BeSocratic

Melanie M. Cooper

TRUSE Conference 2012

Acknowledgements

NSF
Dreyfus Foundation
Cengage

Trouble!

Year	**%DFW**	ACS %ile	# students	# DFW
2001	**23**	61	1200	270
2002	**30**	72	1199	362
2003	**35**	72	1314	453
2004	**44**	**75**	**1429**	**625**

Reforms

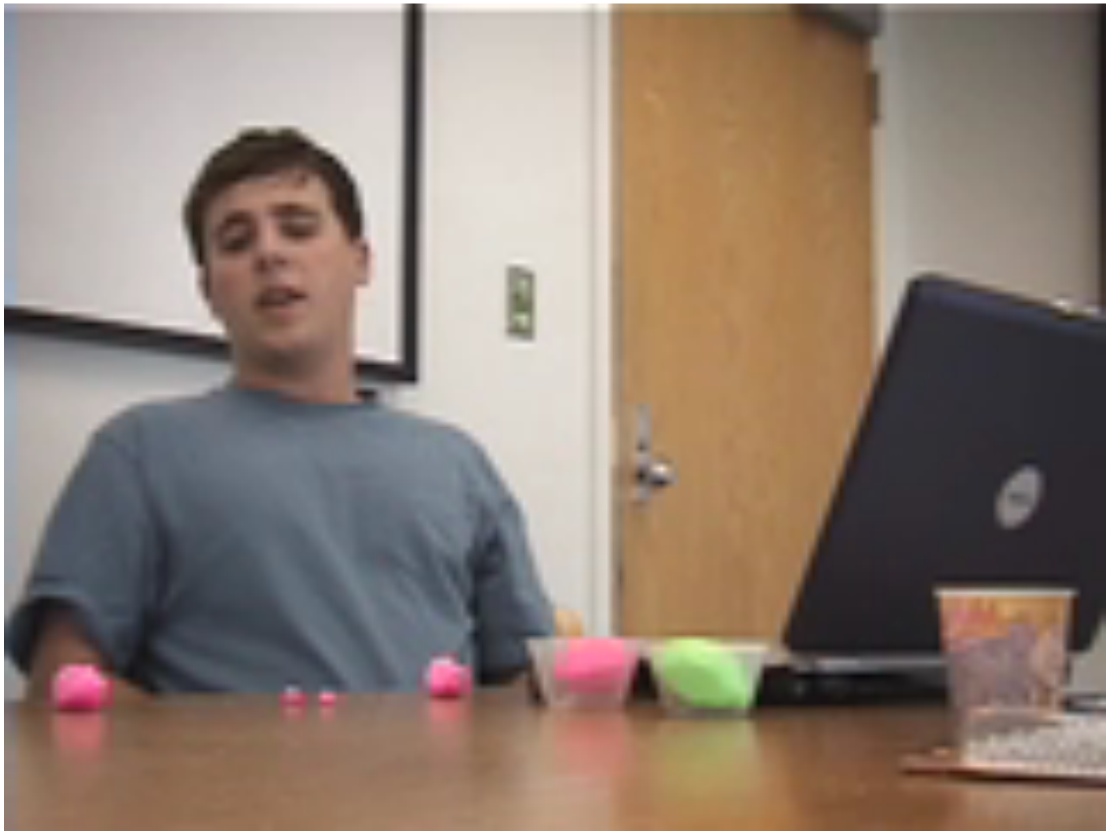
- Weekly meetings to negotiate “big ideas” and learning outcomes and assessments (backward design)
- Reduce class size (to about 100 from 180)
- Remove content (~30%)
- Add “active” learning (group work, clickers etc)
- Each faculty member uses their own notes/class management style
  – there is typically no difference in grade distributions

Success!

Year	**%DFW**	ACS %ile	# students	# DFW
2001	**23**	61	1200	270
2002	**30**	72	1199	362
2003	**35**	72	1314	453
2004	**44**	**75**	**1429**	**625**
2005	**23**	72	1265	290
2006	19	72	1260	240
2007	11	76	1306	150
2008	18	79	1300	230
2009	15	75	1570	236

We can go home

Well – not so fast…



"The potential energy goes up … when you break a bond it releases energy"

What happens to the potential energy when you bring two hydrogen atoms together?

Energy changes and bonding

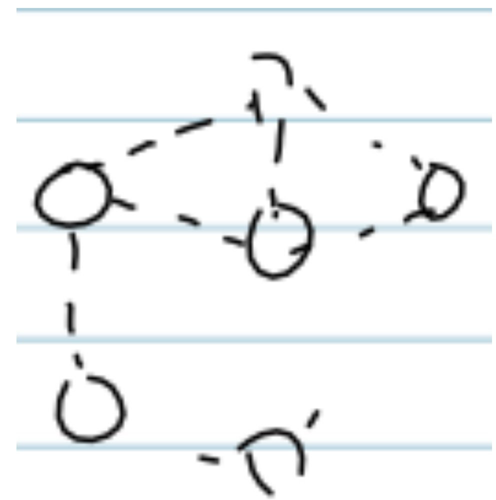
% Students by type with bond energy misconceptions	
Chemistry level (#)	%
General Chemistry (77)	50
Inorganic (13)	54
Organic (172)	65
Analytical (35)	51
Physical (16)	56
Graduate Students (21)	**68**
Post docs (25)	**68**

Jane (OC2): What are intermolecular forces?

Jane: “I think the intermolecular force is talking about, is **talking only in liquid phase.**”

Interviewer: “How is ice structured then? Like what holds it together?”

Jane: “Probably the, the I mean the, since the temperature is very low, umm the activity of each molecule is, is very low. So they are umm, they’re very stable at where they are.”

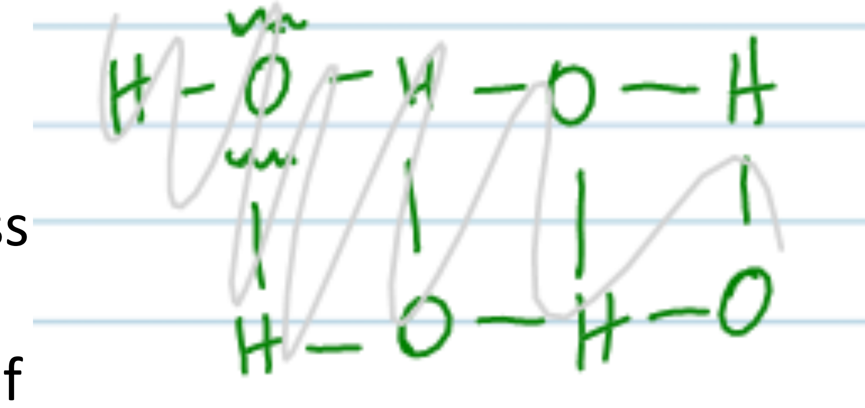


Brittany (GC2): when water boils …

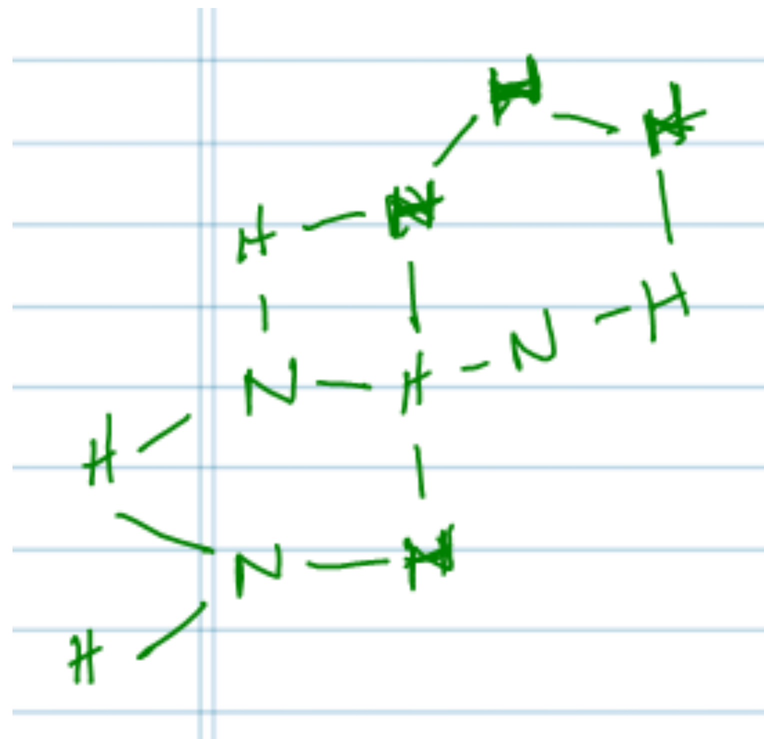
"…all those bonds are broken up it's like pieces of oxygen. It's like particles of oxygen and hydrogen and that can mix with anything so it's **not technically a water molecule** anymore because it's all broken up I guess. I don't know."

Jill (Organic 2)

How boiling H_2O works



Student: Like a bunch of them together would be more like water and I guess they would, and they'd all be connected together but I guess like if they were a gas they would, some of them would split up.



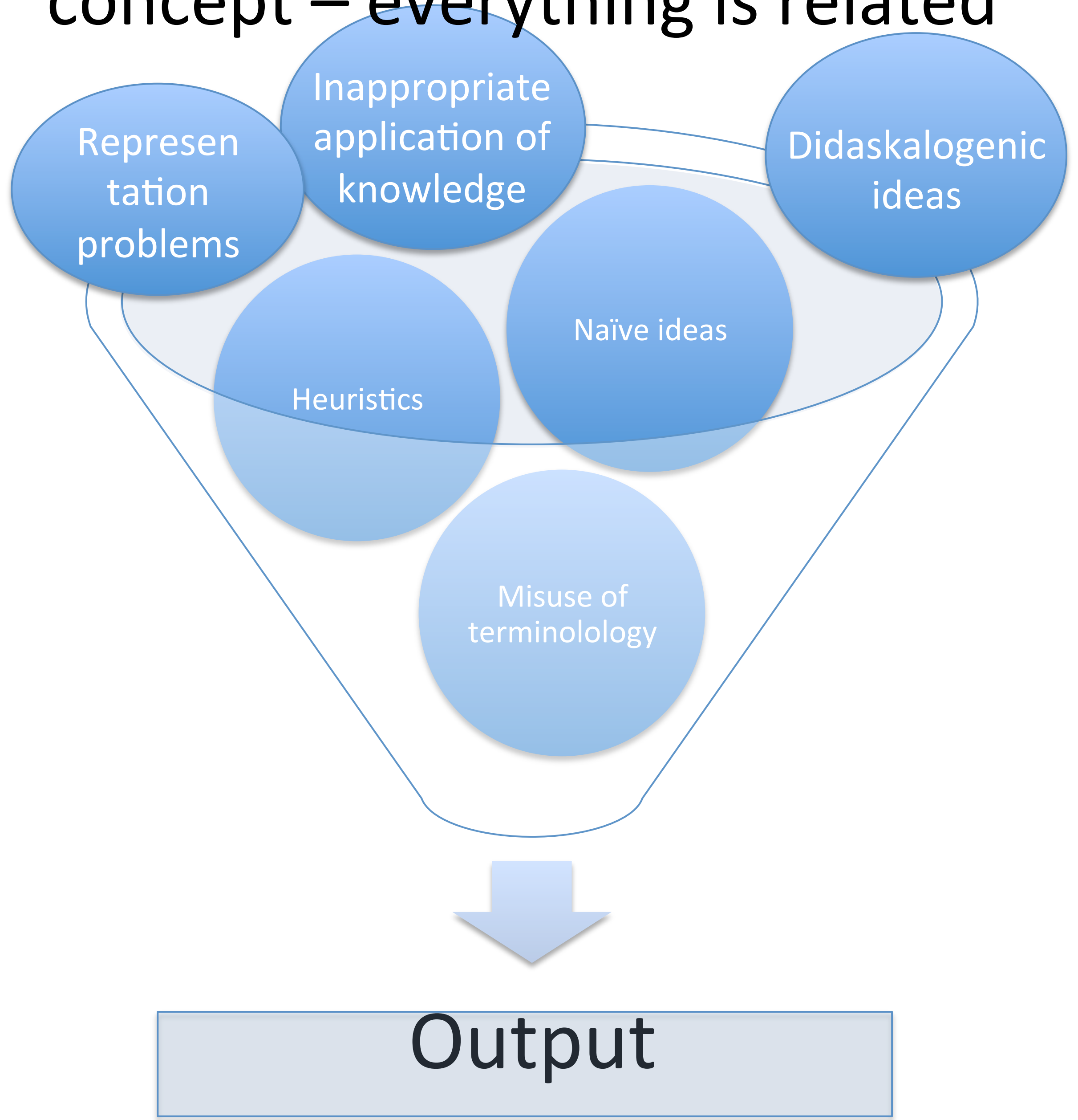
Interviewer: Ok so, so you were talking about like this part would split up, whatever's connecting the waters?

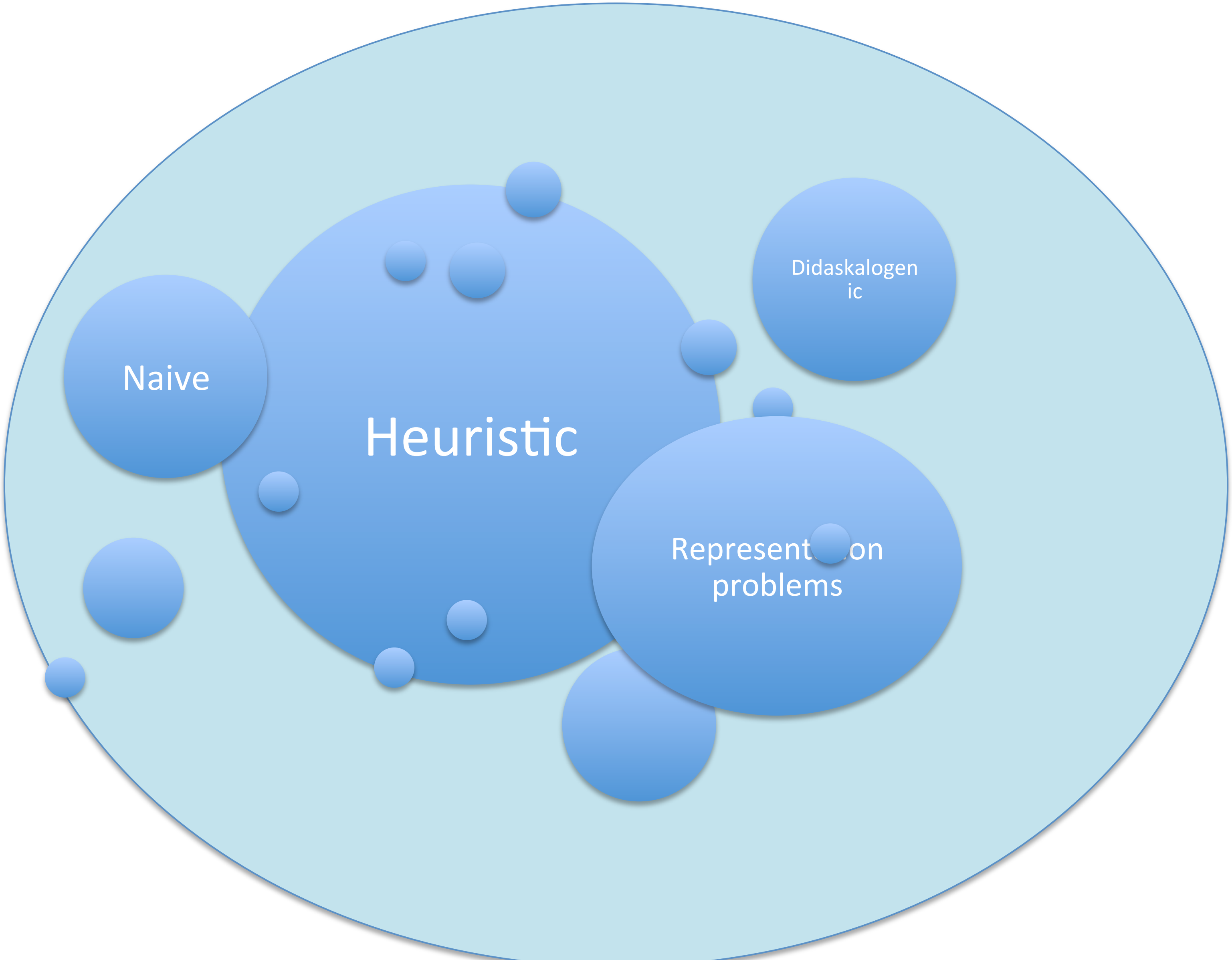
Student: Yeah like, yeah like the bond between two water molecules would break.

