Learning higher-order thinking skills in General Chemistry: Using "*ChemEd X Data*" to teach students self-regulation

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http://goo.gl/33xlc0

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President's Council of Advisors on Science and Technology (PCAST) 2010:
instructors during the first two years of college must focus on deeper and transferable knowledge

P. Atkins. Pure Appl. Chem., Vol. 71, No. 6, pp. 927-929, 1999.
"…we should teach them to judge between conflicting influences. That is the essence of our subject, for it is rare that a single property governs the outcome of a reaction. We need to train our students to judge the likely outcome of conflict"

Atomic size and ionization ← Nuclear charge
Electronic shielding
Orbital size

Example Radius:
r(O) < r(Cl)
r(Li) > r(Mg)

"…I assume there are exceptions to this rule because there is an exception to pretty much every rule in chemistry." **Gen Chem student.**

DATA FIRST!

Structure-property relationships in 1st semester of General Chemistry

Properties of Substance — Substances — Electronic or molecular structure

$$Y \leftrightarrow A\,X$$

(it's never one single factor … and sometimes they come into conflict)

Electronic ground state of elements	↔	Aufbau principle + Hund's rule
Atomic size and ionization energy	↔	Nuclear charge + shielding + orbital size
Ionic lattice energy of crystal solids	↔	Cation's and anion's size and charge
Boiling point of molecular solids	↔	Intermolecular forces + shape + mass
Heat capacity of molecular solids	↔	Intermolecular forces + bonds + mass

