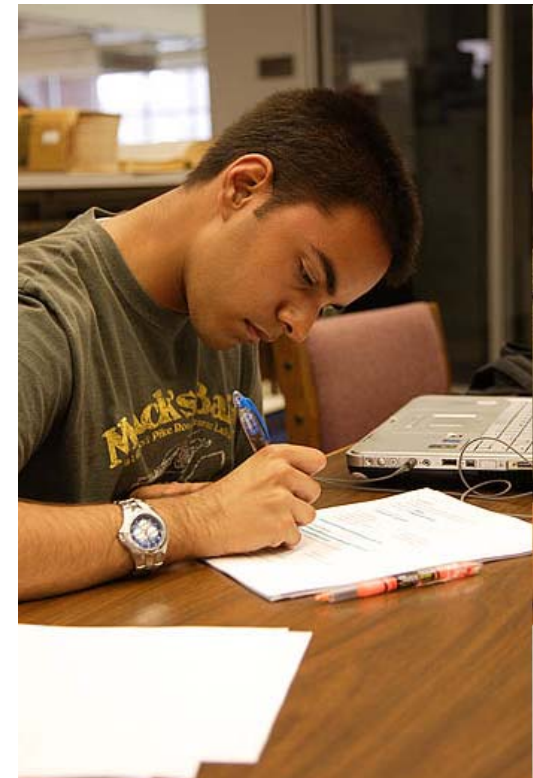
At all levels, science education needs to be redefined, with much less emphasis on the memorization of science facts and terms.

Closely related changes in the introductory science courses in college, emphasizing “science as a way of knowing,” are the key to driving these reforms.

*Science and the World's Future*, Bruce Alberts, MSU STEM Education Symposium

# Backwards Design: Assessment to Reveal Student Thinking

---





# Theoretic Framework: Conceptual Change

---

- Conceptual barriers impair students' understanding complex processes in science
- Conceptual Change
  - Role of prior knowledge in learning
- Student ideas
  - May be identified by students' use of language
  - *Constructed Response* questions can provide insight into student ideas