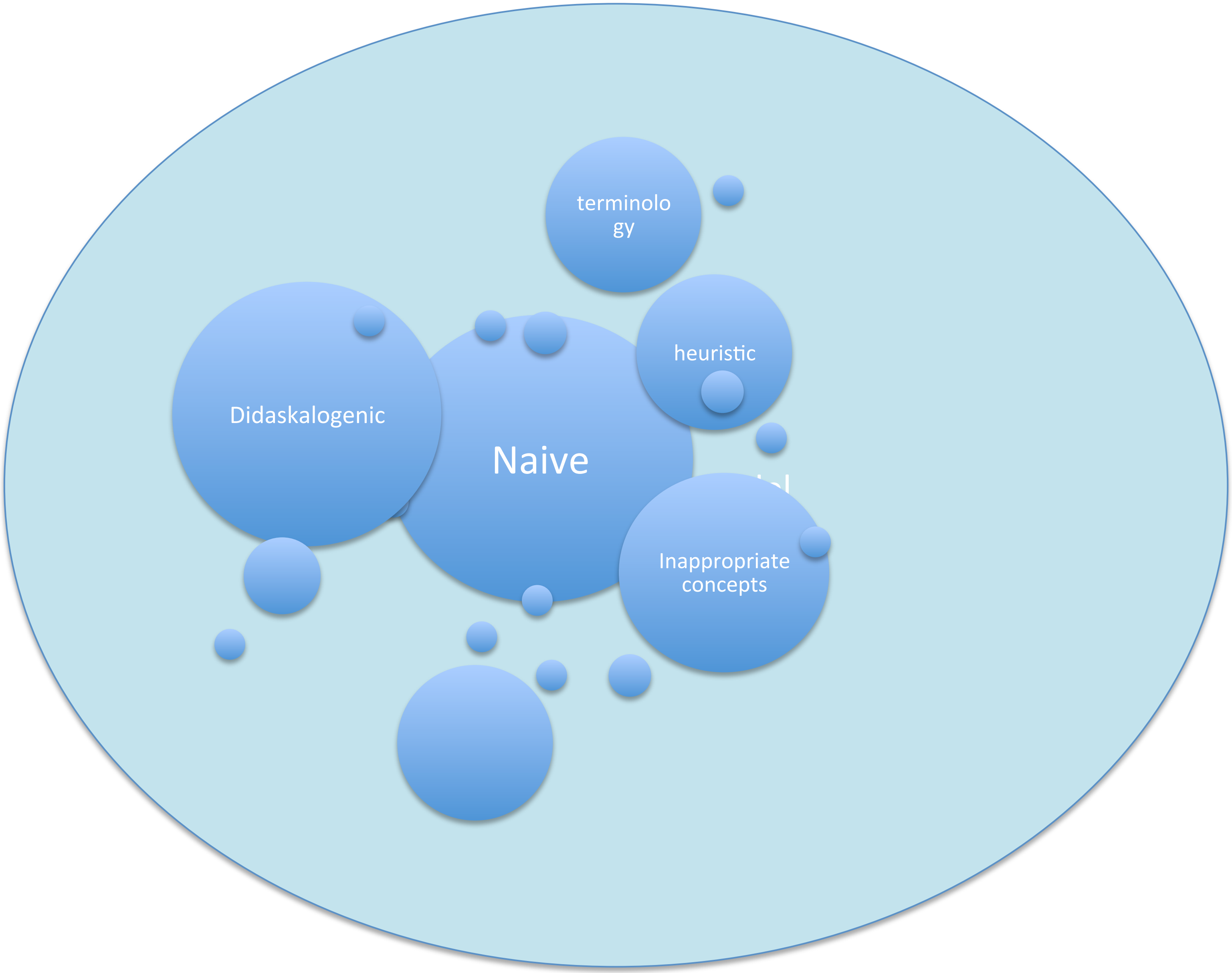
In chemistry there is rarely a single problem or "misconception"

- Naïve ideas (p-prims)
  - Atoms get larger when heated
- Didaskalogenic (instructor induced)
  - Bonds form because atoms "want" octets
- Heuristics
  - Like dissolves like
- Inappropriate application of knowledge
  - Steric hindrance affects boiling points
- Misuse of terminology
  - A Hydrogen bonding isn't actually a bond
- Representational problems
  - Inability to decode meaning from structures
- Inappropriate Models
  - Use of Bohr model of atom to describe bonding

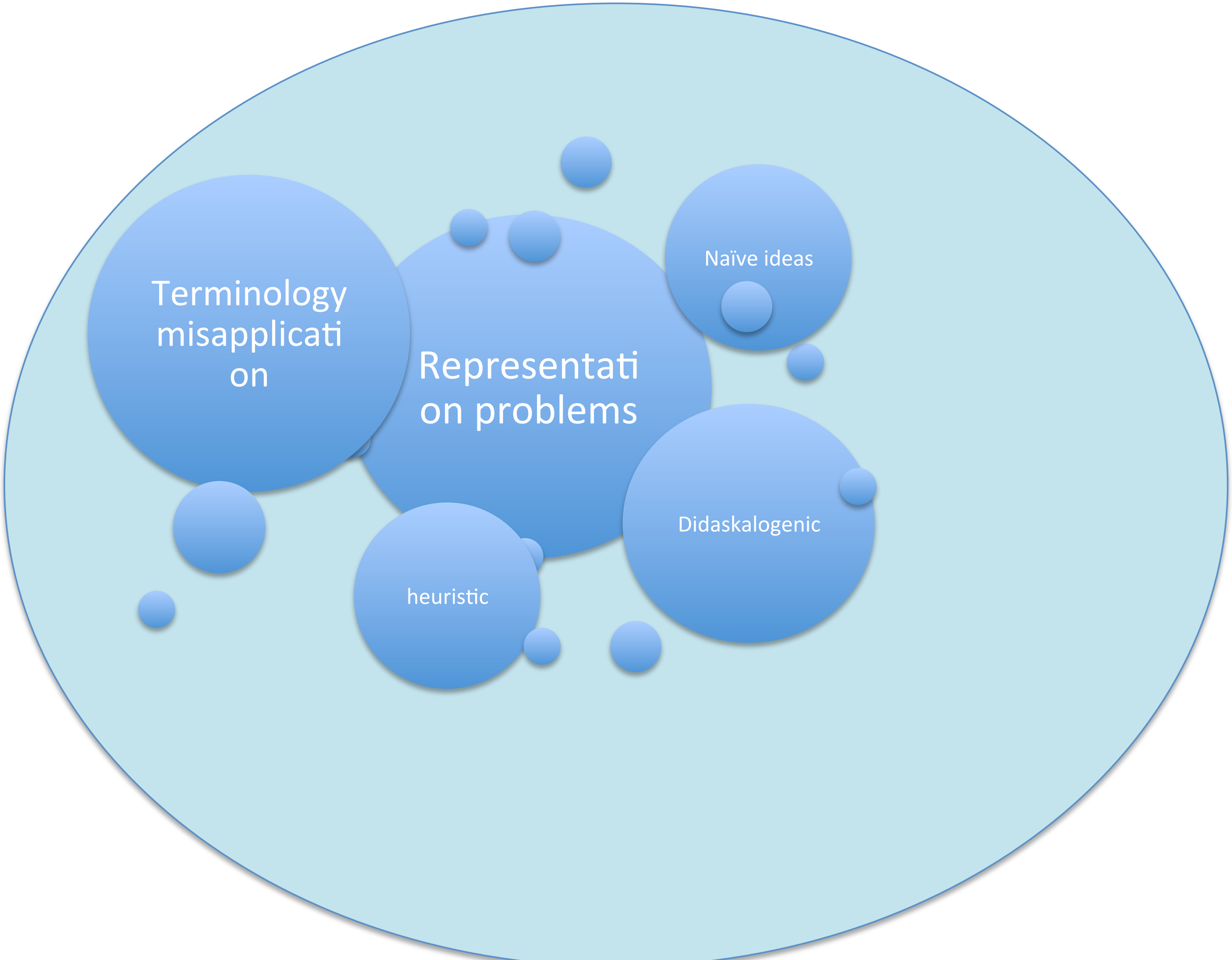
In chemistry there is rarely a single idea or concept – everything is related

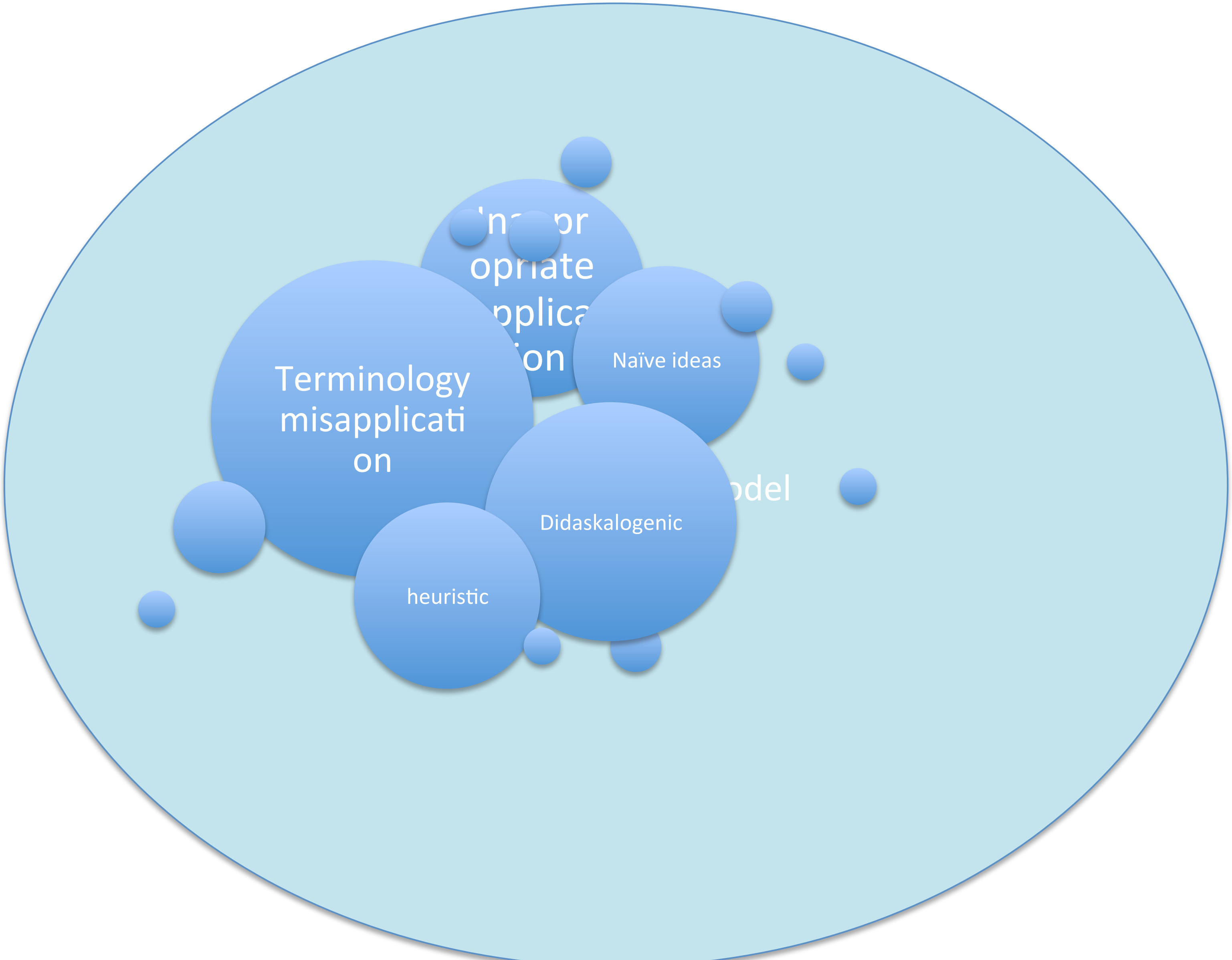



Didaskalogenic
Naive
Heuristic
Representation problems



terminolo
gy
heuristic
Didaskalogenic
Naive
Inappropriate
concepts


Terminology misapplicati on
Representati on problems
Naïve ideas
Didaskalogenic
heuristic


Terminology misapplicati on
Naïve ideas
Didaskalogenic
heuristic

How can we help students develop deeper more coherent conceptual understanding?

And how will we know when we have done that?

The role of assessment

"*to educate and improve* student performance, not merely to *audit* it"

Wiggins, G. (1998). *Educative assessment*: *Designing assessments to inform and improve student performance.* San Francisco, CA: Jossey-Bass

Assessment drives the **enacted** curriculum


PENN STATE

Introductory classes

- Typically large (and growing larger)
- Novice learners
- Standardized (publisher generated) curricula and materials
- **Often where future high school teachers learn content**
  - And, by example, pedagogy

It appears that sorting students is more important than teaching them valuable, transferrable knowledge.

What are we willing to accept as **evidence** of learning?

The nature of the assessments may actually be affecting what is taught (and certainly what is learned)

How can we assess what we say we value? (not testable trivia)

What do we value?

NRC Framework: Science and Engineering Practices

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

http://www.nextgenscience.org/

Next Generation Science Standards - combine content with a science practice:

- Use models to explain that atoms (and therefore mass) are conserved during a chemical reaction
- Construct arguments for which type of atomic models best explains a particular property of matter

http://www.nextgenscience.org/

How will these kinds of performance expectations be assessed?