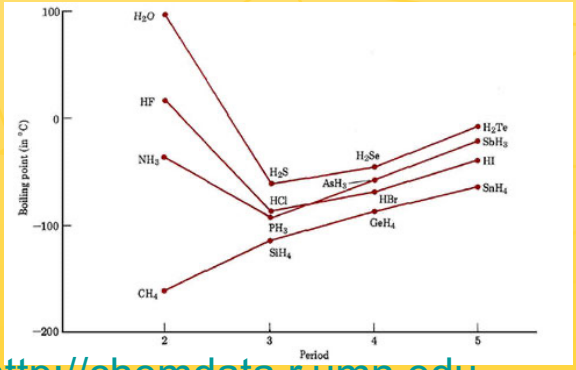
Data-driven exercises

Static, "precooked" data

The web
- Unstructured data
- Non-linear
- Non-sequential
- Open-ended

Remember → Understand → Apply → Evaluate → Create

1. Look at this graph
2. See what I want you to see
3. Explain how everything perfectly fits
4. No exceptions



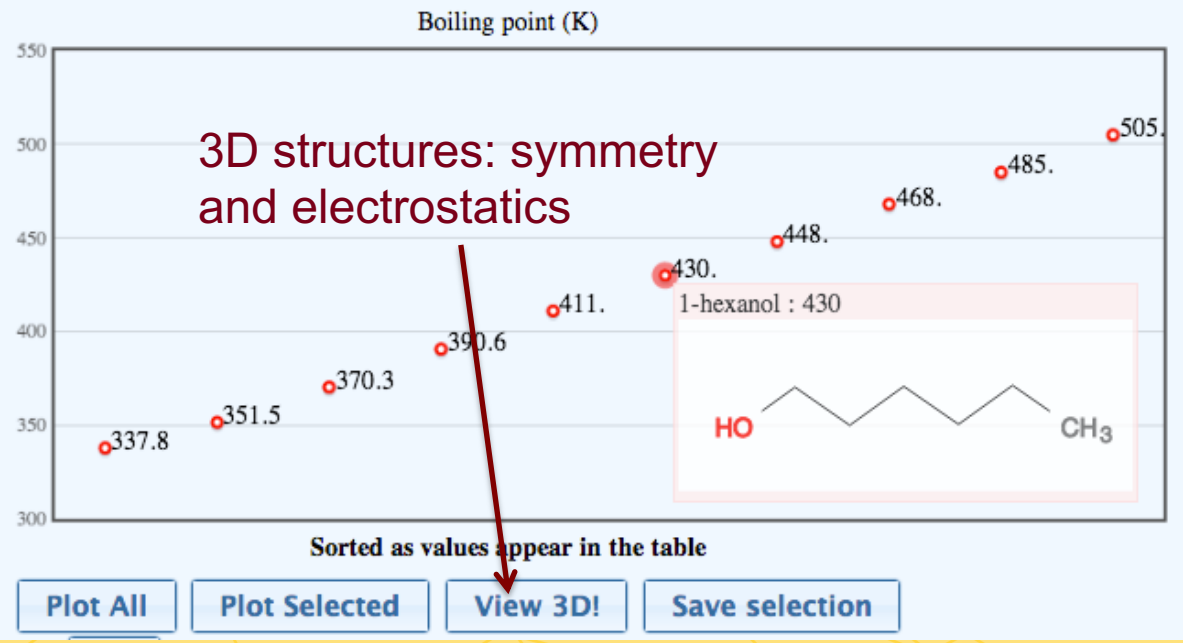
http://chemdata.r.umn.edu

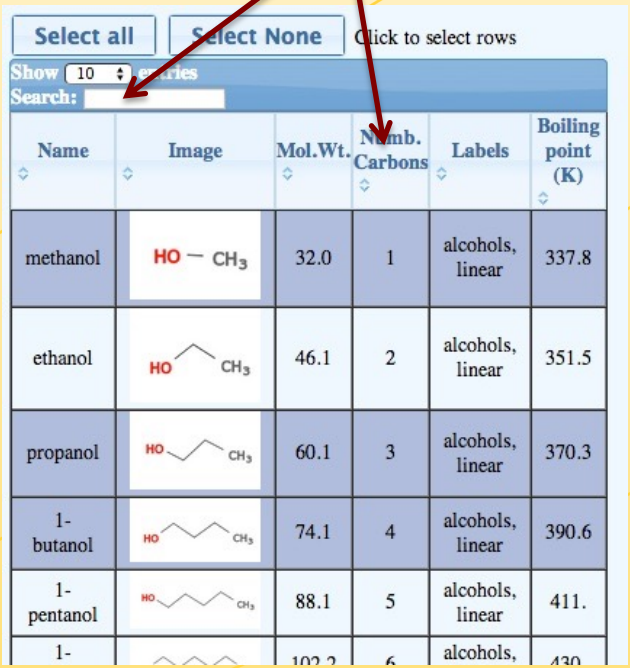
1. Choose some data
2. Represent it
3. Find patterns
4. Find exceptions

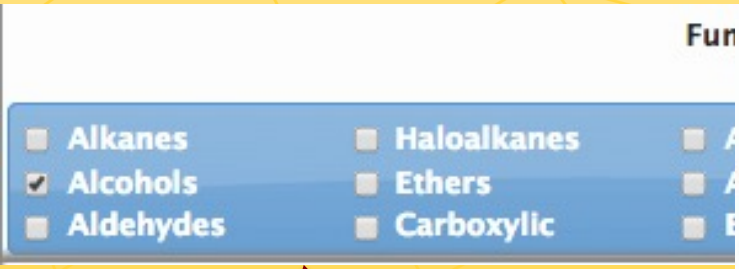
Skills required: Self-regulation
Self-evaluation

