Comparing Formative Feedback Reports: Human and Automated Text Analysis of Constructed Response Questions in Biology

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Constructed Response Questions vs. Multiple Choice

- Constructed response questions require students to create a written answer from their rationalization of the question and the concepts involved in it (Kuechler & Simkin 2010)

- Students treat multiple choice questions and CR questions as different cognitive tasks (Stanger-Hall 2012)

Kuechler, W.L., & Simkin, M.G. (2010). Why is performance on multiple-choice tests and constructed-response tests not more closely related? Theory and an empirical test. *Decision Sciences Journal of Innovative Education 8: 55–73.*

Stanger-Hall, K.F. (2012). Multiple-Choice Exams: An Obstacle for Higher-Level Thinking in Introductory Science Classes. *CBE Life Sci Educ, (11)* 3 294-306. doi: 10.1187/cbe.11-11-0100

Using Constructed Response Questions

- CR questions require a greater investment of time to evaluate than multiple choice questions

- To save time, instructors tend to read a sample of responses

Using Text Analysis to Speed Up Scoring

- Computerized text analysis (TA) can summarize the distribution of key concepts and misconceptions in student writing

- TA identifies words and phrases that can be further analyzed with statistical modeling

Background

- Interested in exploring the use of computerized text analysis to evaluate constructed-response assessments

Haudek, K.C., Kaplan, J.J., Knight, J.K., Long, T., Merrill. J.E., Munn, A., Nehm, R., Smith, M.K., & Urban-Lurain, M. (2011). Harnessing Technology to Improve Formative Assessment of Student Conceptions in STEM: Forging a National Network. CBE—Life Sciences Education (10), 149–155.

- Photosynthesis project: Looking for differences in how students respond to different question stems

Weston, M., Haudek, K.C., Prevost, L.B., Lyons, C., Urban-Lurain, M., & Merrill, J.E. (2012). How do biology undergraduates "explain" photosynthesis? Investigating student responses to different constructed response question stems. Paper presented at National Association for Research in Science Teaching International Conference, Indianapolis, IN.

- Other projects in chemistry, thermodynamics, genetics, and evolution

Haudek, K.C., Prevost, L.B., Moscarella, R.A., Merrill, J.E., & Urban-Lurain, M. (2012). What are they thinking? Automated Analysis of student writing about acid/base chemistry in introductory biology. *CBE Life Sci Educ, 11,* 283-293. doi: 10.1187/cbe.11-08-0084.

Prevost, L.B., Haudek, K.C., Merrill, J.E., & Urban-Lurain, M. (2012). *Deciphering Student Ideas on Thermodynamics Using Computerized Lexical Analysis of Student Writing.* Paper presented at American Society for Engineerin g Education, San Antonio, TX.

Prevost, L.B., Knight, J.K., Smith, M.K., Haudek, K.C., Merrill, J.E., Urban-Lurain, M. (2012). *Using Lexical Analysis to Explore Students' Written Responses to Genetics Concept Assessment-Derived Items.* Presented at National Meeting of the Society for the Advancement of Biology Education Research, Minneapolis, MN.

Ha, M., Nehm, R.H., Urban-Lurain, M., & Merrill, J.E. (2011). Applying Computerized-Scoring Models of Written Biological Explanations across Courses and Colleges: Prospects and Limitations. *CBE Life Sci Educ 10(4)* 379-393. doi 10.1187/cbe.11-08-0081

Research Questions

- How do instructors analyze answers to CR questions?