BeSocratic

Besocratic.clemson.edu

Constructing vs "recognizing"

Computer interfaces impose constraints

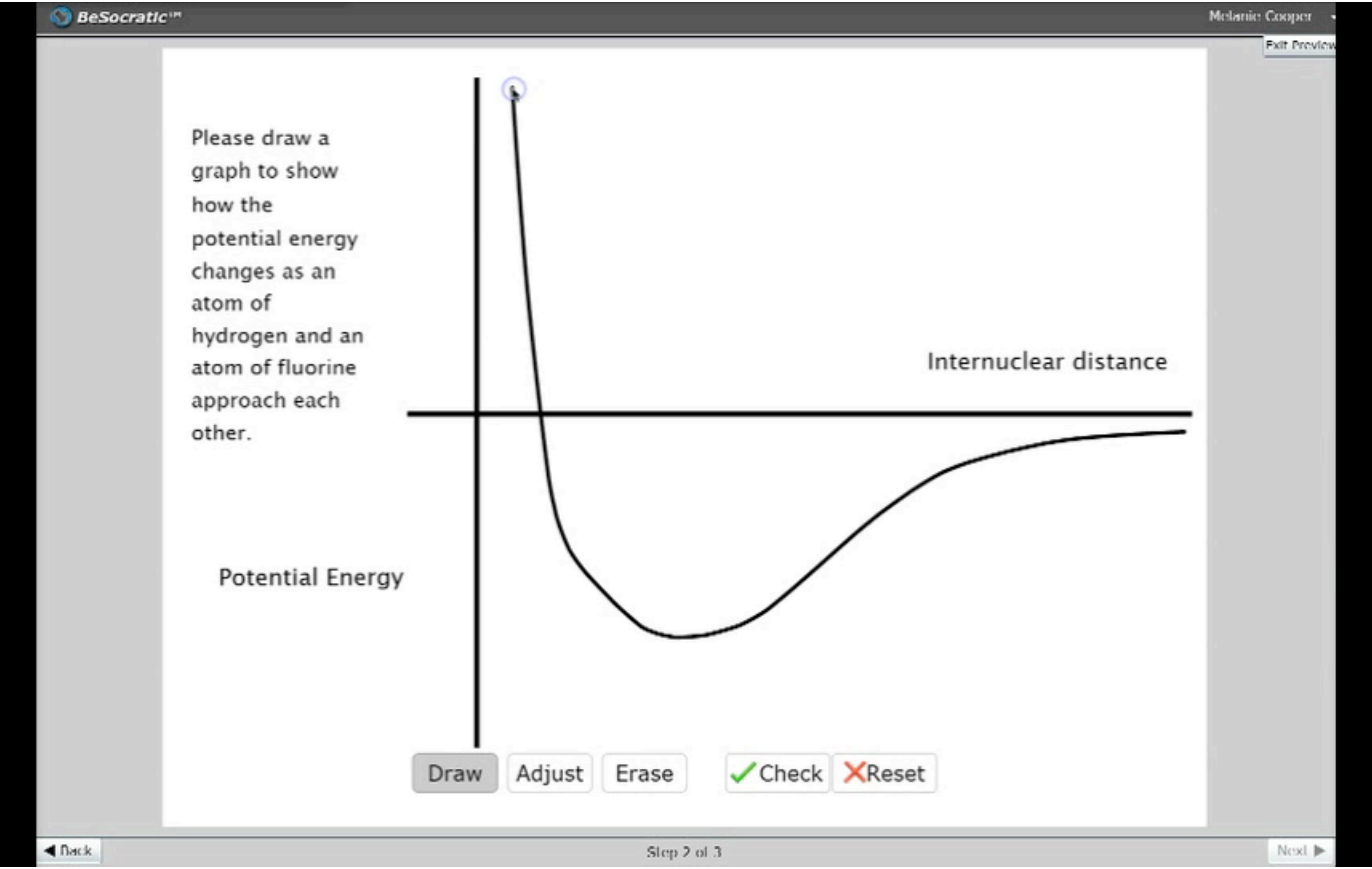
Emerging evidence that drawing, writing and gesturing are important for learning

- K. H. James, T. P. Atwood, *Cognitive Neuropsychology*, 26, 91, (2009)
- P. Sadler, R. Tai, *Science*, 317, 457, (2007)
- *Ainsworth, Prain, & Tytler,. 2011,, Science, 1096*
- *Beilock,S.L.;Goldin-Meadow,S.; 2010, Psychological Science, 1605*
- *Trujillo, Cooper & Klymkowsky. 2012.. BAMBED, in press.*

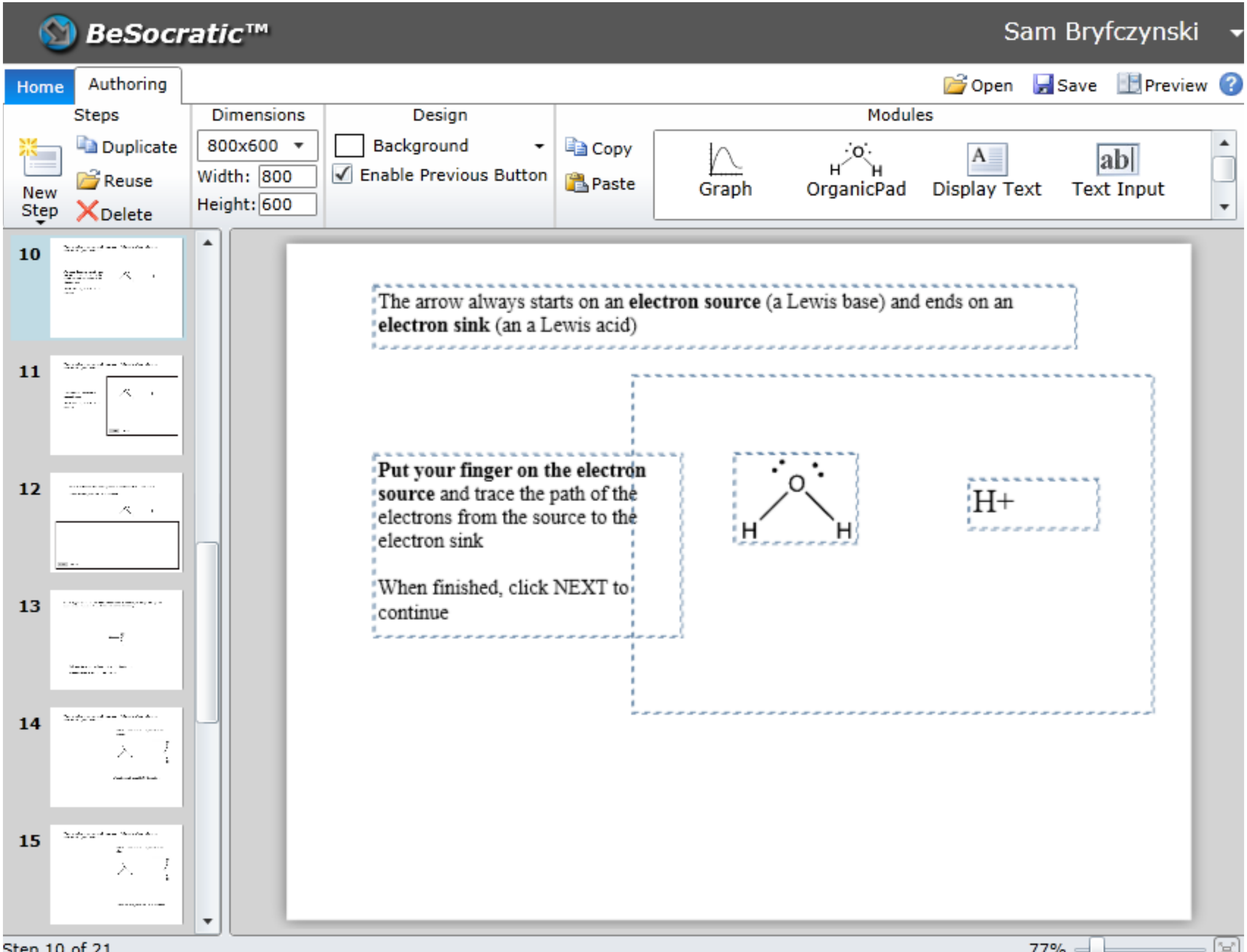
BeSocratic

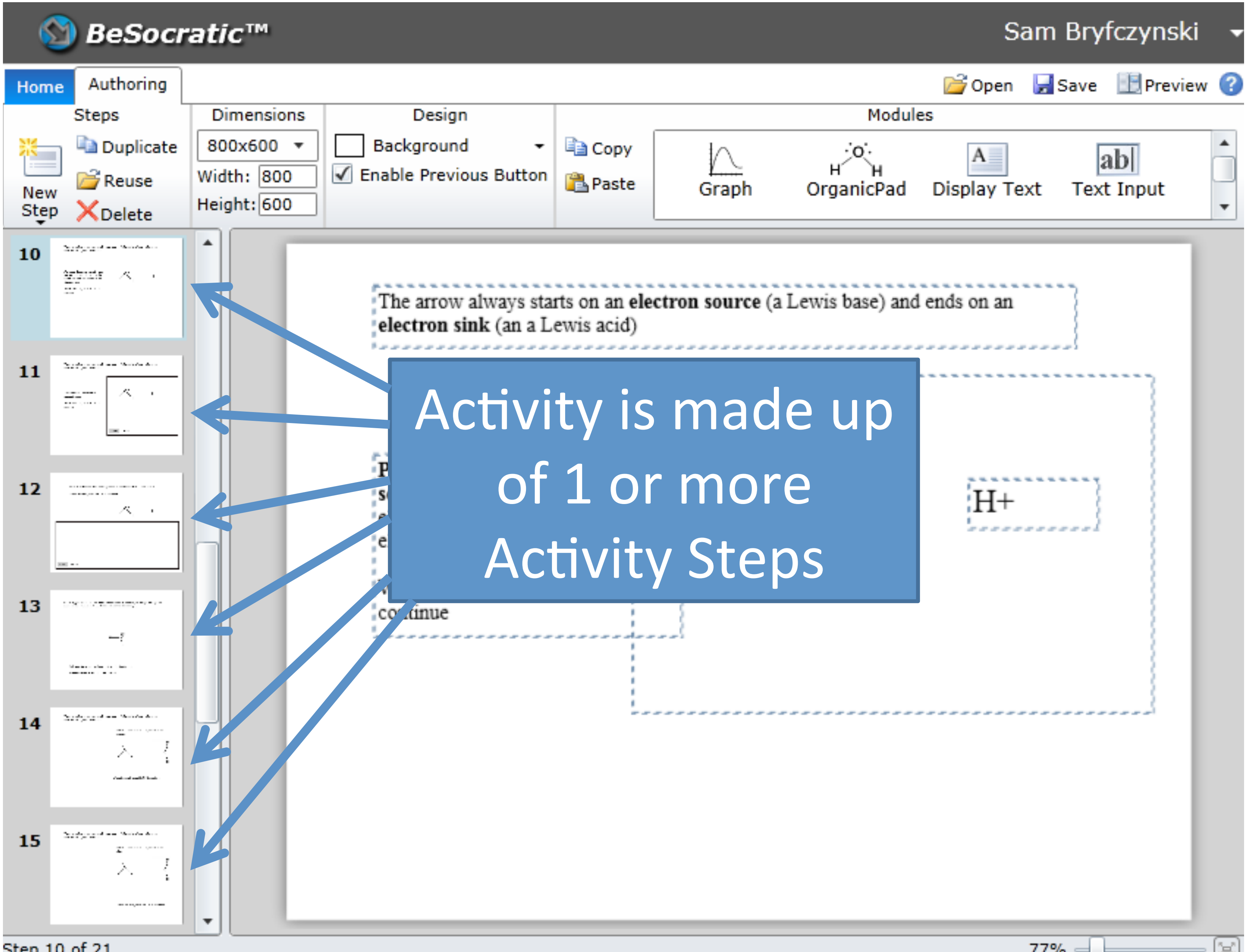
- Allows free form input – graphs, chemical structures, diagrams, gestures, and text
- Provides tiered contextual Socratic feedback
- Collaboration between chemistry, biology, physics, math, computer science

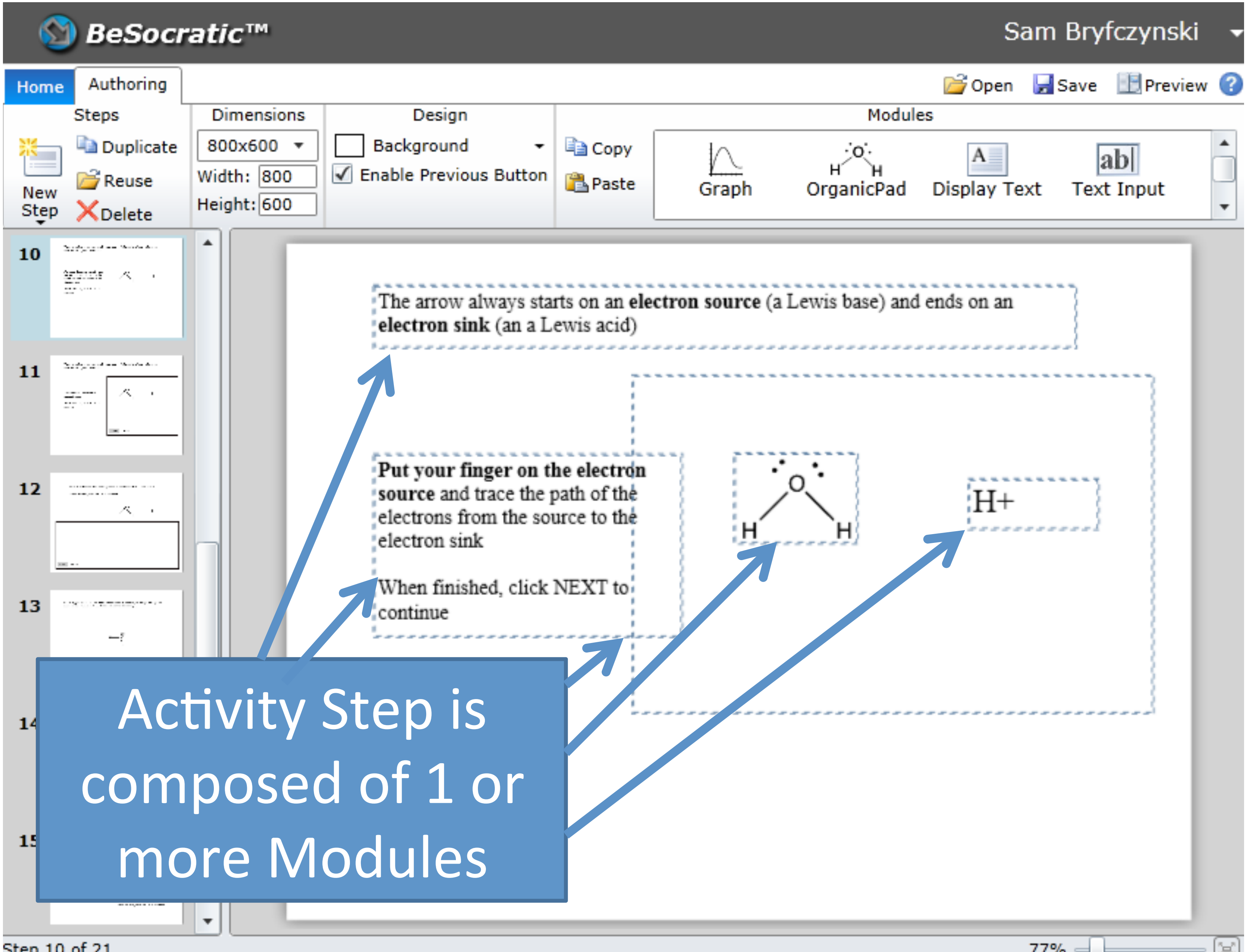
BeSocratic: Student interface



BeSocratic: Author interface


BeSocratic™
Sam Bryfczynski
Home
Authoring
Open
Save
Preview
Steps
New Step
Duplicate
Reuse
Delete
Dimensions
800x600
Width: 800
Height: 600
Design
Background
Enable Previous Button
Copy
Paste
Modules
Graph
OrganicPad
Display Text
Text Input
The arrow always starts on an electron source (a Lewis base) and ends on an electron sink (an a Lewis acid)
Put your finger on the electron source and trace the path of the electrons from the source to the electron sink
When finished, click NEXT to continue
H+
Step 10 of 21
77%


BeSocratic™
Sam Bryfczynski
Home
Authoring
Open
Save
Preview
Steps
Duplicate
Reuse
New Step
Delete
Dimensions
800x600
Width: 800
Height: 600
Design
Background
Enable Previous Button
Copy
Paste
Modules
Graph
OrganicPad
Display Text
Text Input
10
11
12
13
14
15
The arrow always starts on an **electron source** (a Lewis base) and ends on an **electron sink** (an a Lewis acid)
H+
continue
Activity is made up of 1 or more Activity Steps
Step 10 of 21
77%