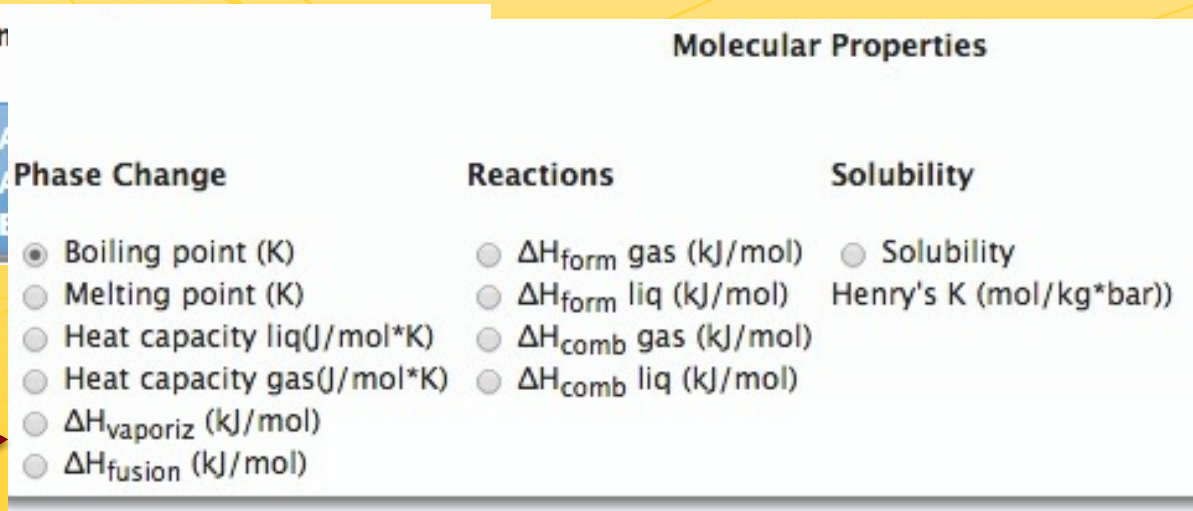
http://chemdata.r.umn.edu

Order and filter



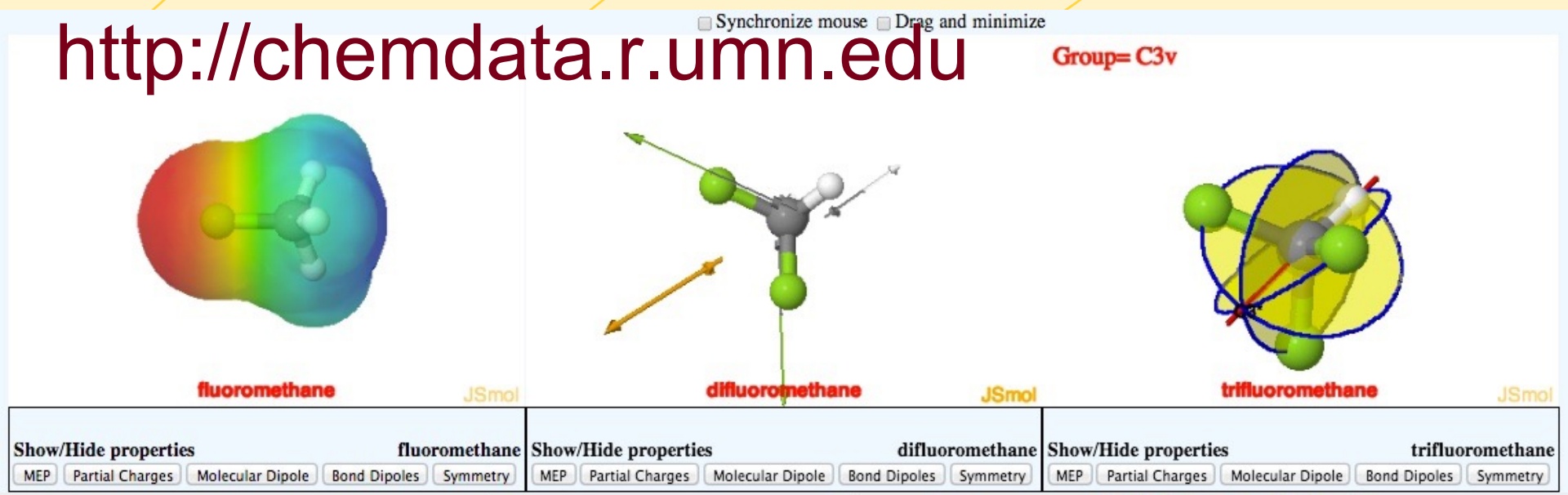


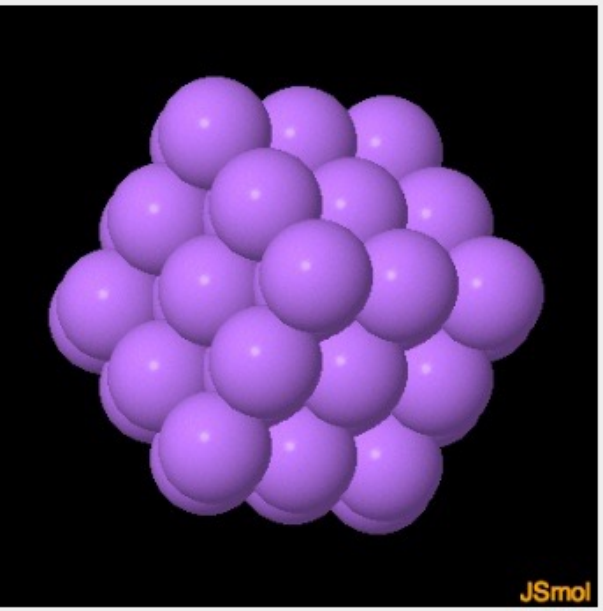