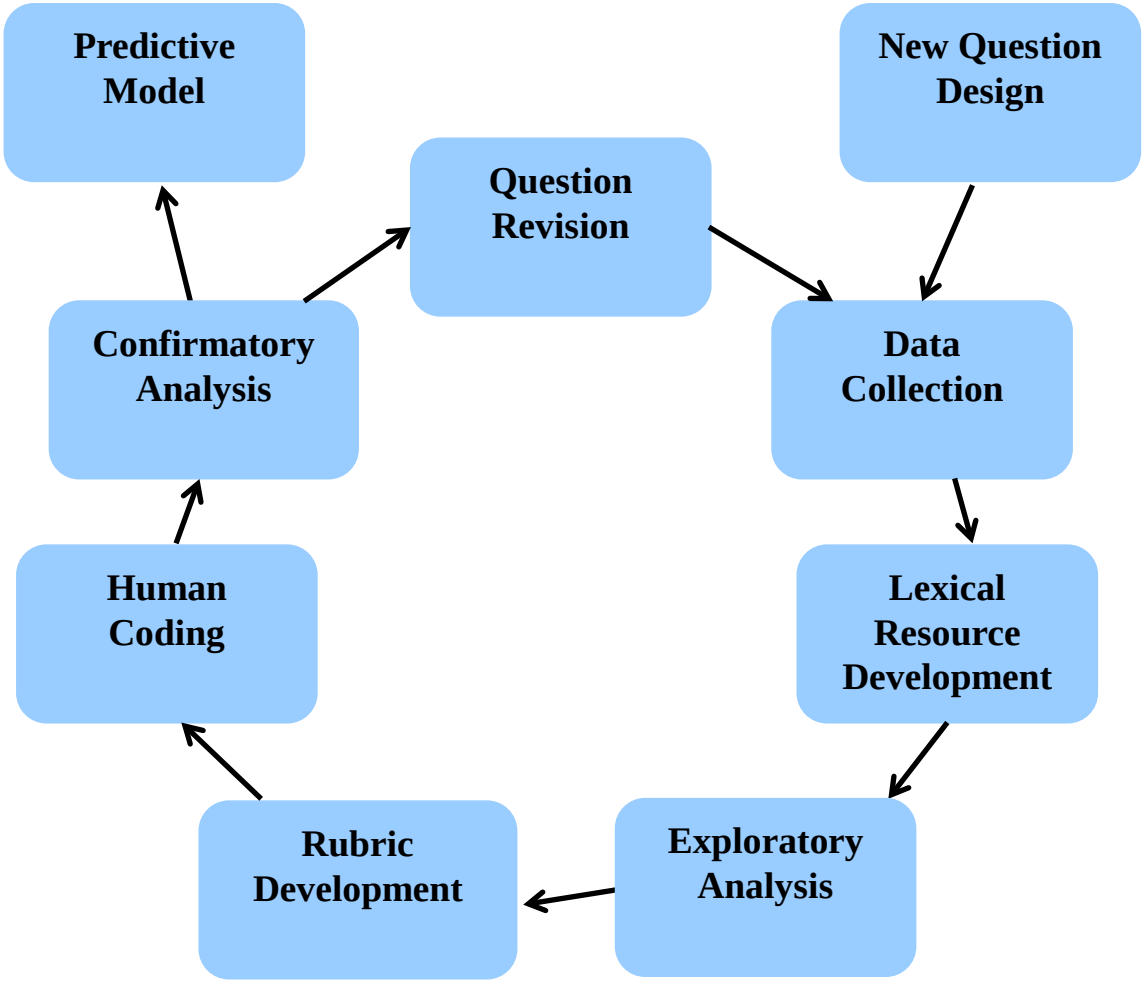
Instructor Analyses

- Expert scorers experienced with reading student written responses
- Had not seen the responses to this question before
- Read for formative assessment of the students' writing

Research Questions

- How do instructors analyze answers to CR questions?
- How do the results from computerized text analysis techniques compare with the instructors' analyses?