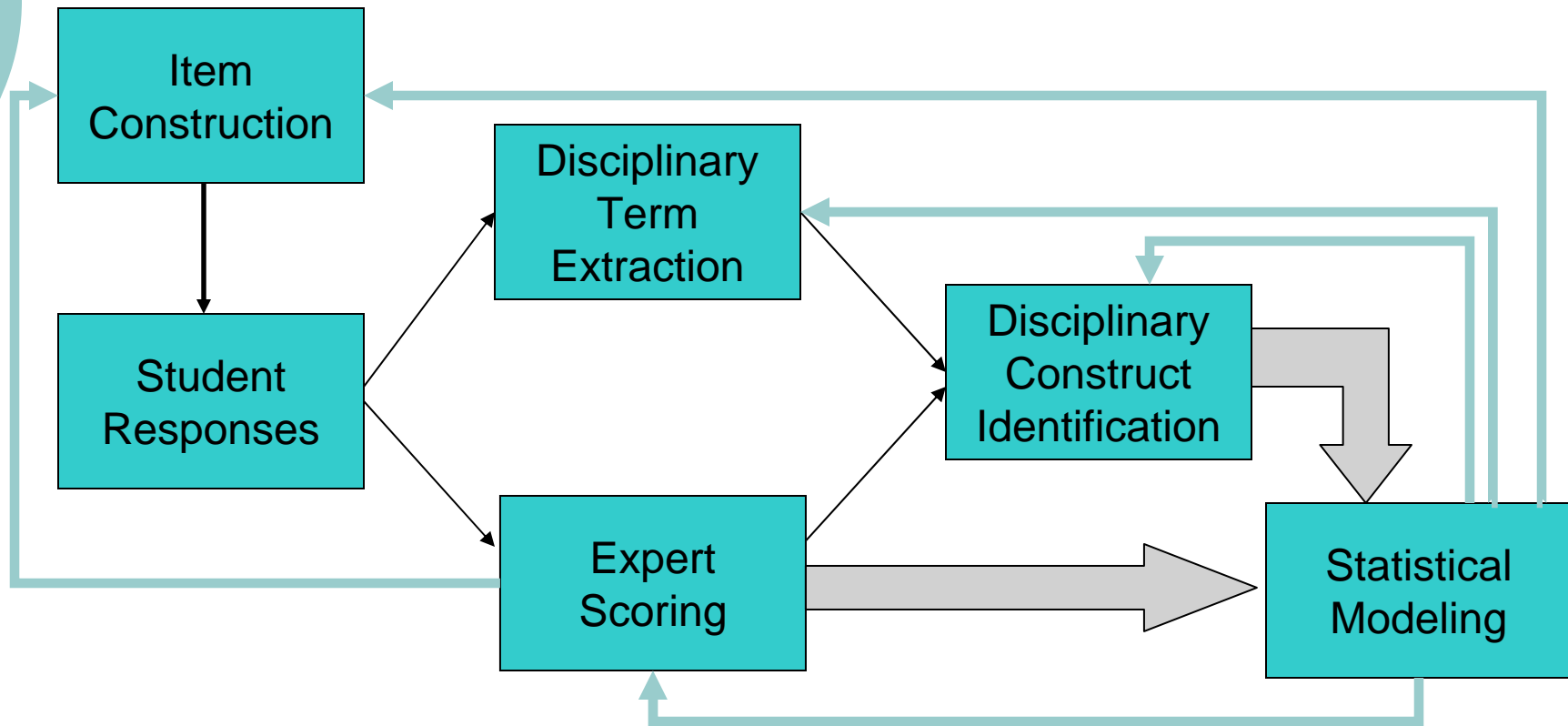
# AACR Objectives

---

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

# Our Approach: Linguistic Feature-Based

---







# Validating by Predicting Expert Ratings

## Example: Chemistry of Biology

---

- Evaluate students' understanding of basic chemistry related to cellular and molecular biology
  - Free energy and acid/base chemistry
- Introductory Biology Cells and Molecules (BS111)
  - Large enrollment (400-500 / section)
  - General chemistry prerequisite

# 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<sub>2</sub>). Which of these small molecules (either or both) is most likely to have an impact on the cytoplasmic pH?

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

Explain your answer



# Sample Student Answers

The amino group can break down compounds faster and can therefore change the pH of the cytoplasm

Has a carboxyl group, is more acidic

The amino group is more basic and can change the pH better than the hydroxyl group.

The hydroxyl group doesn't affect the pH as much as an amino, which has a  $\text{NH}_2$ .

The level of Hydrogen concentration defines the pH.

The amino group is an acid. It will cause the pH in the compound to rise.

Hydroxyl is a base.

# Expert Ratings of Explanations

---

- Two experts rated explanations from correct answers using 3-level rubric
  - 36% ● Level 1: Correct explanations of functional group chemistry (may include correct supporting reasoning)
  - 12% ● Level 2: Partly correct explanations with errors in facts or reasoning
  - 51% ● Level 3: Totally incorrect/irrelevant response
- 
- Cronbach Alpha > .92

# Predicting Expert Ratings

---

Expert Rating	Computer Predicted Rating		
	1	2	3
1	<b>82.9</b>	12.2	4.9
2	21.4	<b>42.9</b>	35.7
3	6.9	12.1	<b>81.0</b>

- 77% of the cases scored correctly,  $p < .001$
- Expert/computer inter-rater reliability  
Intraclass correlation = 0.835

# Weight Loss: Multiple Choice

---

You have a friend who lost 15 pounds of fat on a diet. Where did the mass go?

- 44% A) The mass was released as  $\text{CO}_2$  and  $\text{H}_2\text{O}$ .
- 23% B) The mass was converted to energy which was used up.
- 21% C) The mass was converted to ATP molecules.
- 9% D) The mass was broken down to amino acids and eliminated from the body.
- 3% E) The mass was converted to urine and feces and eliminated from the body.

DQC question, BS 111, Fall, 2006 (N = 459)