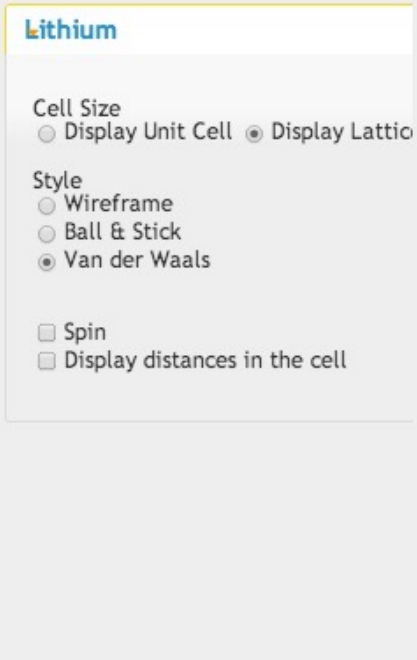


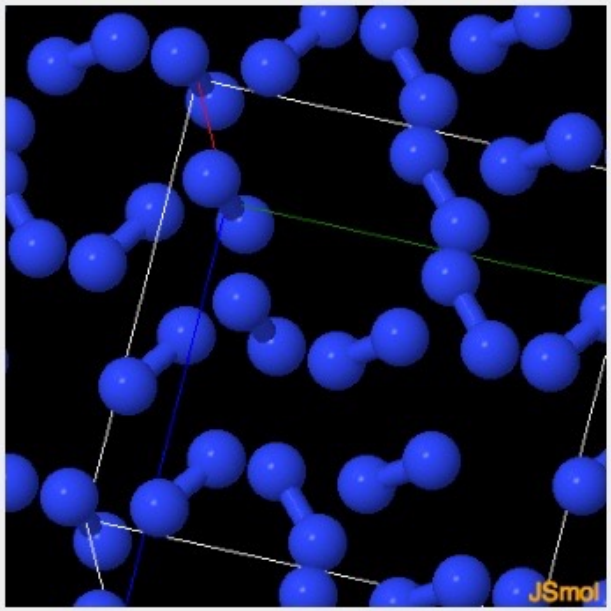
Select func. groups and properties.
Hundreds of compounds.