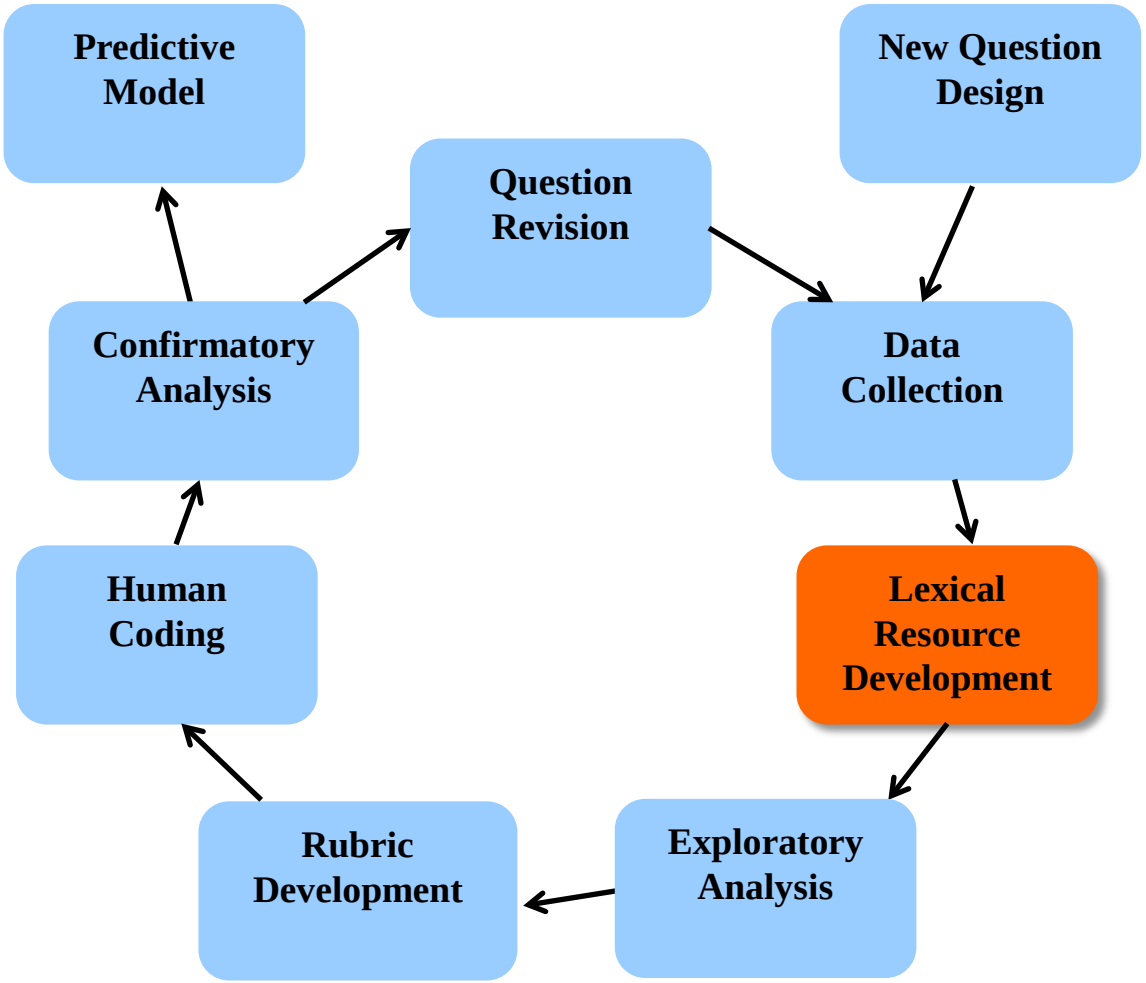
Assessment Development Process



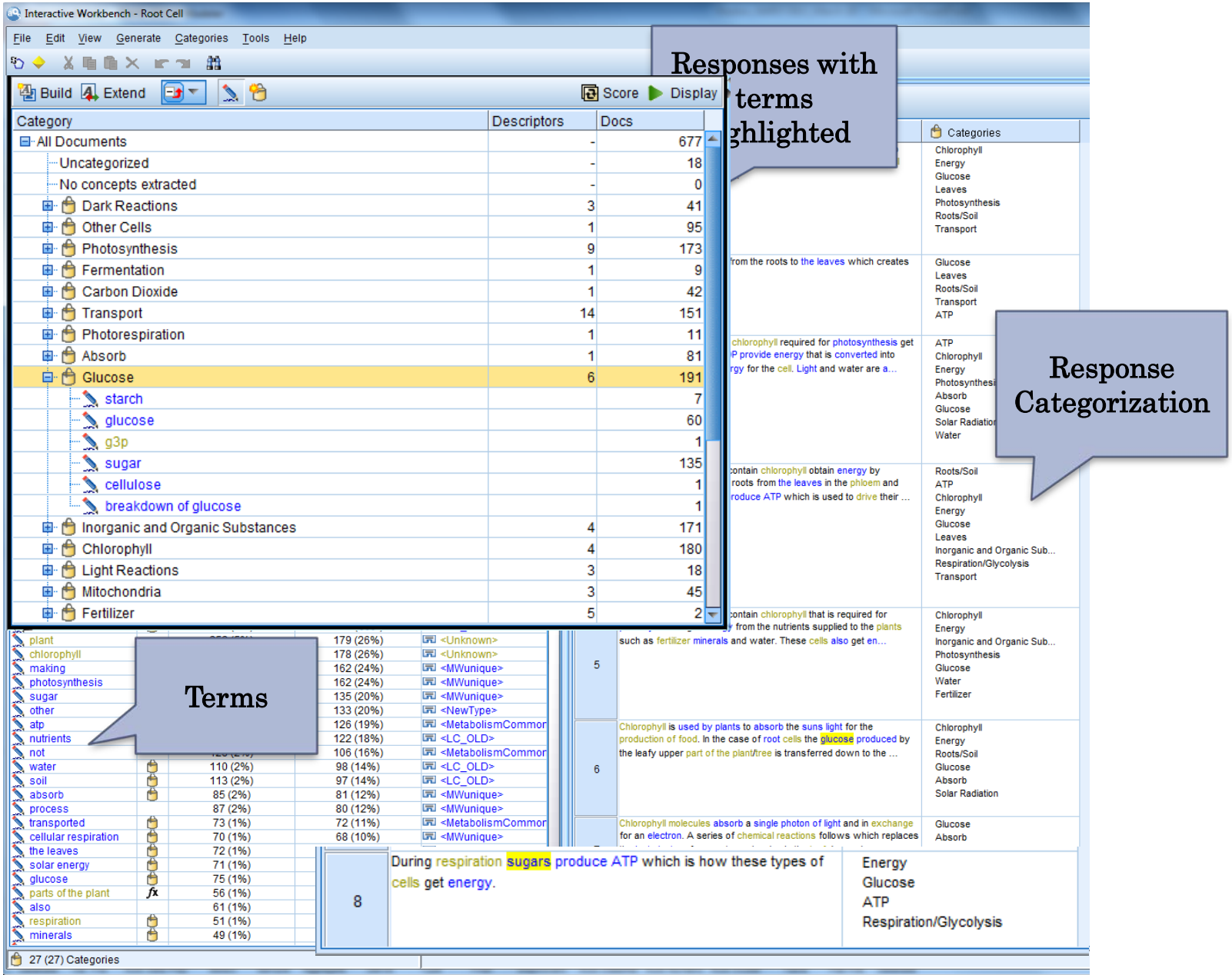
Study Design

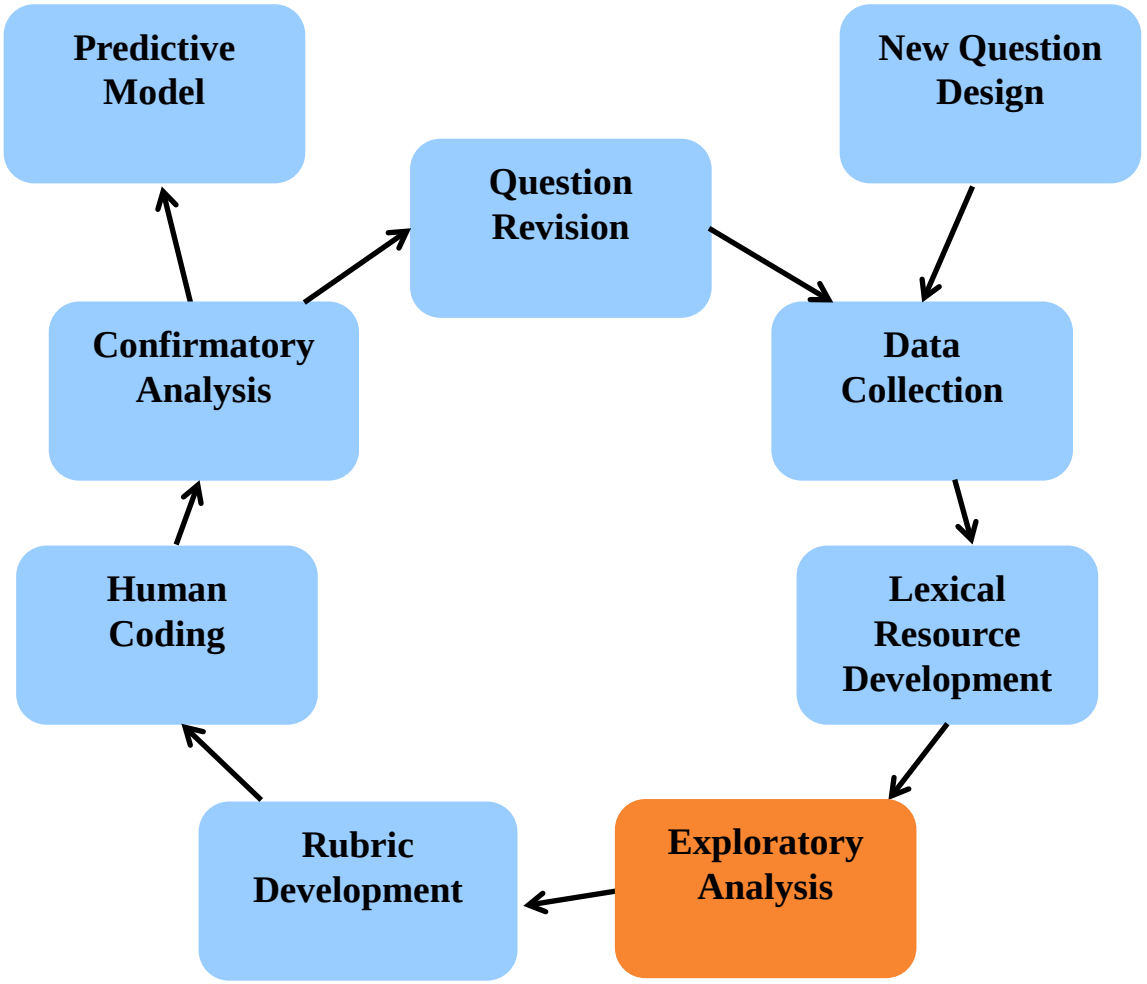
Not all cells in plants (e.g. root cells) contain chlorophyll required for photosynthesis. How do these cells get energy? (Parker et al. 2012)

- Introductory biology course: Cells and Molecules
  - Prerequisite is general chemistry
- Given as a homework on an online course management system
- Post-instruction on cell metabolism
- 360 out of 468 students responded