Activity Step is composed of 1 or more Modules

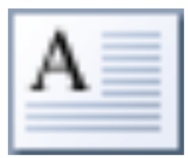
BeSocratic Modules

Image

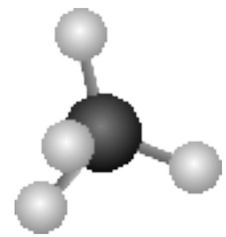
Drawing

Text Box

Video

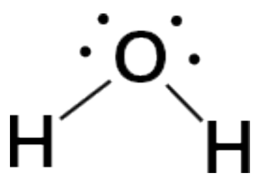


Text

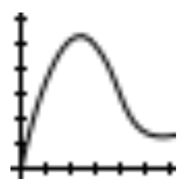


3D Model

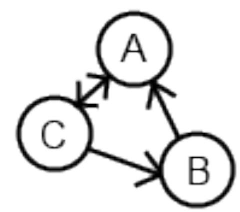
Chalkboard



OrganicPad

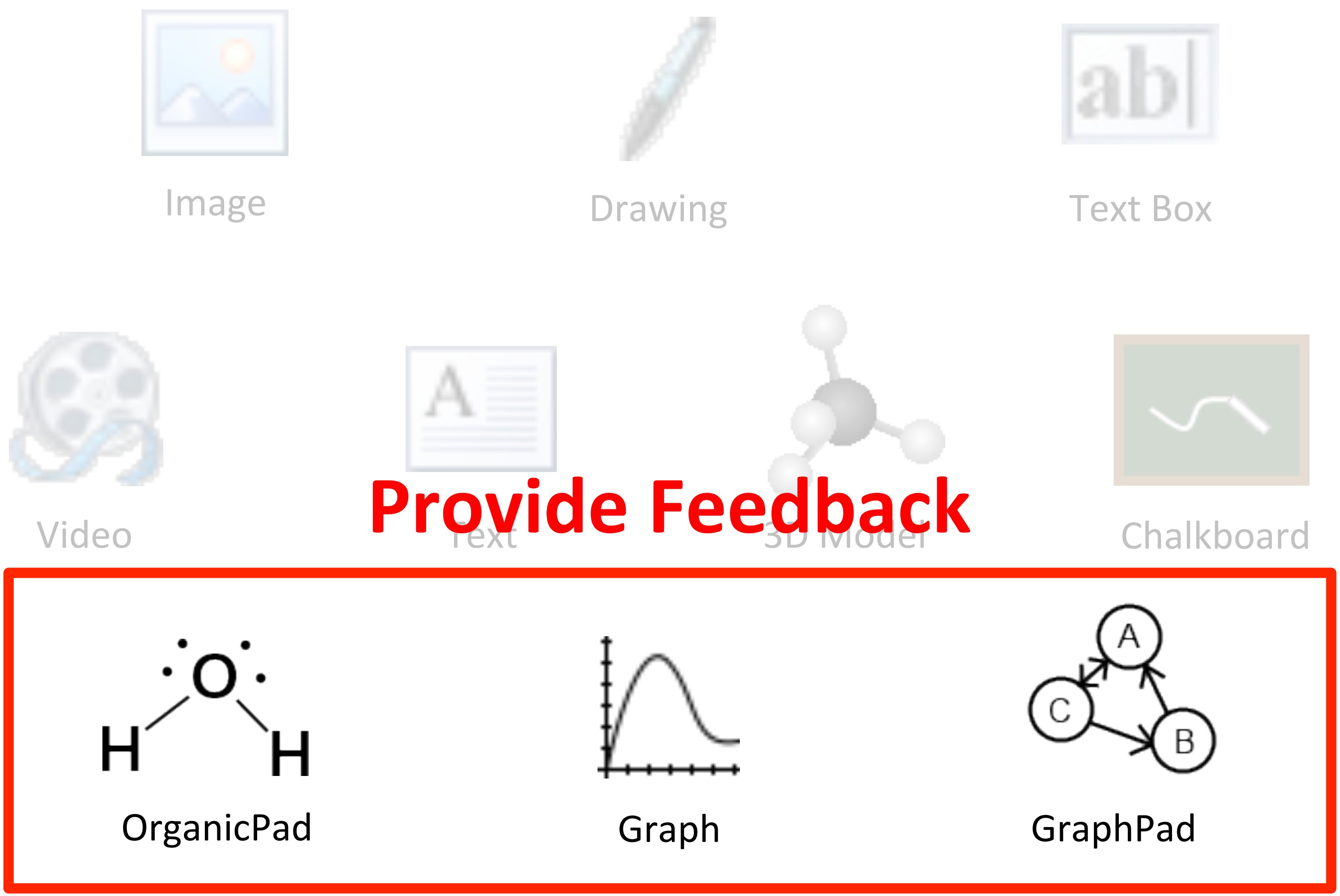


Graph

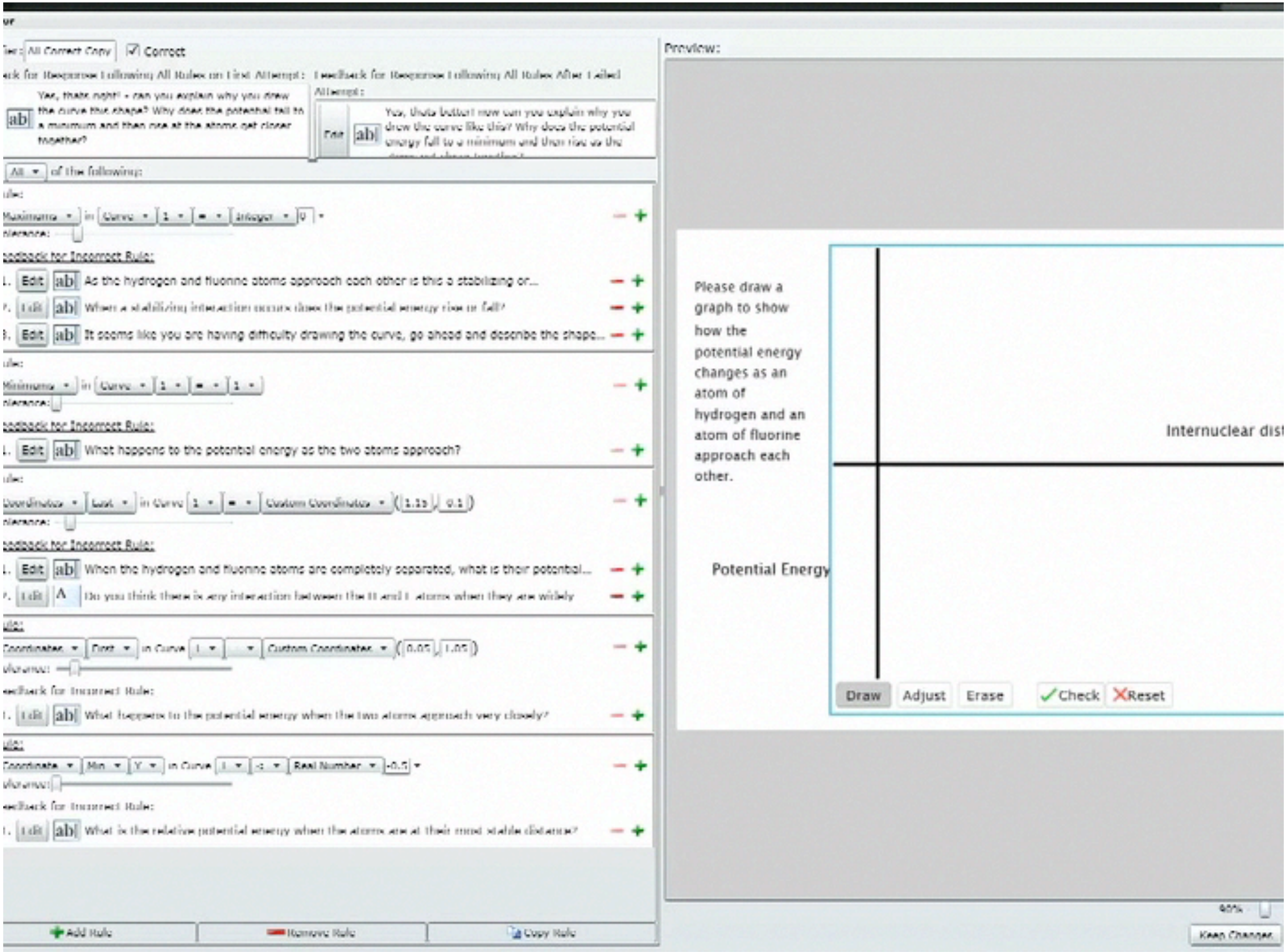


GraphPad

BeSocratic Modules

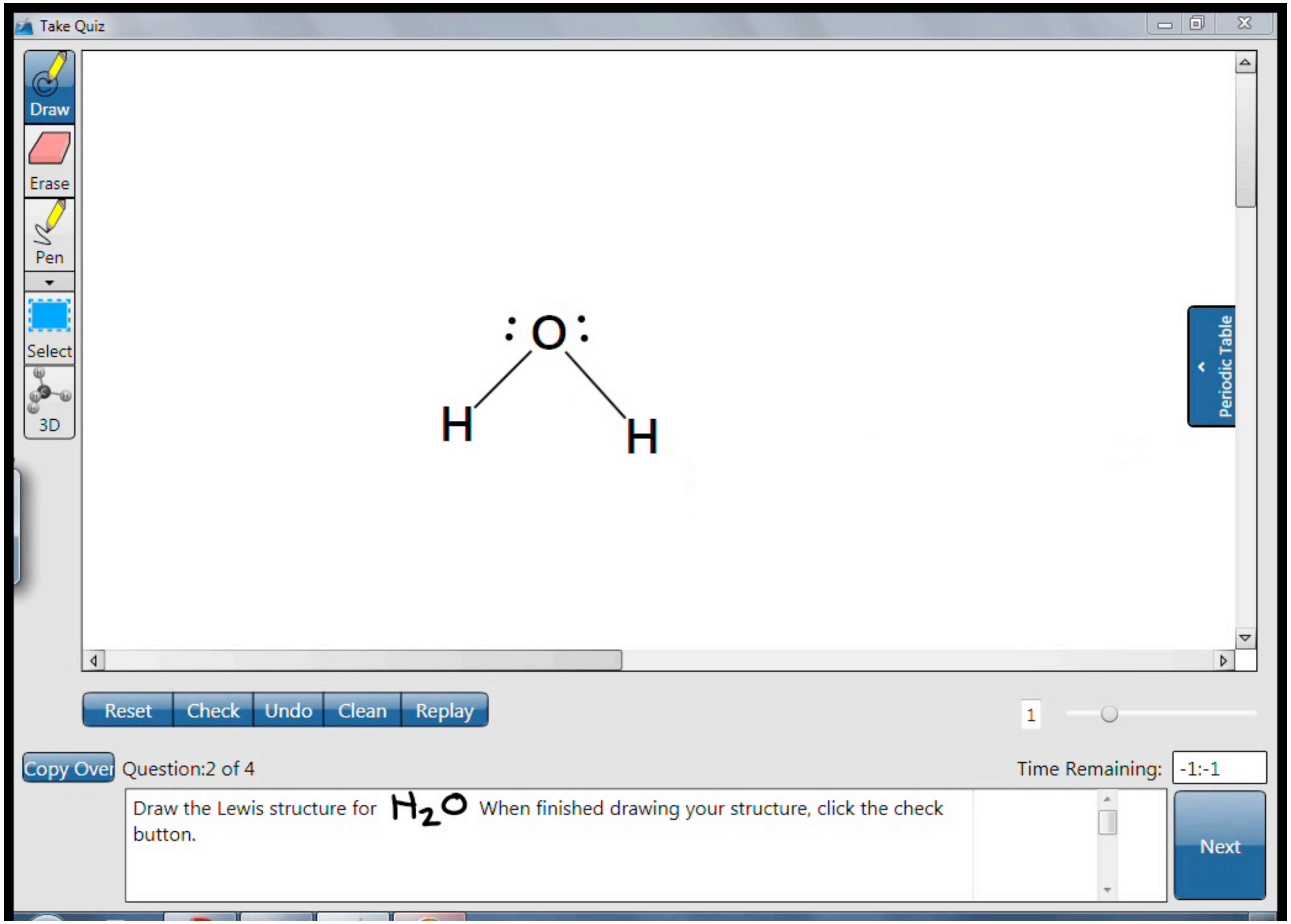


Graphs: Author Interface



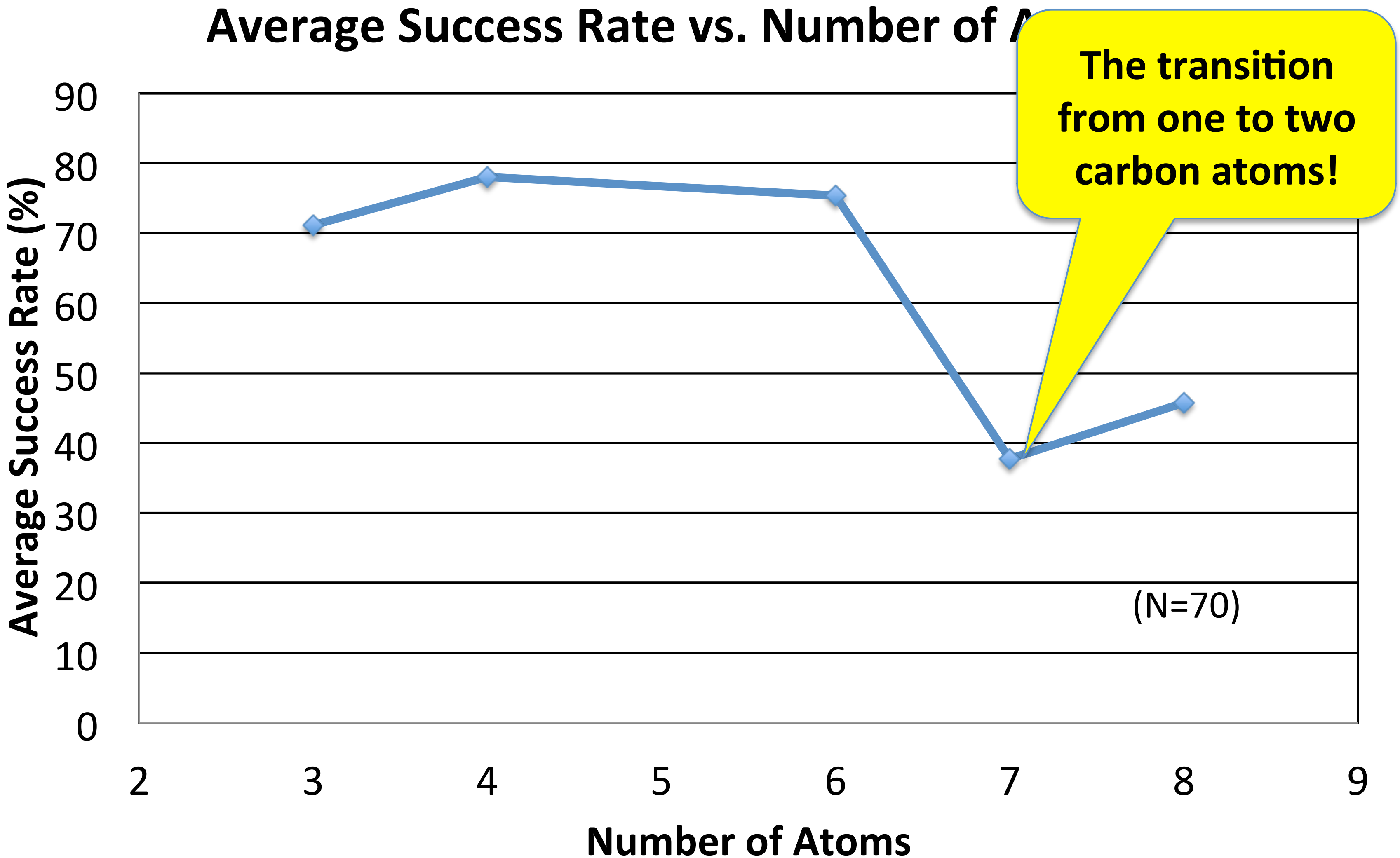
Now back to student problems!

We used OrganicPad to see how students develop the ability to draw Lewis structures



Cooper, M. M. et al. *Chem. Educ. Res. Pract.* **2009**, 10, 296-301.