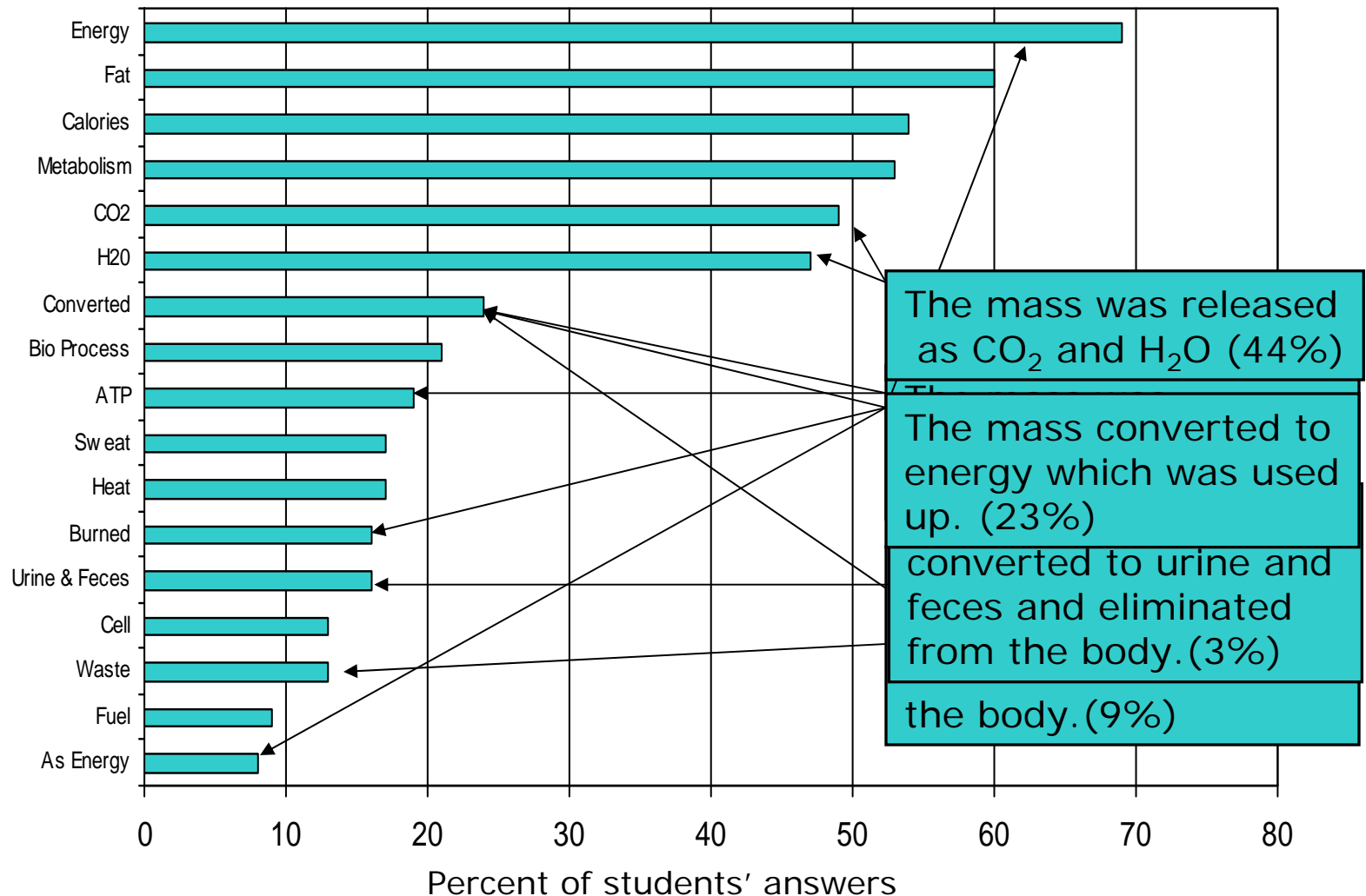
# Weight Loss: Constructed Response

---

You have a friend who lost 15 pounds of fat on a diet. Where did the mass go?

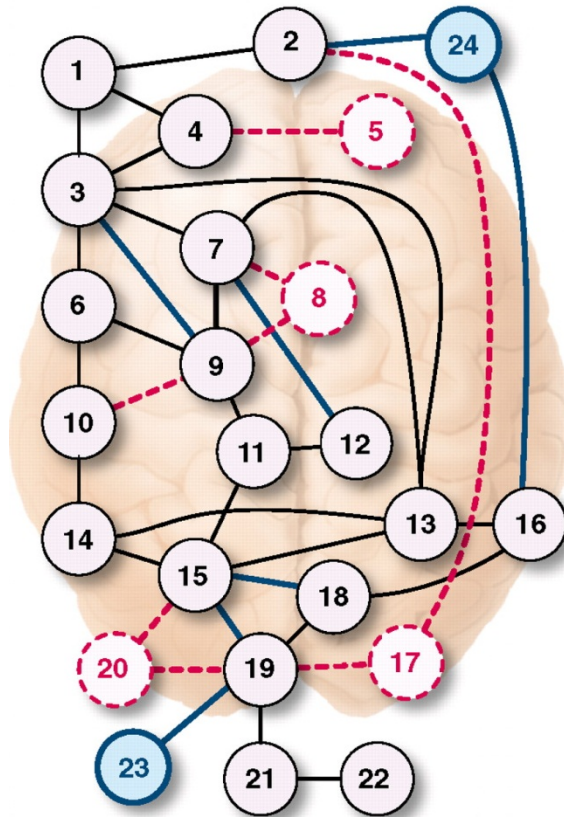
BS 111, Fall, 2009, (N = 316)