Predictive Model
New Question Design
Question Revision
Confirmatory Analysis
Data Collection
Human Coding
Lexical Resource Development
Rubric Development
Exploratory Analysis

Automated Analysis

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Exploratory Analyses

Instructor Analyses

- A random sample of 50 responses was chosen to be read separately by the two instructors
- Instructor 1 tallied emergent ideas in the students' writing
- Instructor 2 also kept track of key ideas

Automated Analysis

- Full 360-response dataset
- K-means cluster analysis

Instructor 1		Instructor 2		Automated Analysis	
Distribution of Responses	Description of Cluster	Distribution of Responses	Description of Cluster	Distribution of Responses	Description of Cluster
15%	1. Accurate description based on the transport of glucose and/or cellular respiration	22%	1. Sugar being transported	13%	1. Sugar being transported through the plant
20%	2. Transport of energy	14%	2. Energy being transferred throughout the plant	23%	2. Energy being used form other parts of the plant
14%	3. Roots drawing something from the soil for energy	22%	3. Energy comes from nutrients from the soil	17%	3. Nutrients from the soil
16%	4. Special processes such as C4 photosynthesis, Calvin Cycle, and Kreb's Cycle	10%	4. Incorrect process such as C4 photosynthesis and heterotrophy	16%	4. Special processes such as electron transport chain and heterotrophy
2%	5. Force-dynamic style explanation	10%	5. Respiration as the process involved	12%	5. Cellular respiration as the process involved
		4%	6. Energy being transferred and nutrients from the soil	16%	6. Incorrect source of energy such as from other organisms

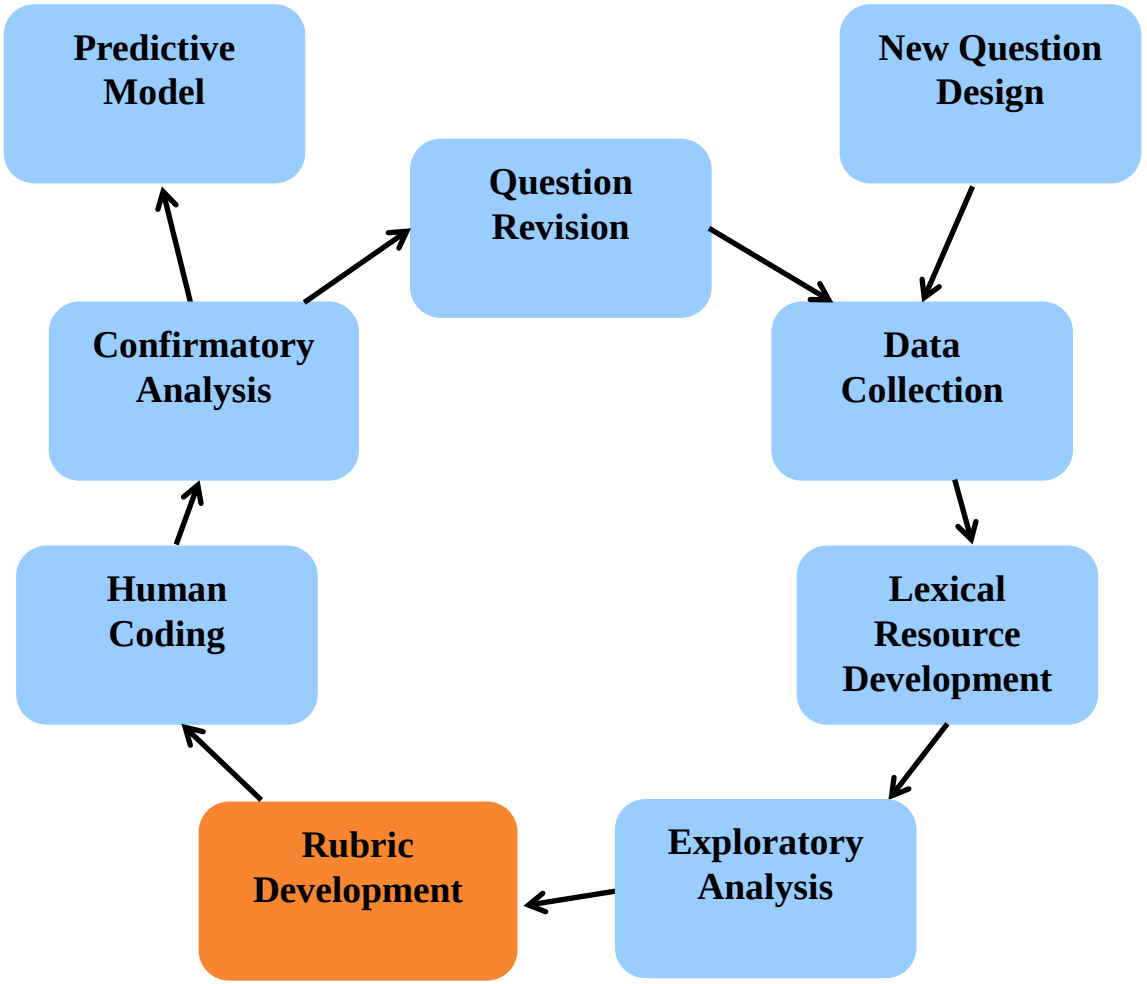
Exploratory Analysis: Clustering Based on Emergent Ideas