Organic chemistry students can't draw Lewis structures

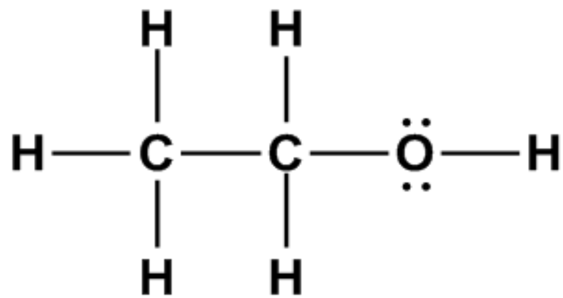


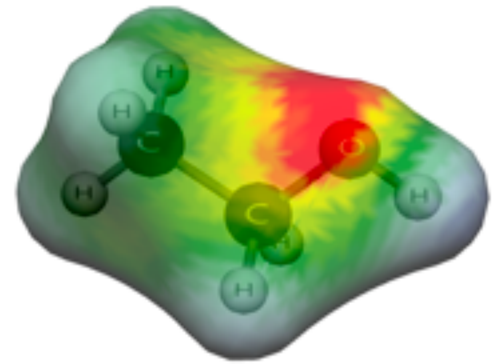
Cooper, M. M.; Grove, N. P.; Underwood, S. M.; Klymkowsky, M. W. *J Chem Educ. 2010, **87**, 869-874* , DOI: 10.1021/ed900004y

Meaningful learning

The road from

C_2H_6O





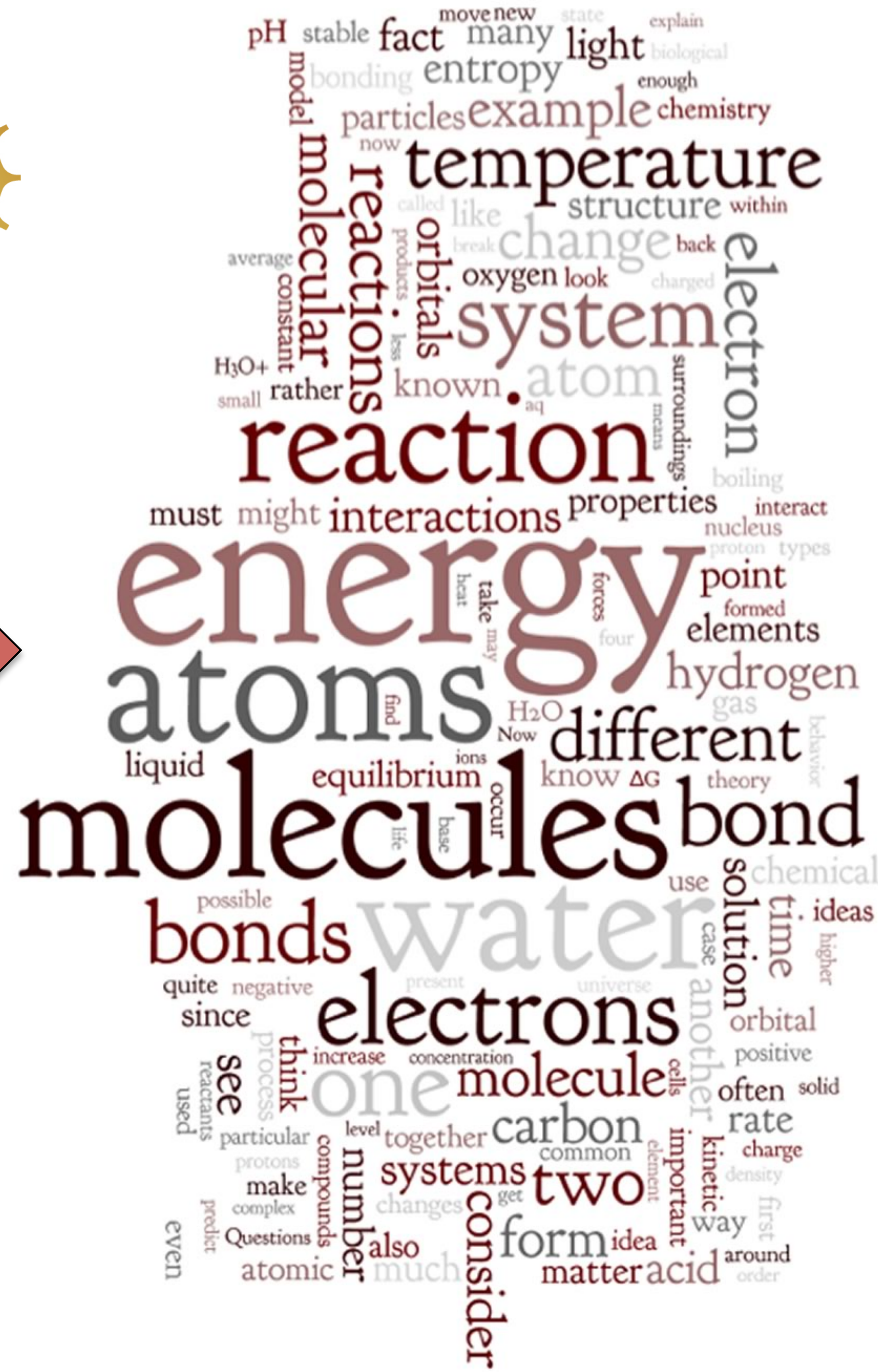
Properties:

(Liquid - with high boiling point (H-bonding), both acidic and basic properties, susceptible to nucleophilic attack when protonated, etc).

Is difficult, complex, counter-intuitive, and all too often meaningless to many students

Lost in Lewis Structures Cooper, M. M.; Grove, N. P.; Underwood, S. M.; Klymkowsky, M. W. *J Chem Educ. 2010, **87**, 869-874* , DOI: 10.1021/ed900004y

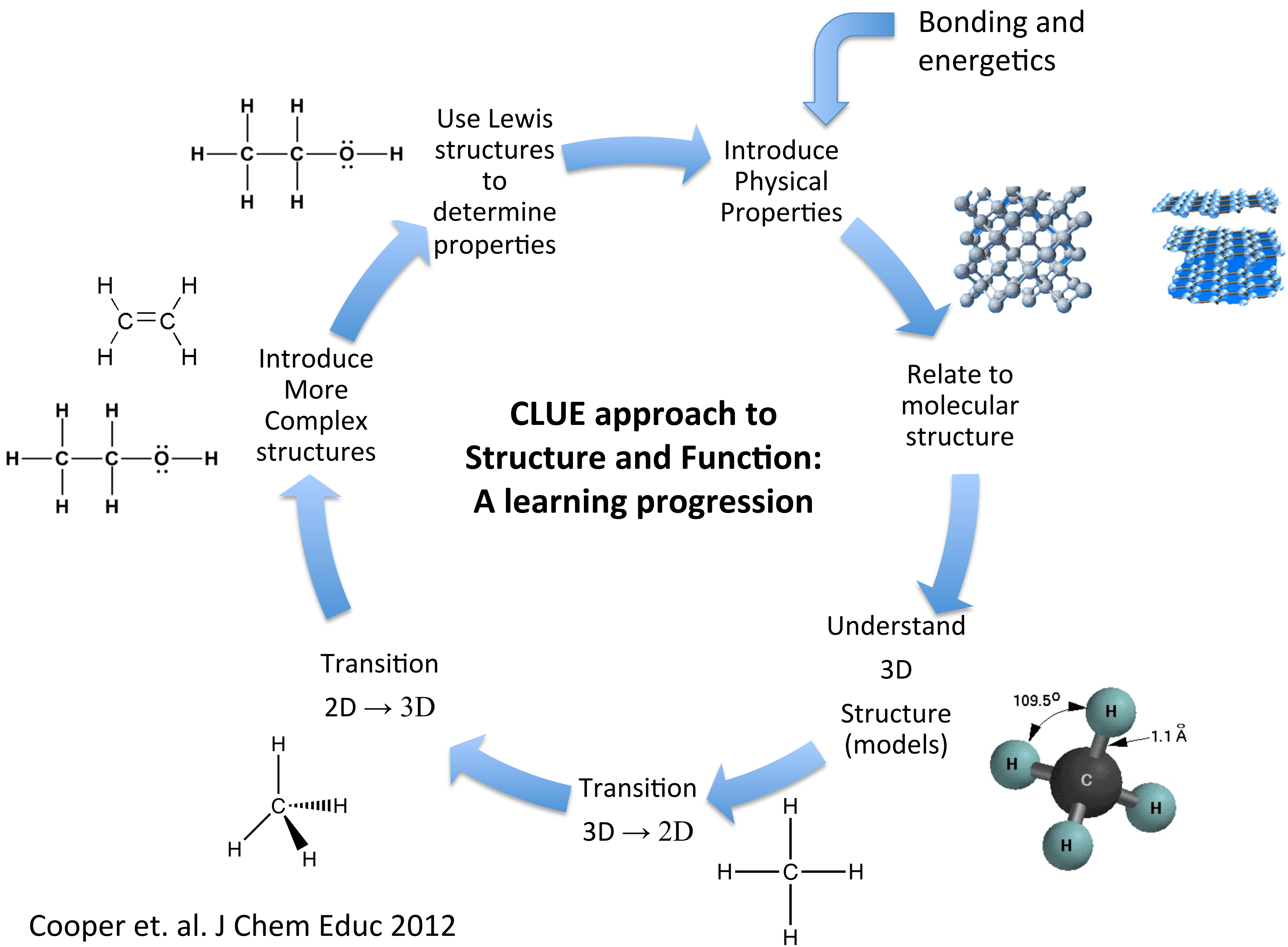
Our hypothesis: teaching for meaningful learning should help students improve their ability to construct **and use** Lewis structures



http://besocratic.colorado.edu/CLUE-Chemistry

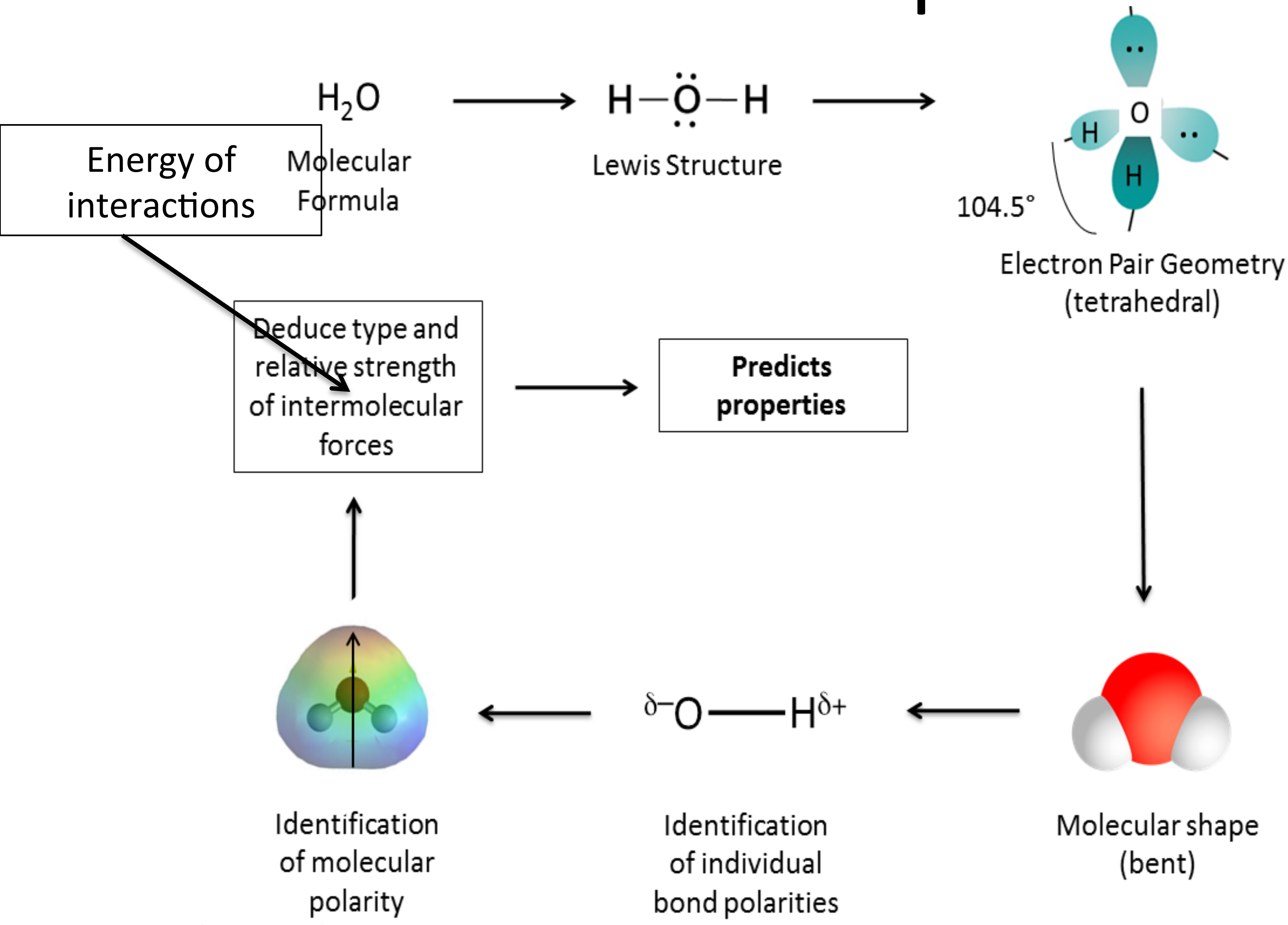
Learning Progressions

Corcoran. Mosher,
and Rogat, 2009



Cooper et. al. J Chem Educ 2012

Structure-Properties



Cooper et. al. CERP 2012

How to assess this complex construct?

The same cohort of control and treatment students were followed for two whole years.

	Fall Semester	Spring Semester	After 2 semester of O-Chem
Control (Traditional)	N = 120	N = 83	N = 32
Treatment (CLUE)	N = 93	N = 56	N = 24

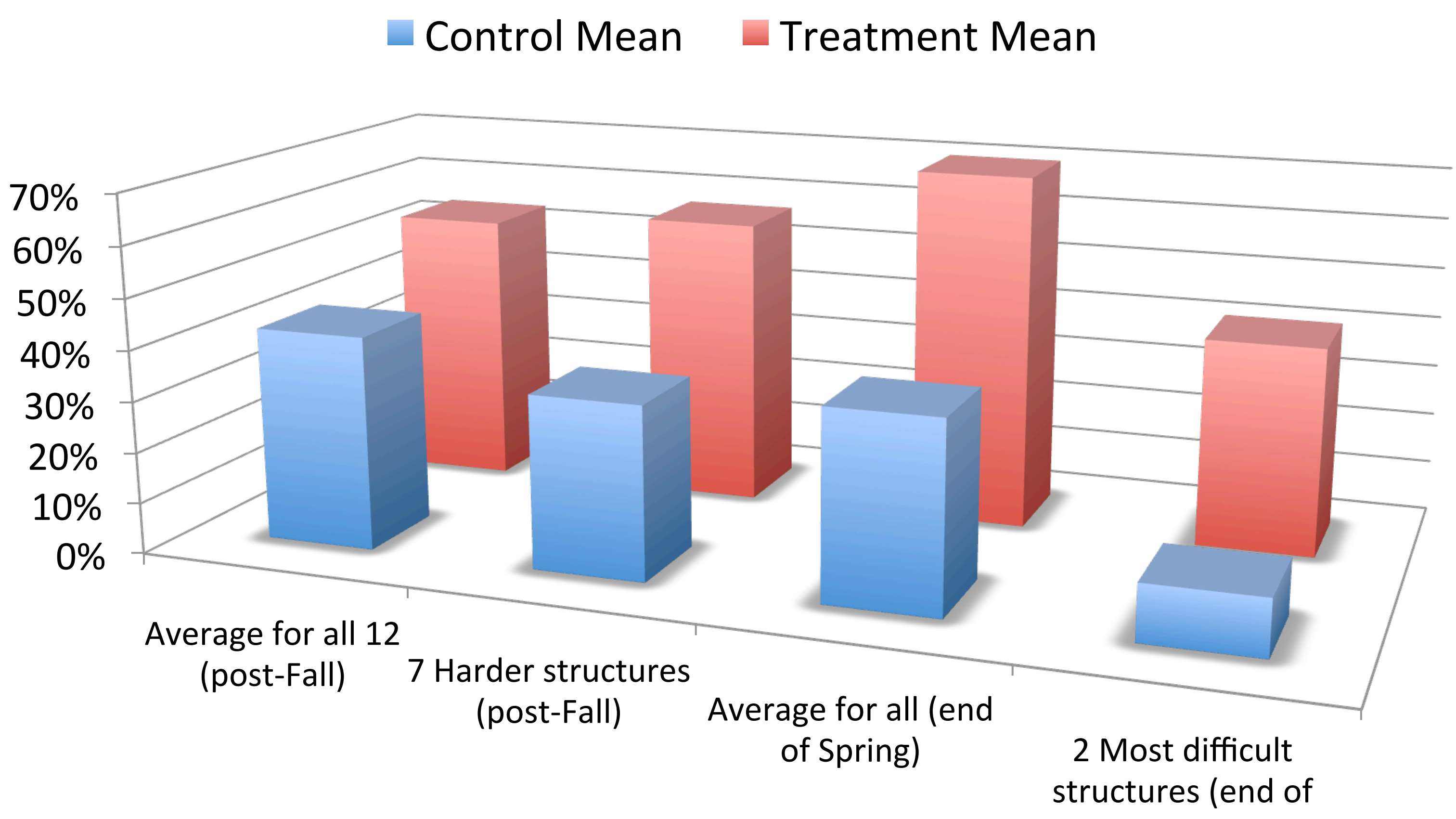
Comparison of pre-test assessments: Fall 2010

Pre-Instruction Assessments	Control Group Mean	Treatment Group Mean	p-value	U
SAT Composite	1186	1190	.76	3861
TOLT	8 (out of 10)	8 (out of 10)	.35	3650
Intellectual Accessibility – ASCIv2	46%	45%	.63	3800
Emotional Satisfaction – ASCIv2	56%	56%	.95	3945
Motivation – MSLQ	79%	80%	.69	3827

Note: all activities relating to this assessment were conducted AWAY from the lecture sections (in lab). None of the researchers were involved in the collection of the data.