# Concepts in Students' Answers





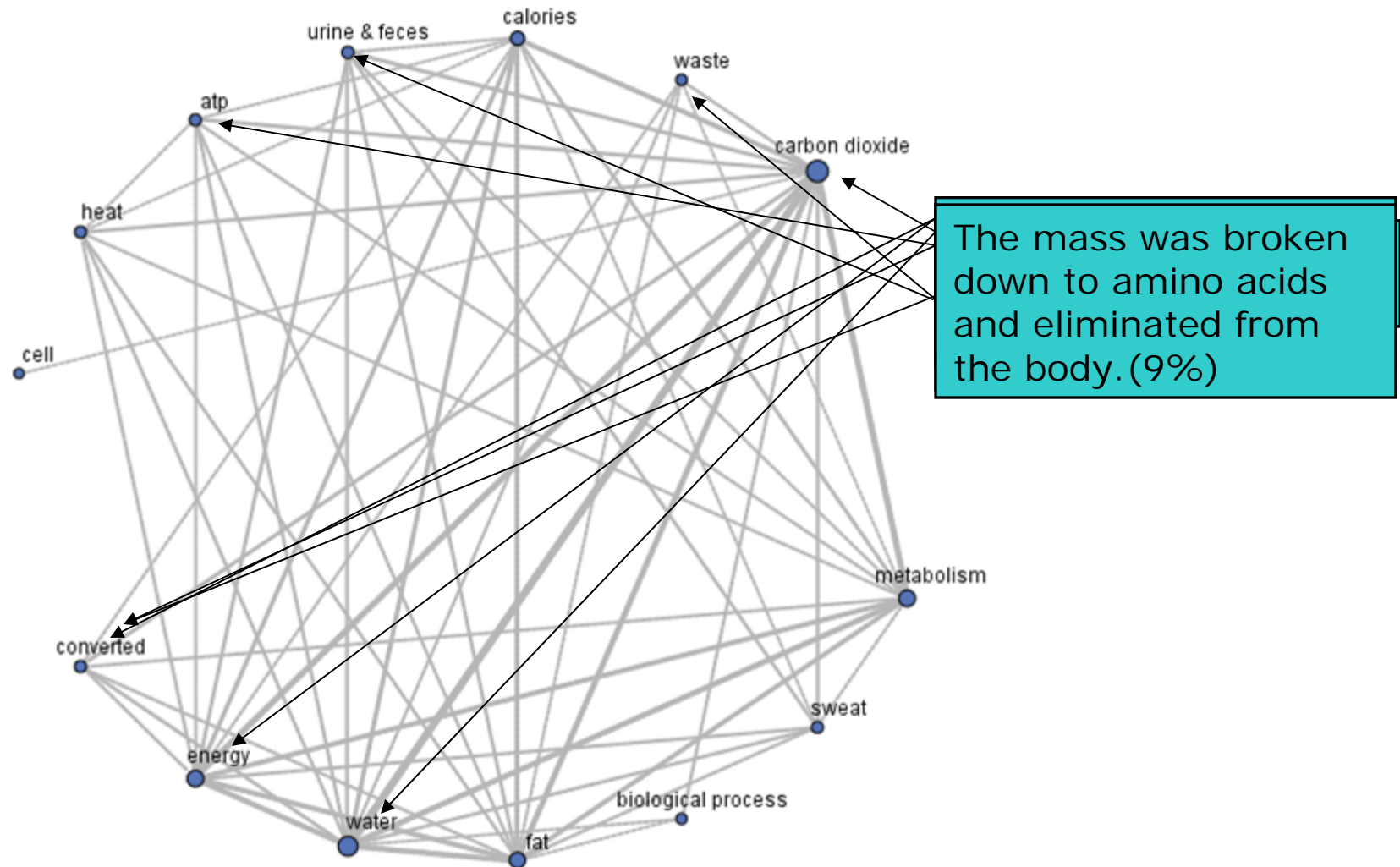
# Conceptual Change: Role of Prior Knowledge in Learning



Expansion and modification of a hypothetical reader's knowledge structure.