These cells take energy from what is around it. For example the root cells take energy from the soil that it is in. Also some cells get their energy transported from the part of the plant that contains chlorophyll.

Instructor 1: Transport of energy

Instructor 2: Energy being transferred and nutrients from the soil

Automated Analysis: Energy being used from other parts of the plant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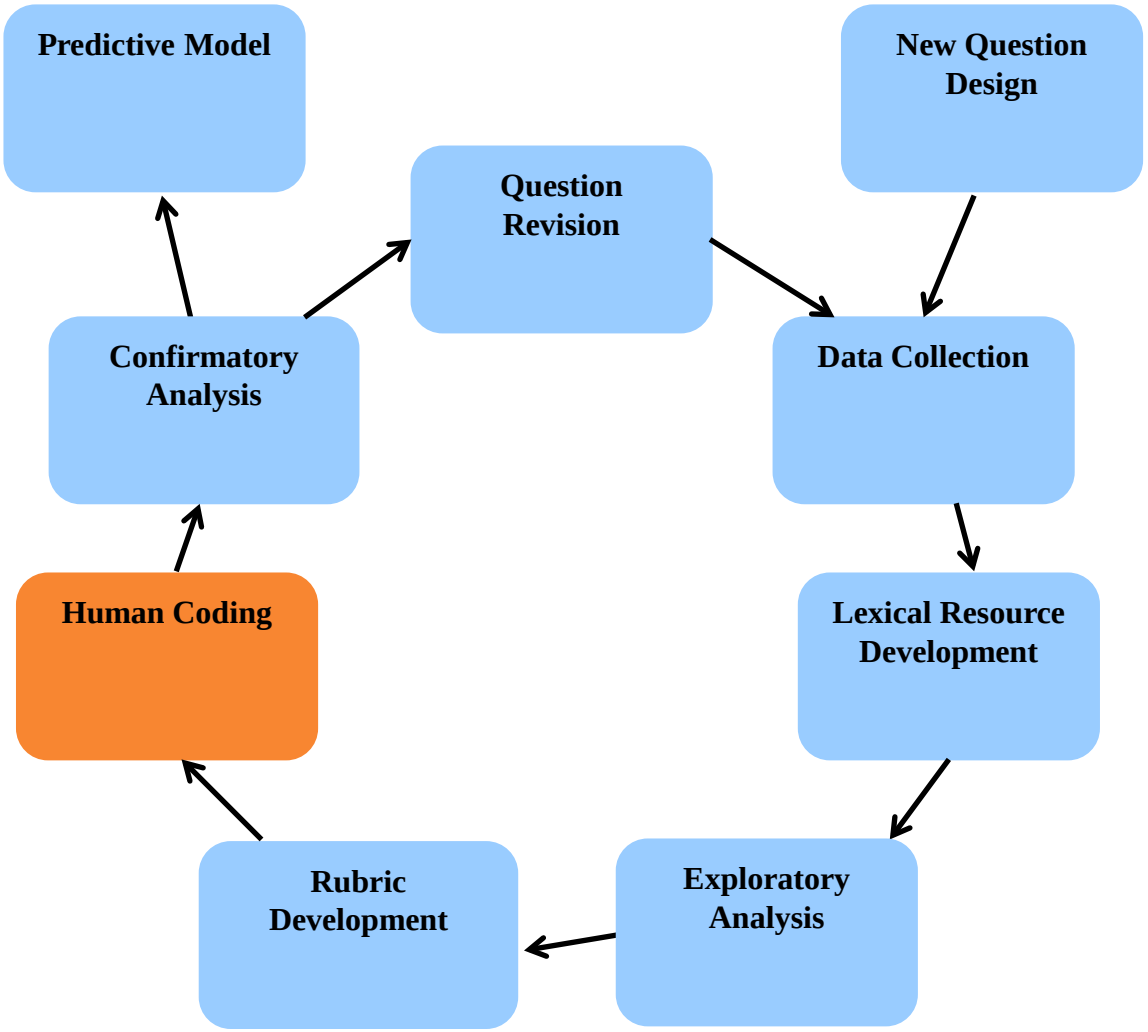
Developing an Analytic Rubric