Development and Assessment of a Molecular Structure and Properties Learning Progression, Cooper, Underwood, Hilley & Klymkowsky, "in press"

Comparison of Lewis Structure drawing ability



	Control Mean	Treatment Mean	p-value	r
Average for all 12 (post-Fall)	42%	54%	.006	.19
7 Harder structures (post-Fall)	34%	57%	< .001	.34
Average for all (end of Spring)	37%	70%	< .001	.6
2 Most difficult structures (end of Spring)	11%	41%	< .001	.43

Is this an instructor effect?

Fall 2009 Data: All students in traditional sections

	N	Mean % Correct	p-value
Instructor "A" (traditional)	56	65.8	0.997
Control Group	98	66.2	

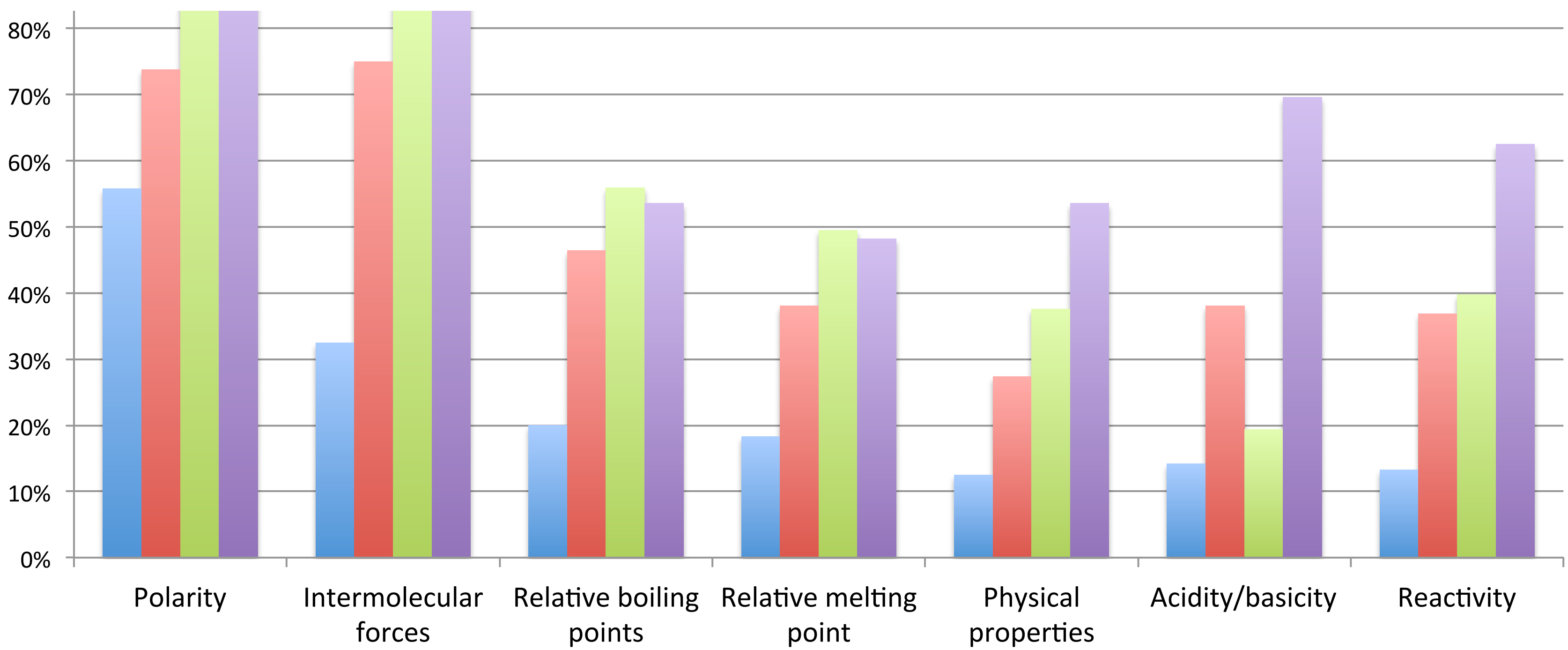
CLUE students appear to have some lasting improvement - **but do they know what Lewis structures are for?**

We have developed a survey instrument

Implicit Information from Lewis Structures Instrument (IILSI)

Underwood and Cooper, *Chem. Educ. Res. Pract.*, 2012 DOI:10.1039/C2RP00010E

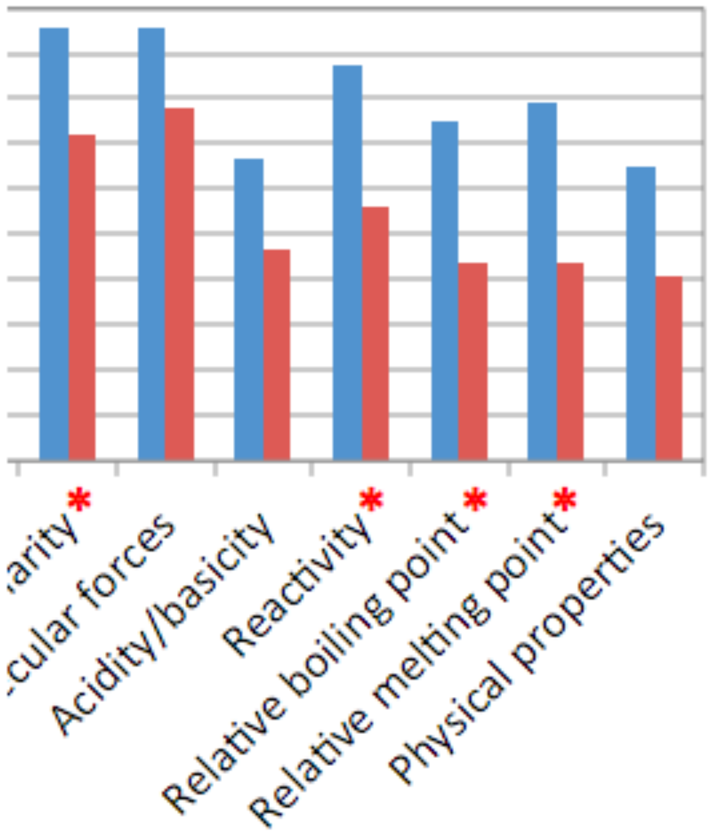
Chemical Formula	Post Fall Control	Post Fall Treatment	p-value	End of Spring Control	End of Spring Treatment	p-value
Relative boiling points	20%	56%	< .001	46%	54%	.512
Relative melting points	18%	50%	< .001	38%	48%	.311
Physical properties	13%	38%	< .001	27%	54%	.003
Acidity/basicity	14%	19%	.408	38%	70%	< .001
Reactivity	13%	40%	< .001	37%	63%	.005

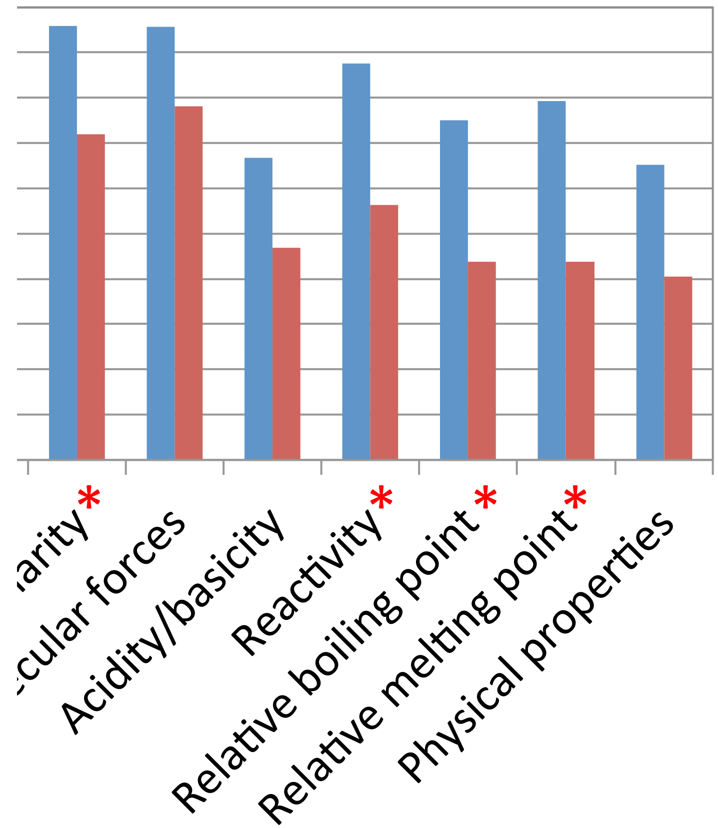


Development and Assessment of a Molecular Structure and Properties Learning Progression, Cooper, Underwood, Hilley & Klymkowsky, “in press”

End of 1st Semester End of 2nd Semester

CLUE (N=24) Traditional (N=32)

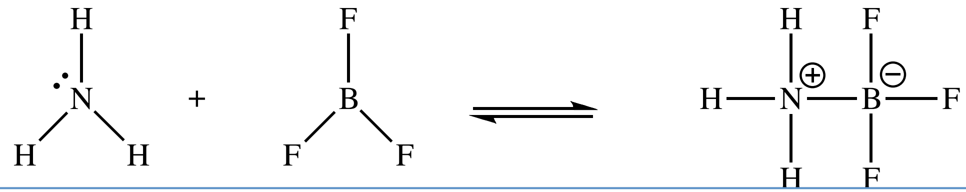




Effect Size: 0.26, 0.30, 0.28, 0.32

We are also analyzing a trove of qualitative data…

Please describe in **detail** what you think is happening **at the molecular level** for this reaction?



Control Students "Warrants"

- Thus the **nucleophile** (with its lone pairs) reaches out to attack the B.
- B is combining with the electrons on the N so that they can **both from an octet**
- The lone pair on the nitrogen forms a bond to the boron in the fourth bonding area, although boron **usually** is content with **only** having **three bonds**.
- This species is charged and could undergo a reaction to **dissociate back** into the other species on the left.
- **Entropy decreases** as a covalent bond is formed.

Using BeSocratic for making a scientific explanation or argument

Students answer a question, and are then taken through the steps:

1. making a claim
2. Providing data or evidence
3. Linking the two with an explanation

BeSocratic has built-in coding capabilities

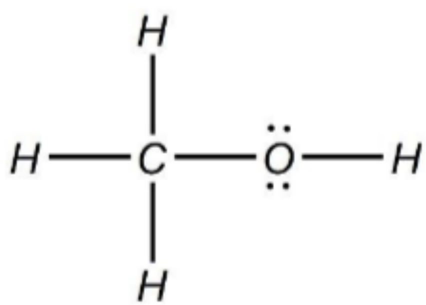
Preview:

Codes

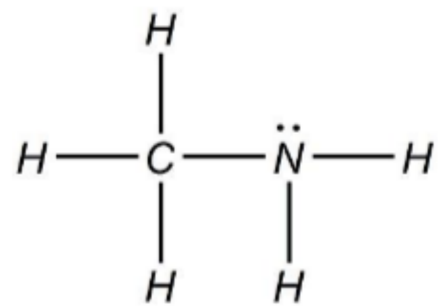
- Claim
- Data/Evidence
- Warrant
- Cant

Based on the Lewis structures of ammonia (NH3) and water (H2O) below, which one of them is a stronger **acid**? Please explain your reasoning.

Now let's look at two slightly more complicated compounds. Based on the Lewis structures of methanol (CH3OH) and methanamine (CH3NH2) below, which one of them is a stronger **base**? Please explain your reasoning.



methanol



methanamine

Methanamine is a stronger base because it contains more hydrogen atoms. Bases are proton donators so because Methanamine has more protons to donate it is a stronger base.

Students are then provided with their initial answer and asked to edit it

Please explain the trend in atomic radius across a row in the periodic table

As you go across a row, the atomic radius decreases.

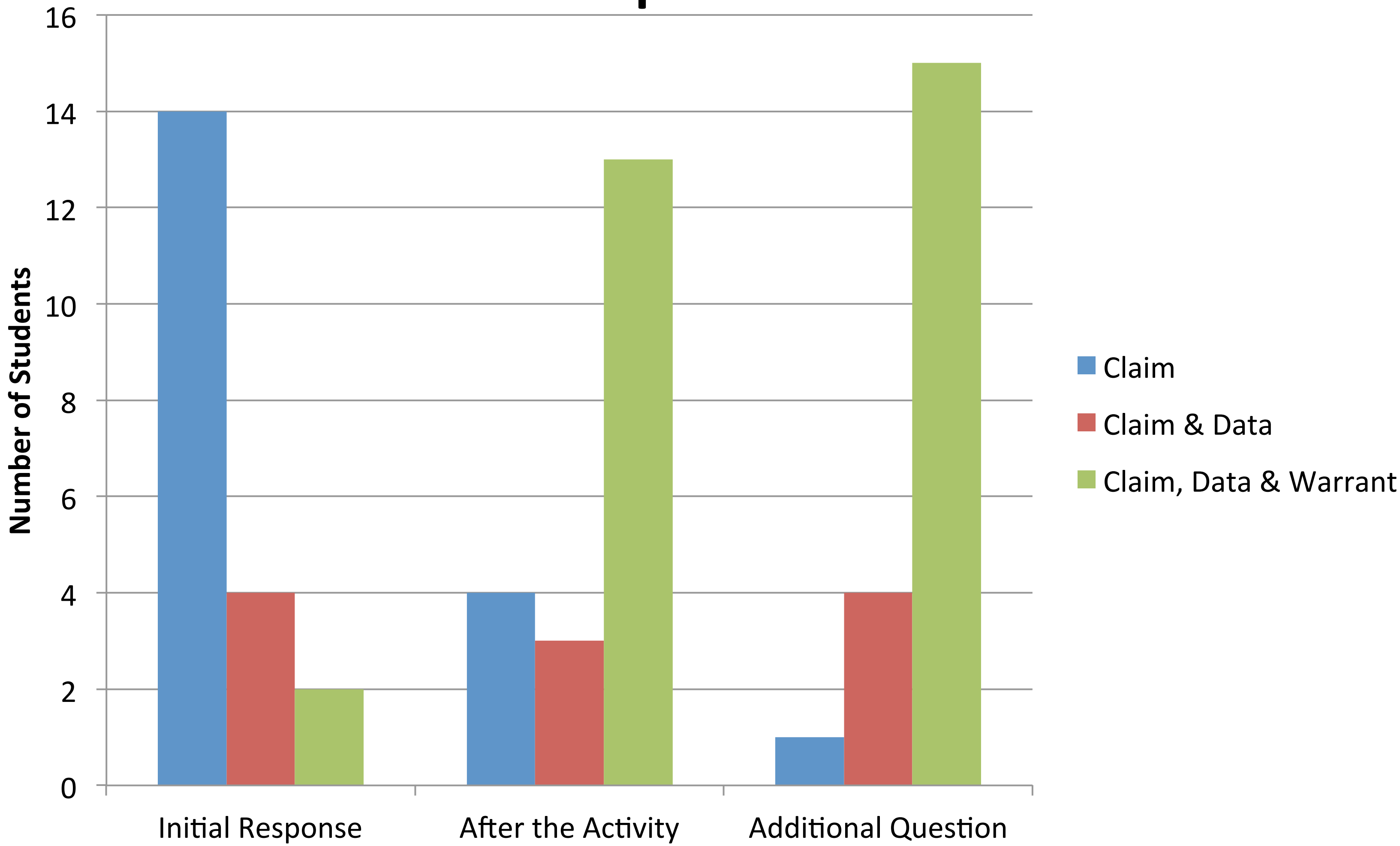
As you move from lithium to flourine on the periodic table, the atomic radius becomes smaller because of the increase in effective nuclear charge of the atoms.