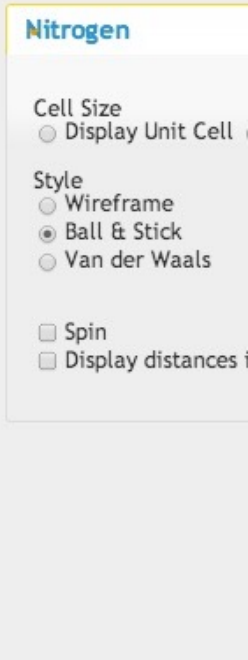
http://chemdata.r.umn.edu











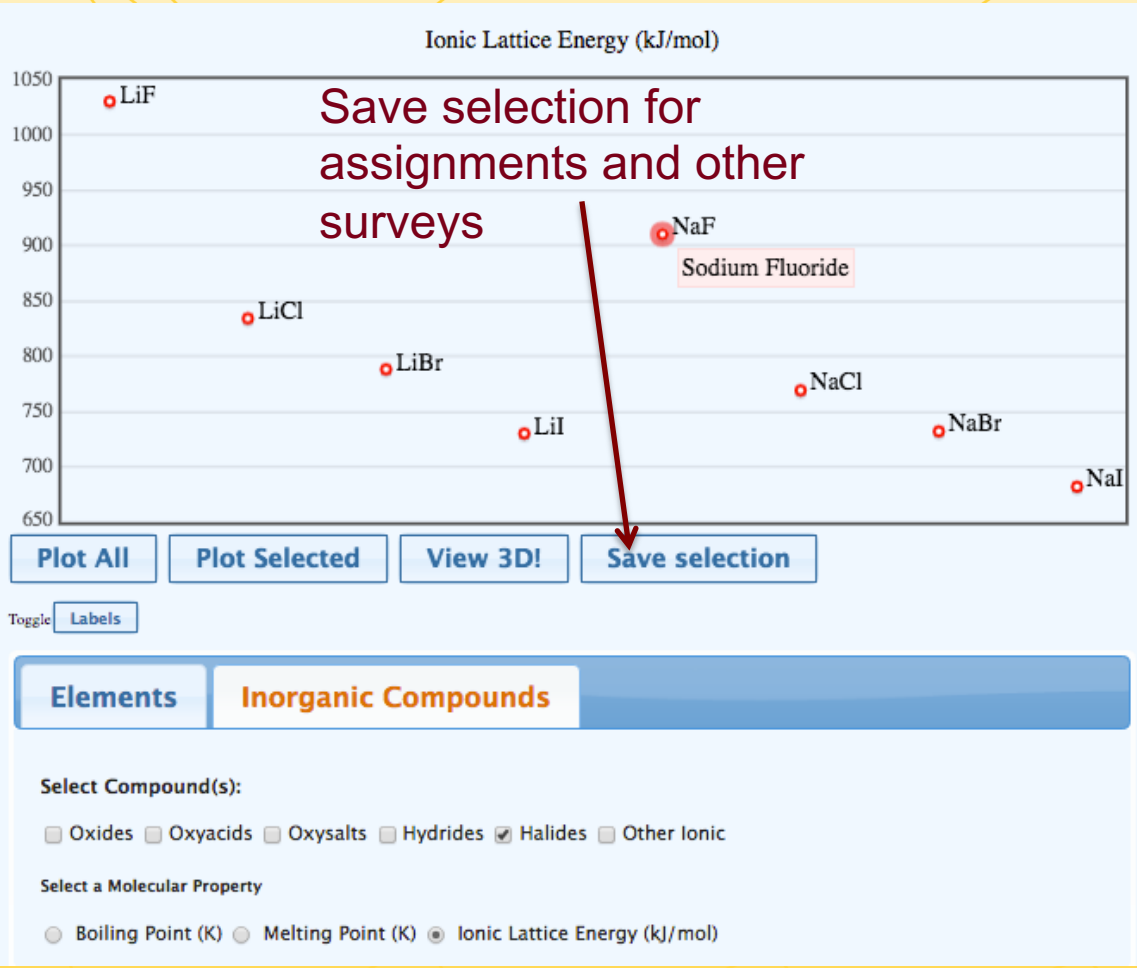
Popup window | Take a picture | Reset

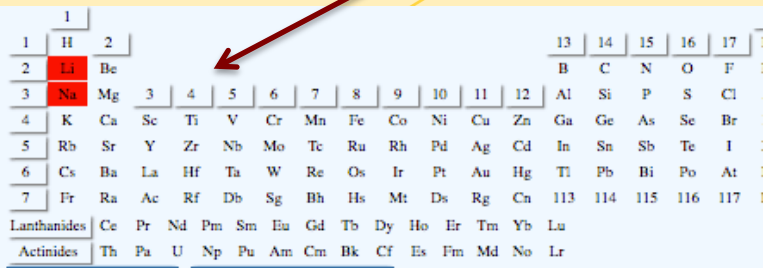
Popup window | Take a picture | Reset

Experimental and computed data

http://chemdata.r.umn.edu

Periodic table for easy selection





Select All | Select None | Click to Select Rows

Show 100 entries

Search:

Name	Formula	Compound Label	Ionic Lattice Energy (kJ/mol)
Lithium Fluoride	LiF	Halide	1030
Lithium Chloride	LiCl	Halide	834
Lithium Bromide	LiBr	Halide	788
Lithium Iodide	LiI	Halide	730
Sodium Fluoride	NaF	Halide	910
Sodium Chloride	NaCl	Halide	769
Sodium Bromide	NaBr	Halide	732

ChemEd X Data http://chemdata.r.umn.edu

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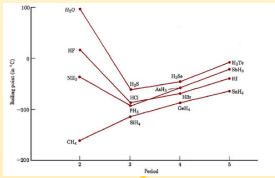
Using ChemEdXData
Example 1:Boiling point of molecular solids

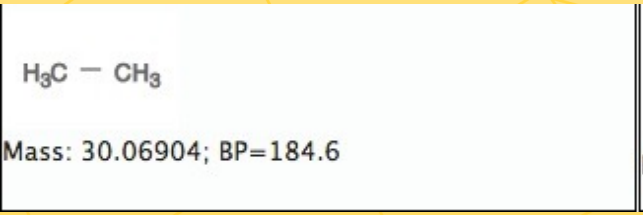


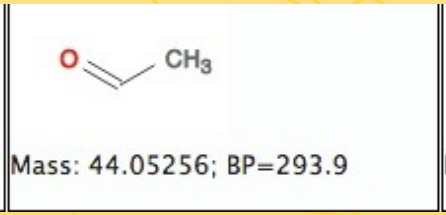
The exercise had several questions classified here according to its cognitive level