Instructor 1 Analytic Bins	Instructor 2 Analytic Bins
1. Correct source	1. Transport sugars
2. Incorrect source/unspecified energy	2. Transport energy
3. Incorrect source /nutrients from soil	3. Transport ATP
5. Correct Process	4. Respiration
6. Incorrect Process	5. Dark Reactions
4. Water as Source	6. Soil/nutrients
	7. From surroundings
	8. Transport products of photosynthesis
	9. C4 photosynthesis
	10. Heterotrophy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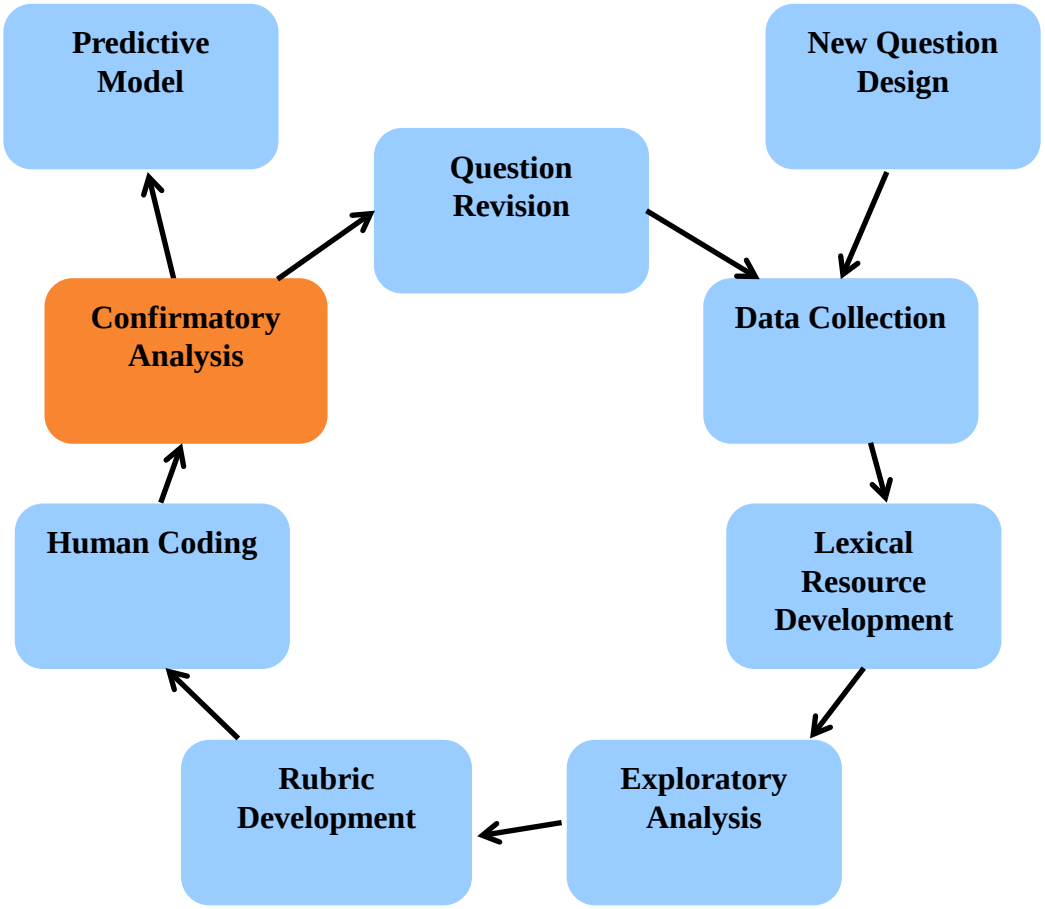
- Human scoring was done using Instructor 1's rubric
- An assistant was calibrated to Instructor 1 using 120 responses from a previous semester
- Then, used that calibration to score more responses
  - 360 responses (FS12) + 316 responses (FS10) = **676 responses total**



- Discriminant analysis predicts human scoring
- 676 responses used to build model
- Leave-one-out system of classification