Correct prior knowledge (black)  
Newly acquired knowledge (blue)  
Corrected misconceptions (red)

# Relationships Among Concepts in Students' Writing





# Conceptual Change: Instructional Implications

---

- Student ideas are heterogeneous
- Instruction should start with student ideas
- Cannot simply “replace” misconceptions

Chi, M. (2008). Three types of conceptual change: Belief revision, mental model transformation, and categorical shift. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (pp. 61-82). New York: Routledge.



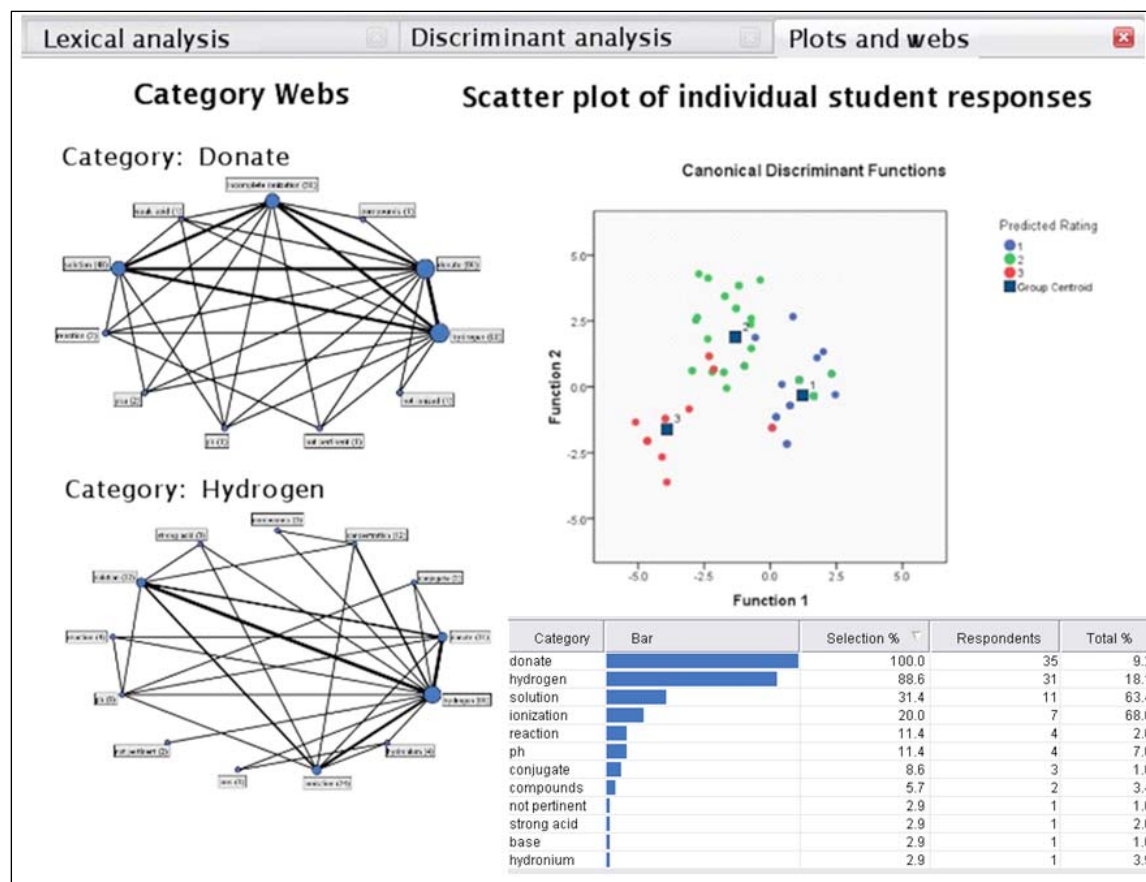
# Current Work

---

Automated Analysis of Constructed Response  
Concept Inventories to Reveal Student Thinking:  
Forging a National Network for Innovative  
Assessment Methods