Please explain the trend in atomic radius across a row in the periodic table

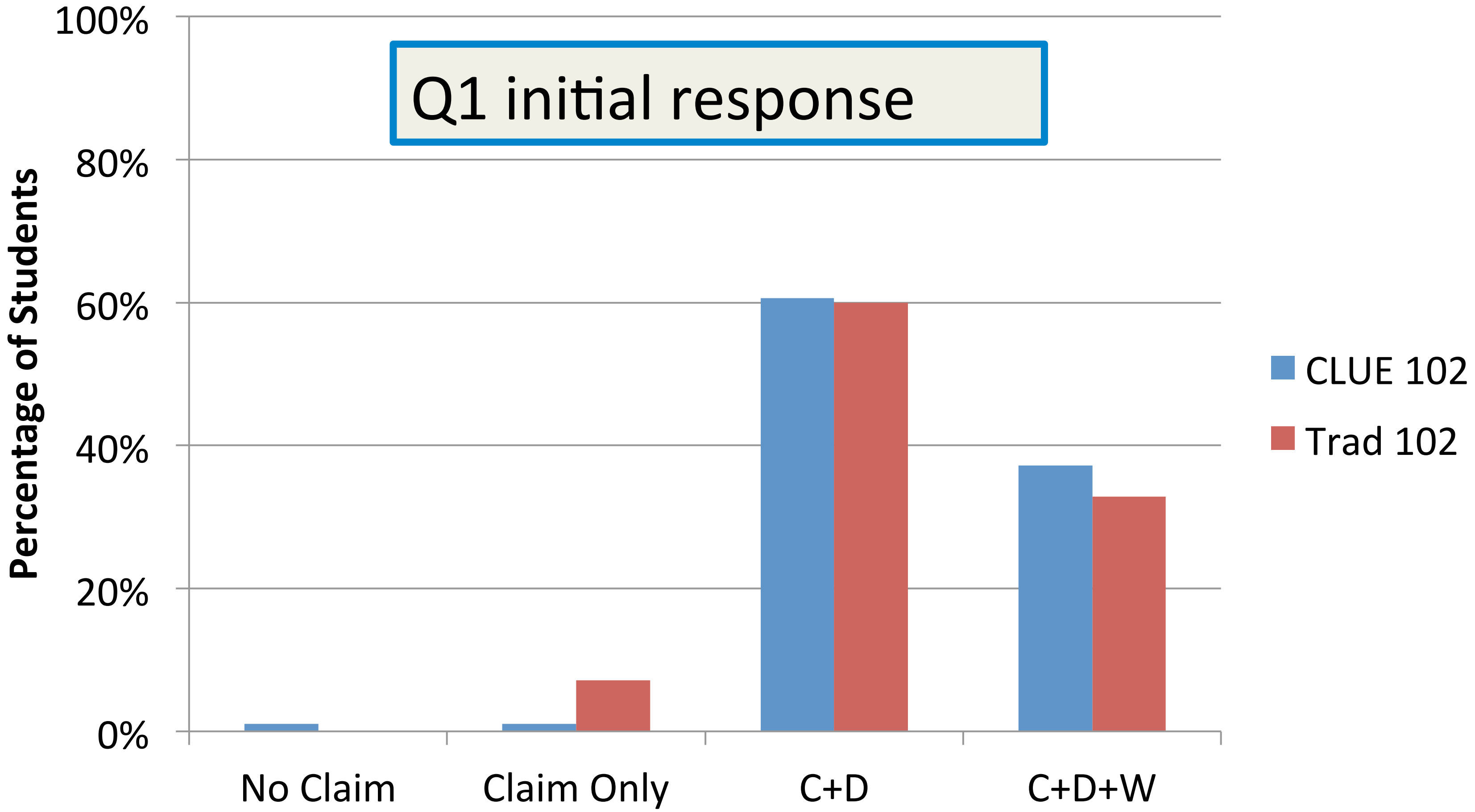
As you go across a row, the atomic radius decreases. This is because the number of protons increases as you go across a row. The more protons that are present, the stronger pull the nucleus has on the electrons. Therefore, the radius is smaller because the electrons are pulled in closer to the nucleus.

As you move from lithium to flourine on the periodic table, the atomic radius becomes smaller because of the increase in effective nuclear charge of the atoms. The increase in the number of protons will pull the electrons closer to the nucleus.

Explain the trend in atomic radius across the periodic table



Which is the strongest acid (NH_3 or H_2O) why?



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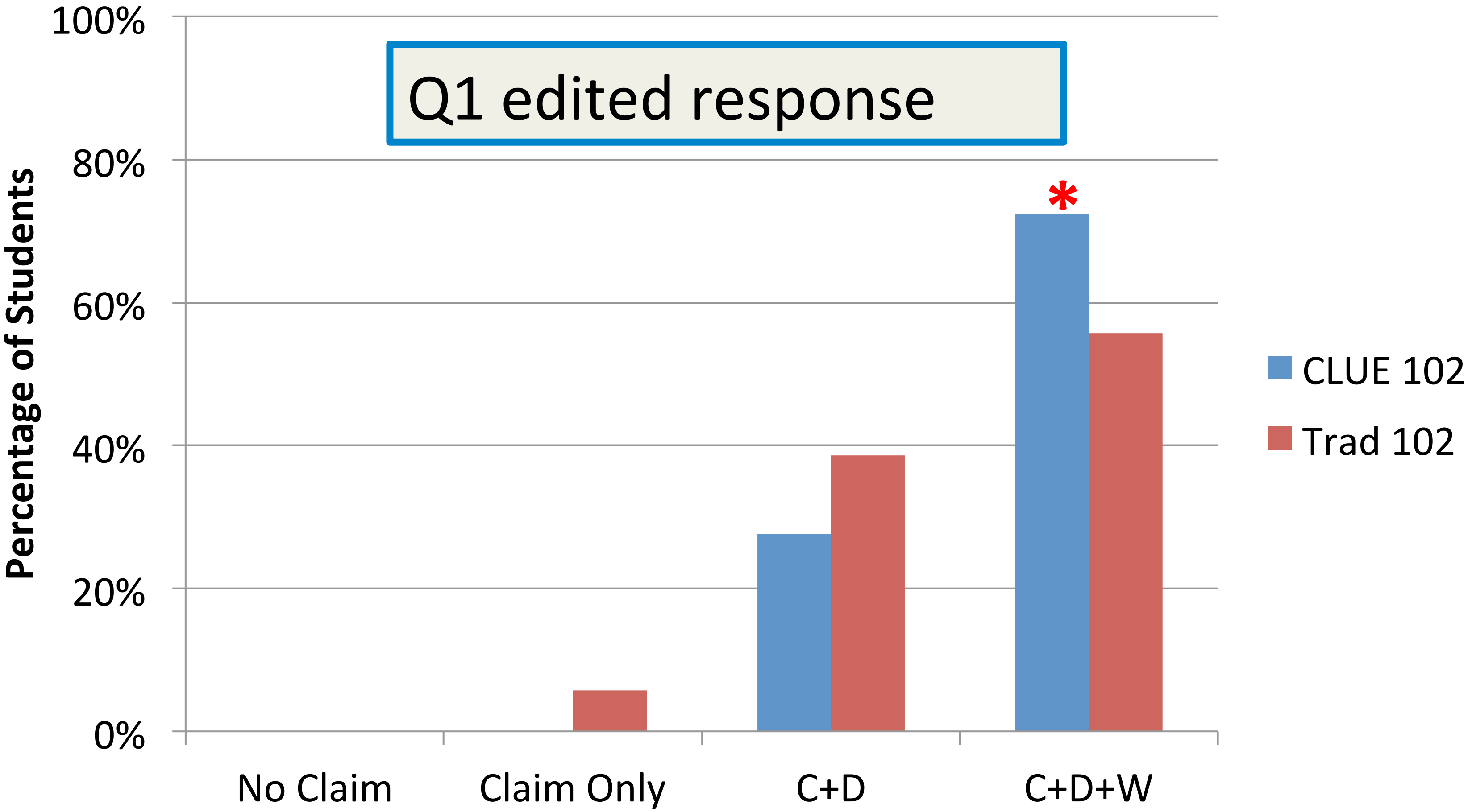
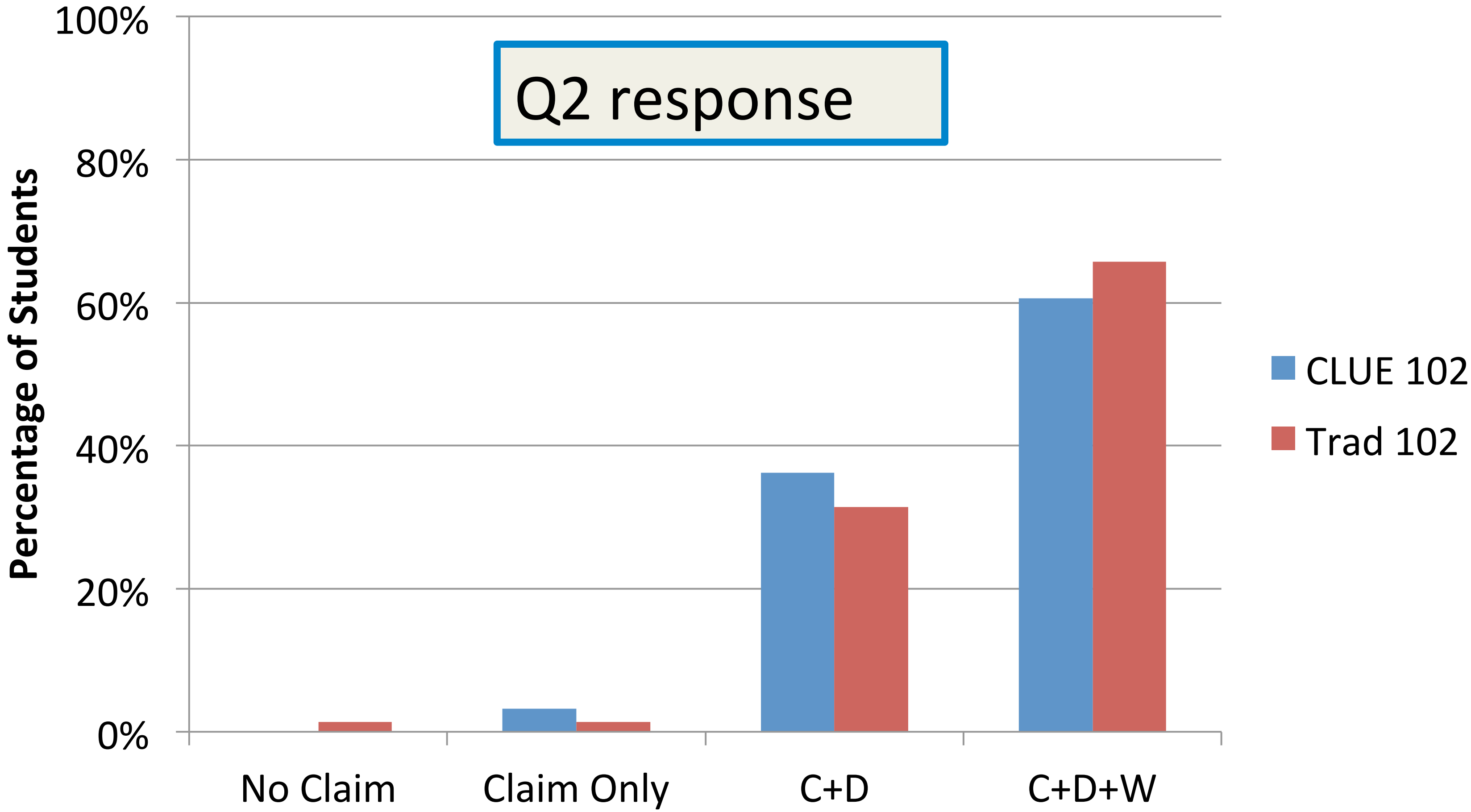
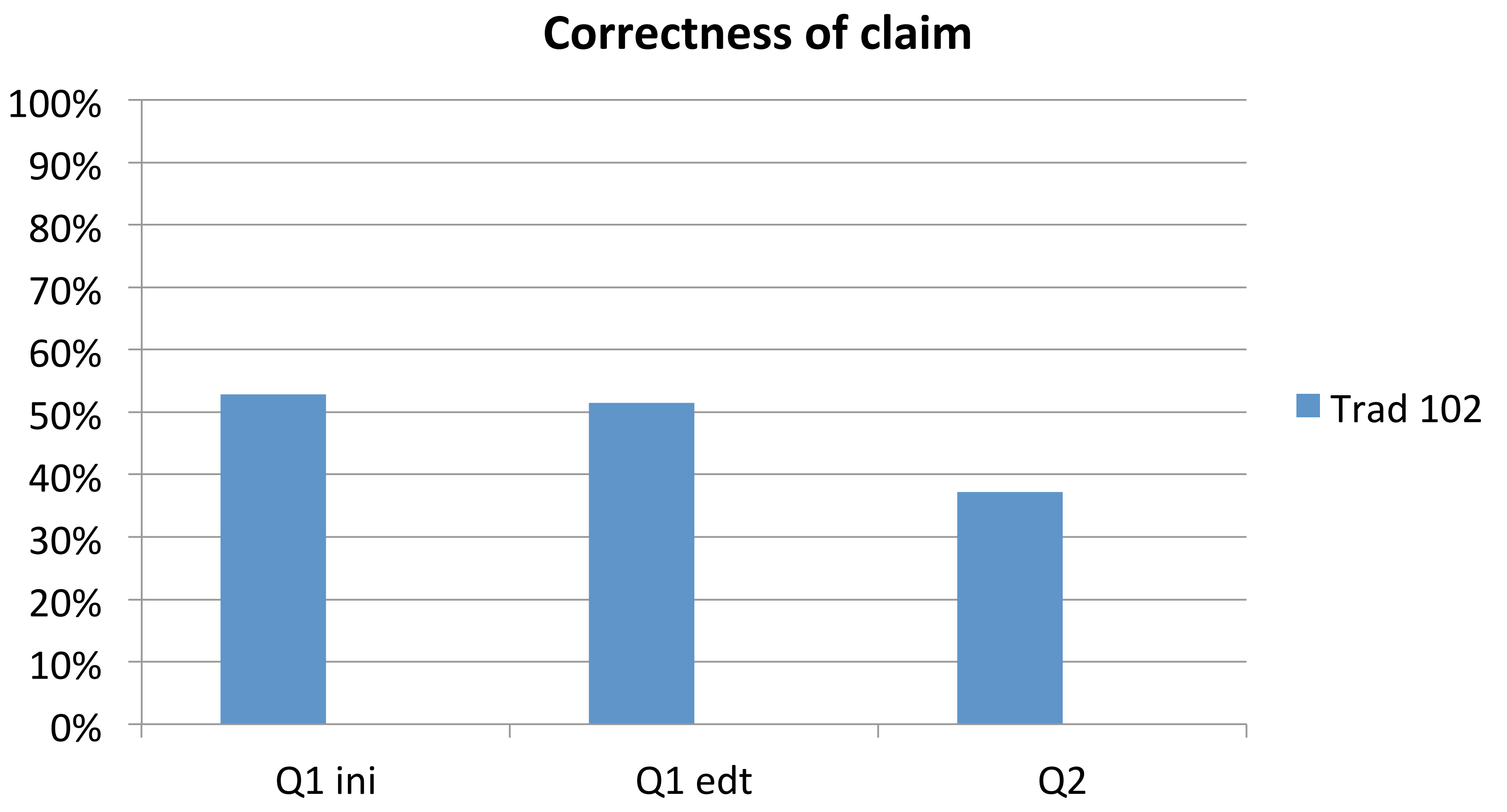