Automated Scoring with an Analytic Rubric

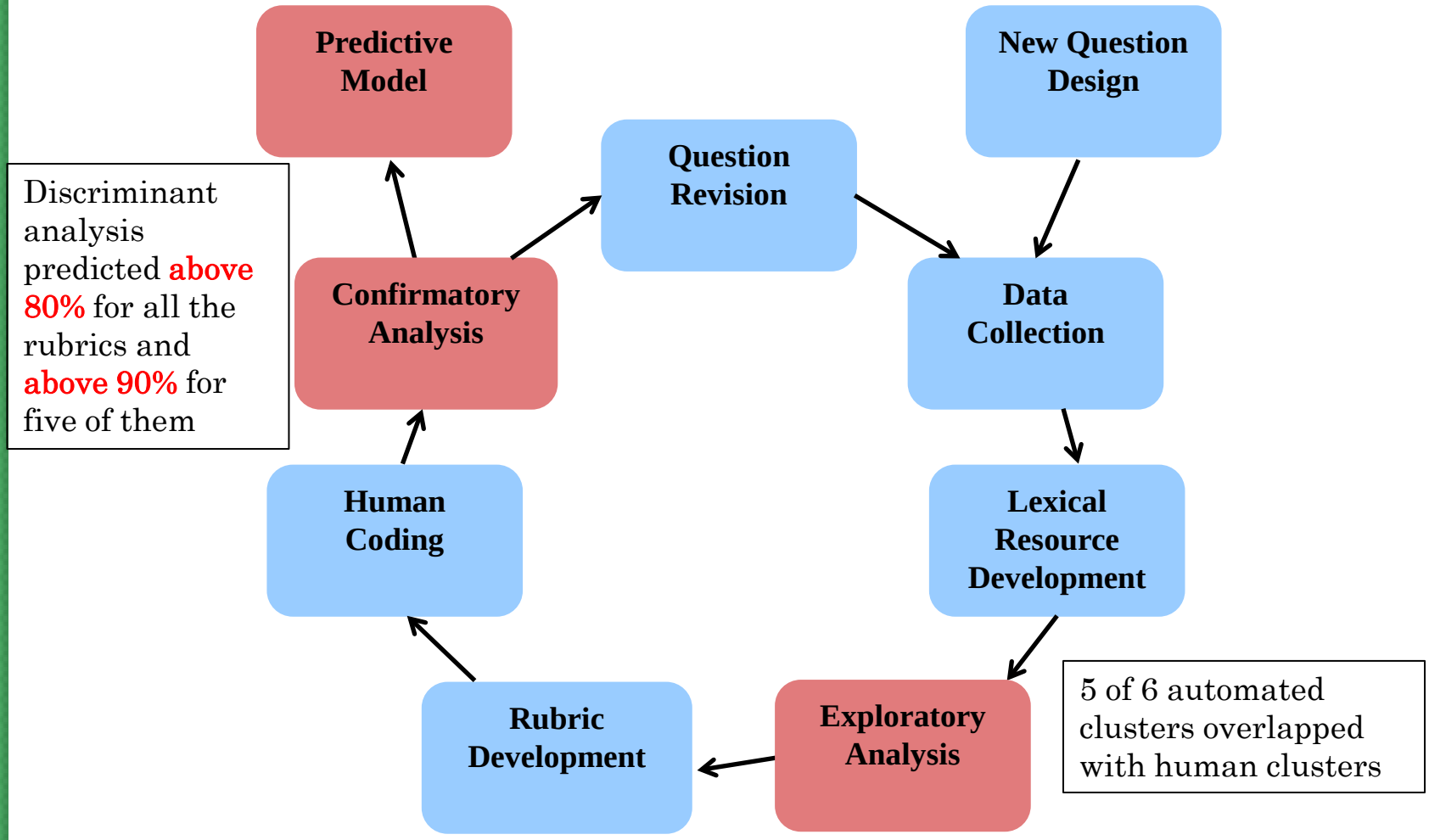
Rubric	Description	Human Scoring	Correctly Classified
1. Correct Source	Any name for a product of photosynthesis	26%	94.2%
2. Incorrect source/unspecified energy	Energy or ATP being transported	26%	81.7%
3. Incorrect source /nutrients from soil	Energy comes from nutrients from the soil	19%	90.7%
4. Incorrect Source/water	Water without anything else or water with nutrients from the soil	11%	94.1%
5. Correct Process	Respiration or glycolysis	17%	96.8%
6. Incorrect Process	Various incorrect processes	12%	92.6%

n=360

Research Questions

- How do instructors analyze answers to CR questions?
  - Instructors who participated in this project did initial exploratory analyses to look for key ideas and misconceptions
  - Then, used those ideas to make analytic scoring rubrics

How do the results from automated text analysis techniques compare with the instructors' analyses?



Time Requirements

- Exploratory analysis
  - Instructor 1, 11 minutes
  - Instructor 2, 45 minutes
  - Automated analysis, 15 minutes

- Analytic rubric scoring
  - Human scoring took approximately 5 hours after calibration
  - Automated analysis took less than 5 minutes

Future Direction

- Just-in-Time Teaching (JiTT) instructor formative feedback reports

Prevost, L.B., Haudek, K.C., Norton Henry, E. Berry, M.C., and Urban-Lurain, M. 2013. Automated Text Analysis Facilitates Using Written Formative Assessments for Just-in-Time Teaching in, Large Enrollment Courses Proceeding of the American Society of Engineering Education Annual Conference, Atlanta,GA.

Questions

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