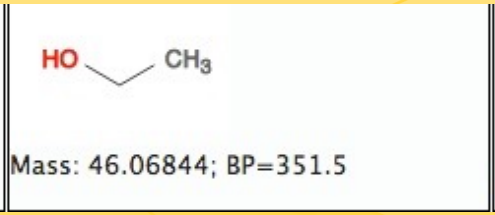
Level 1: (*remember*) Recognize intermolecular forces present in molecules

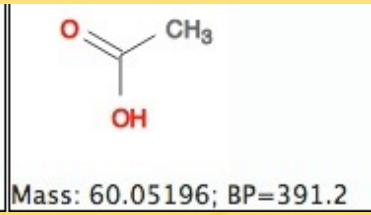
Level 2-3: (*understand*) Mass or dipole in the series of CH_3F, CH_2F_2, CHF_3 ,CF_4

Level 2-3 : (*apply*) Which of the following datasets are good "controlled experiments" or "Control Variable Strategy" (CVS)



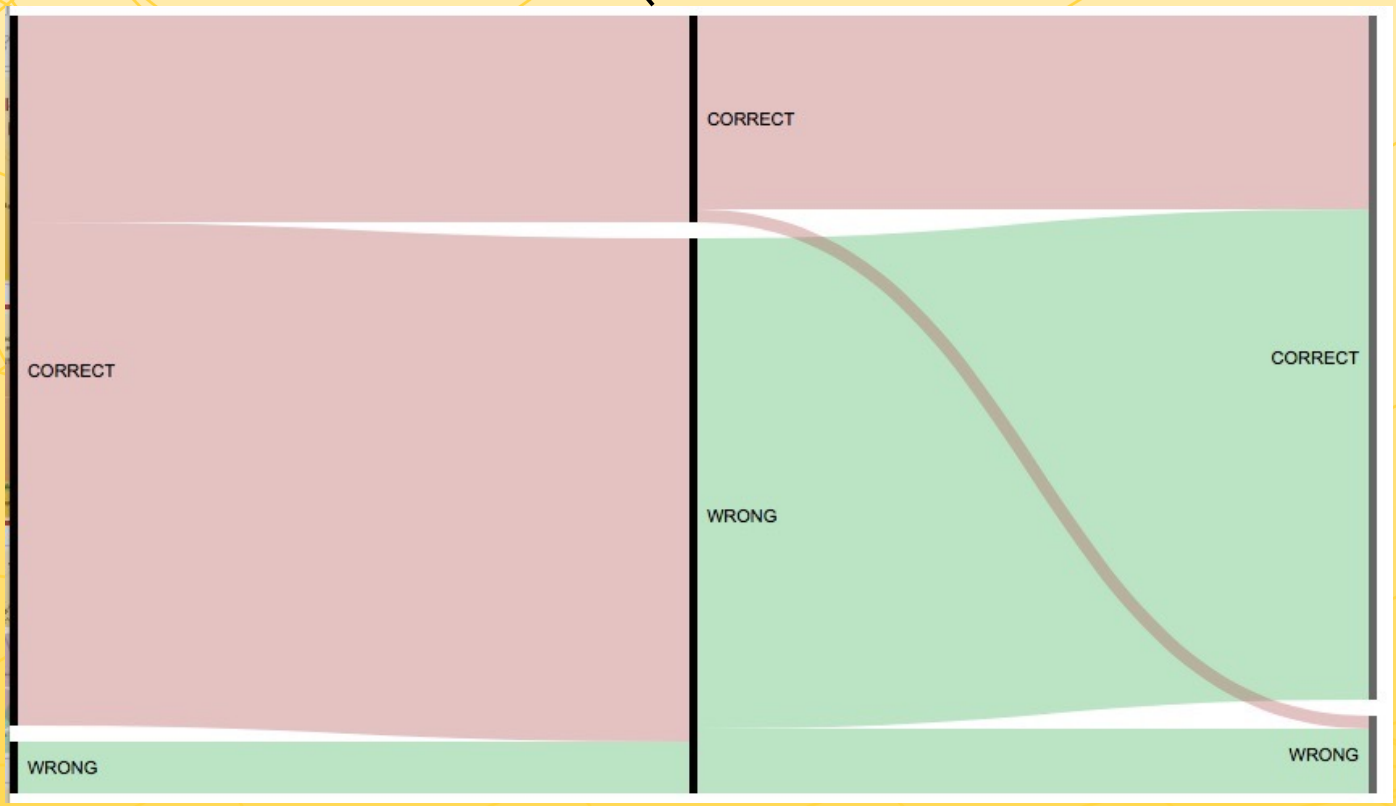






Level 4: (*build*) Build a controlled experiment or "Control Variable Strategy" (CVS) to investigate the role of mass in boiling points of molecules