- CCLI - II
- MSU, OSU, CU-B, U-W, WMU
- Constructed response versions of concept inventory questions
  - Cellular metabolism
  - Genetics
  - Evolution
  - Geoscience
- Questions, libraries, text analysis packages

# Future Work Web Portal

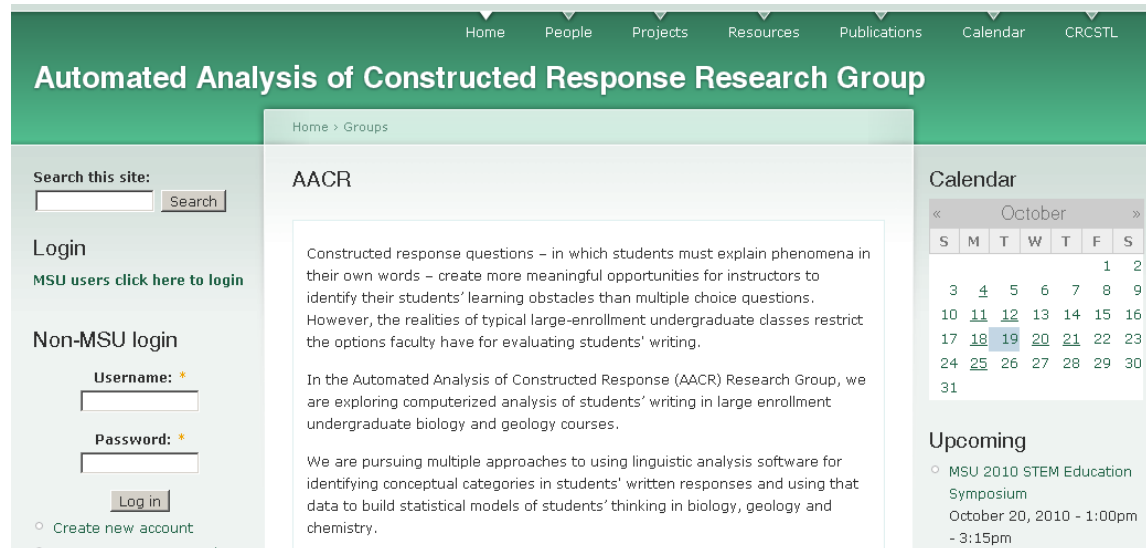


# Questions

## Mark Urban-Lurain

Division of Science and Mathematics Education  
Michigan State University  
urban@msu.edu

aacr.crcstl.msu.edu



The screenshot shows the homepage of the Automated Analysis of Constructed Response Research Group (AACR). The header is green with navigation links: Home, People, Projects, Resources, Publications, Calendar, and CRCSTL. Below the header, the title "Automated Analysis of Constructed Response Research Group" is displayed. The main content area is divided into three columns. The left column contains a search bar, a login section for MSU users (with a link to click here to login), and a non-MSU login section with fields for Username and Password, a Log in button, and links for Create new account and Request new password. The middle column is titled "AACR" and contains two paragraphs of text. The right column contains a calendar for October and an "Upcoming" section listing the MSU 2010 STEM Education Symposium on October 20, 2010, from 1:00pm to 3:15pm.

Home People Projects Resources Publications Calendar CRCSTL

### Automated Analysis of Constructed Response Research Group

Home > Groups

Search this site:

**Login**  
MSU users [click here to login](#)

**Non-MSU login**

Username: \*

Password: \*

[Create new account](#)  
[Request new password](#)

### AACR

Constructed response questions – in which students must explain phenomena in their own words – create more meaningful opportunities for instructors to identify their students' learning obstacles than multiple choice questions. However, the realities of typical large-enrollment undergraduate classes restrict the options faculty have for evaluating students' writing.

In the Automated Analysis of Constructed Response (AACR) Research Group, we are exploring computerized analysis of students' writing in large enrollment undergraduate biology and geology courses.

We are pursuing multiple approaches to using linguistic analysis software for identifying conceptual categories in students' written responses and using that data to build statistical models of students' thinking in biology, geology and chemistry.

### Calendar

« October »

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

### Upcoming

- MSU 2010 STEM Education Symposium  
October 20, 2010 - 1:00pm - 3:15pm