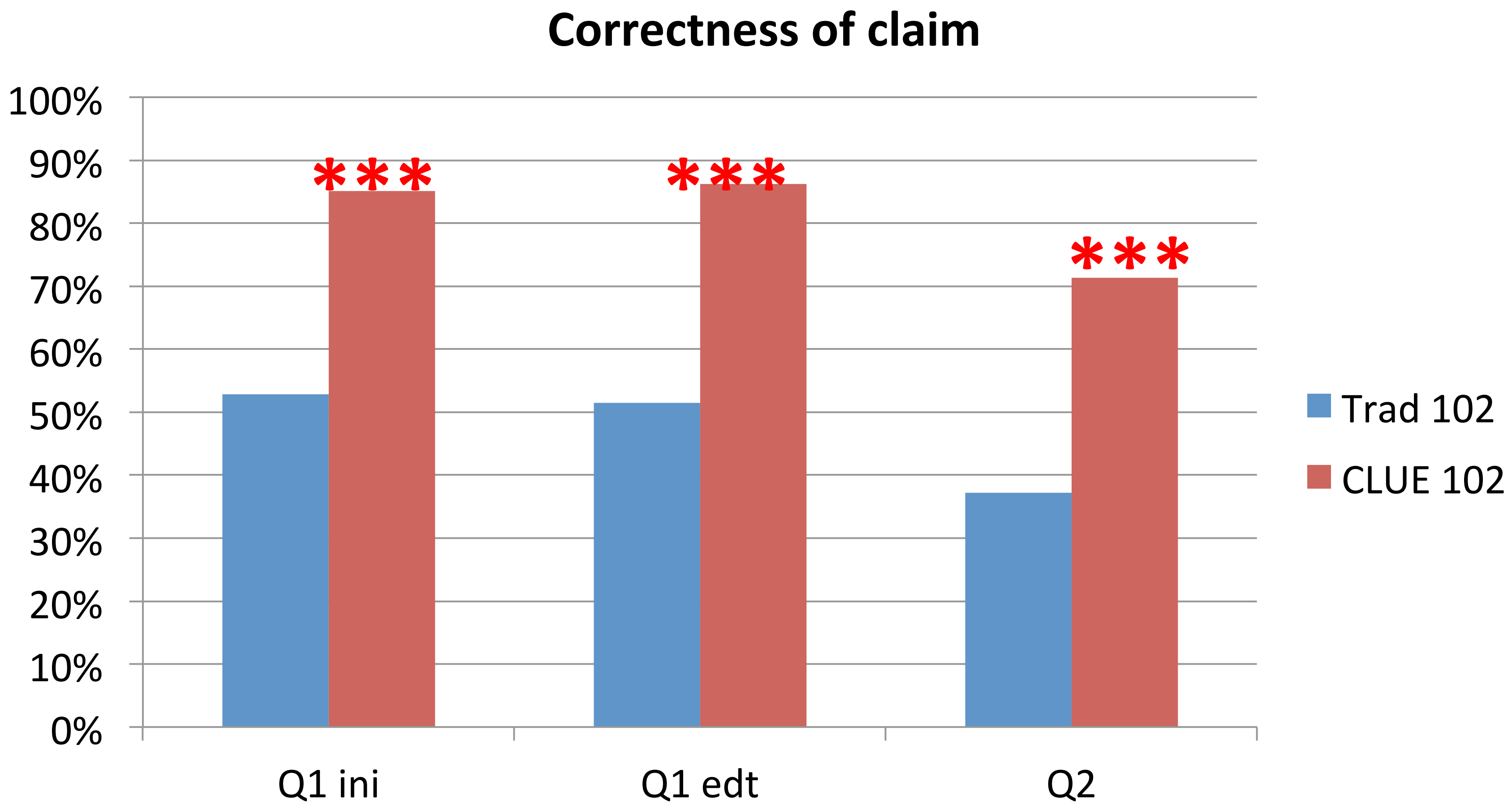
Which is the strongest acid (CH_3NH_2 or CH_3OH) why?



Is the claim correct? (which is a stronger acid?)



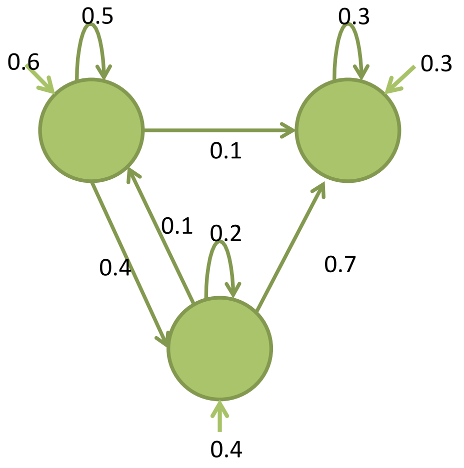
Is the claim correct?



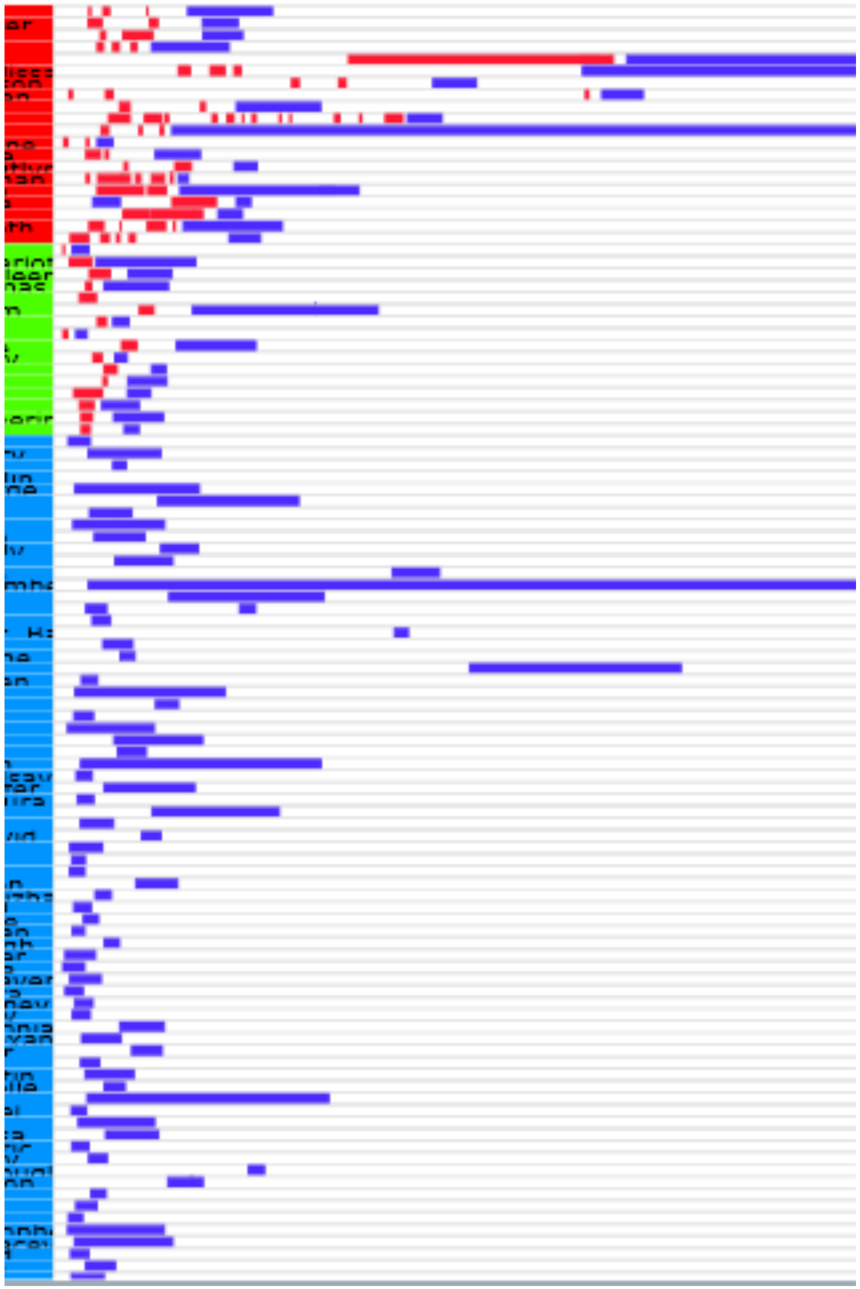
We are working on:

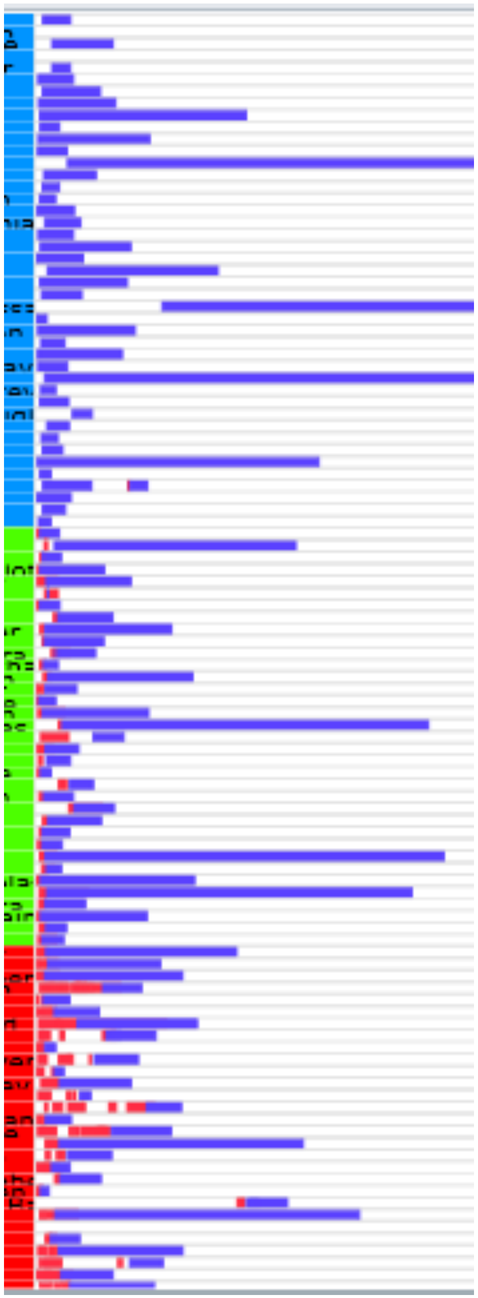
BeSocratic analysis of graphical, text & time data:

Clustering analysis and Hidden Markov Modeling

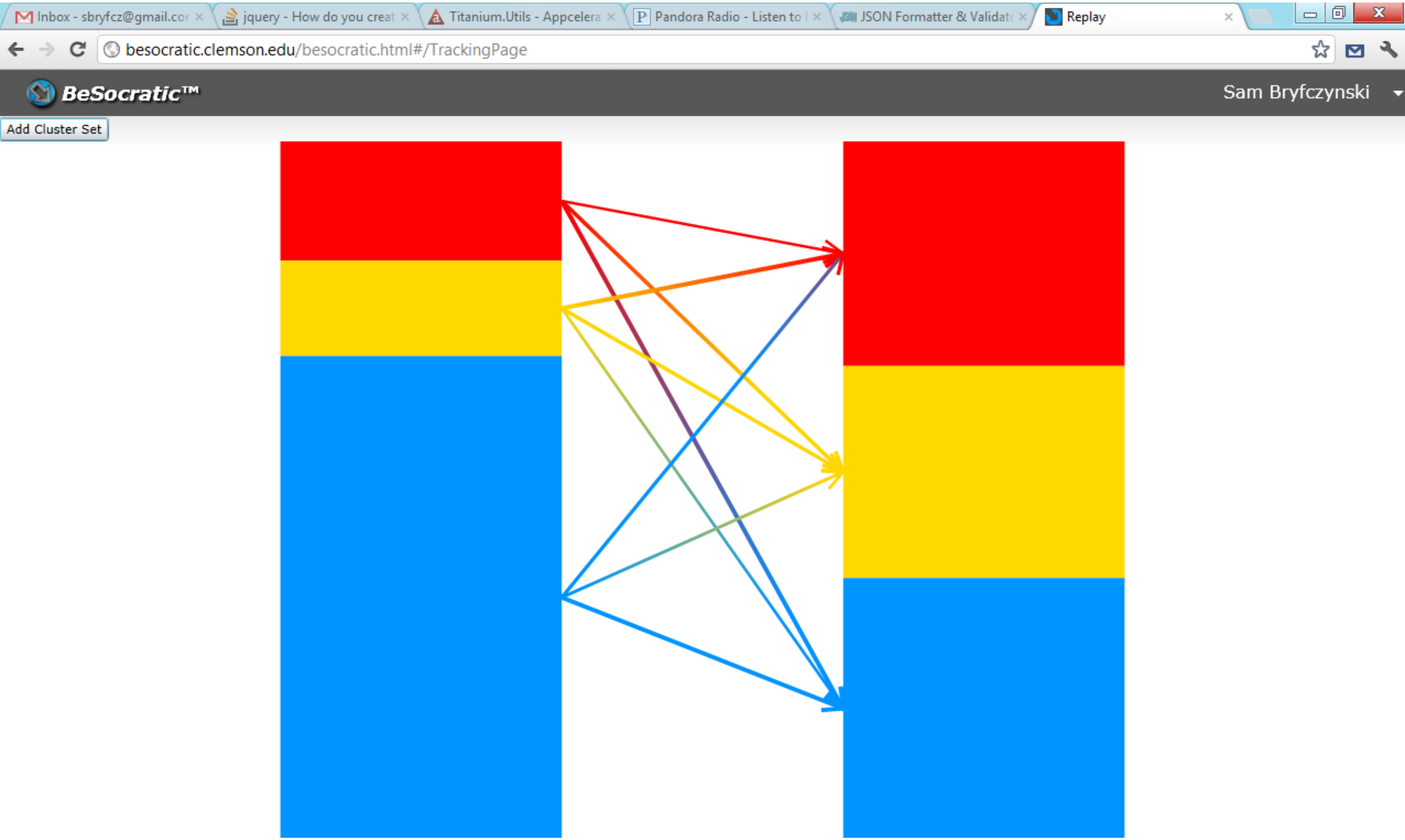


to predict and intervene with unproductive approaches





Easy -> Harder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BeSocratic™
Sam Bryfczynski
Add Cluster Set

Summary

- Conventional tests may be misleading about what students know
- Merely changing the pedagogical approach is not enough (but will produce some effect)
- Misconceptions are rarely simple – but may be a result of a dynamic set of disconnected and incoherent things
- Designing courses and curricula with explicit links both within and among the major core ideas may product more transfer and lasting learning
- Using formative assessments that require students to construct and explain their understanding may help students develop valuable skills