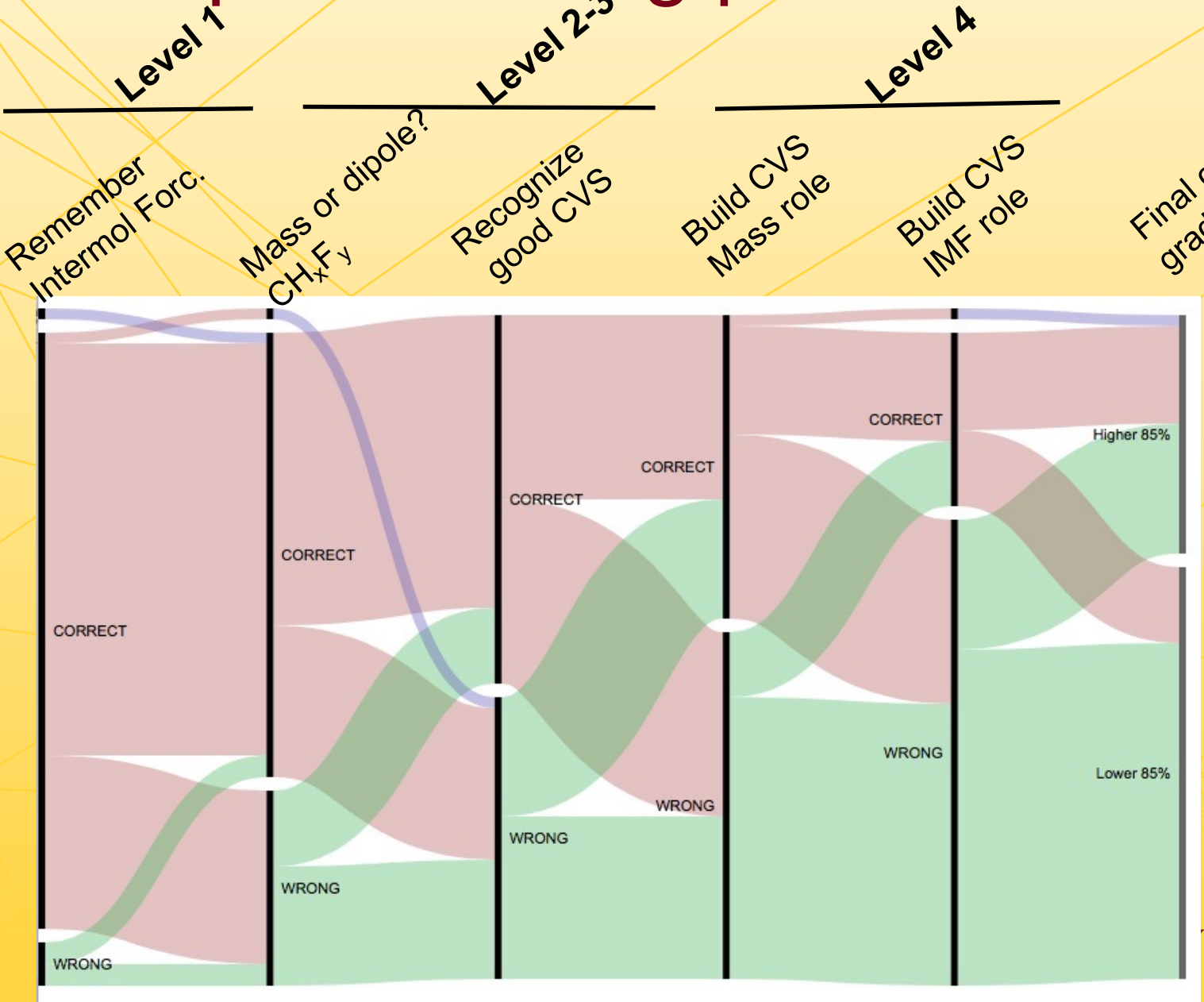
Using ChemEdXData
Example 1:Boiling point of molecular solids



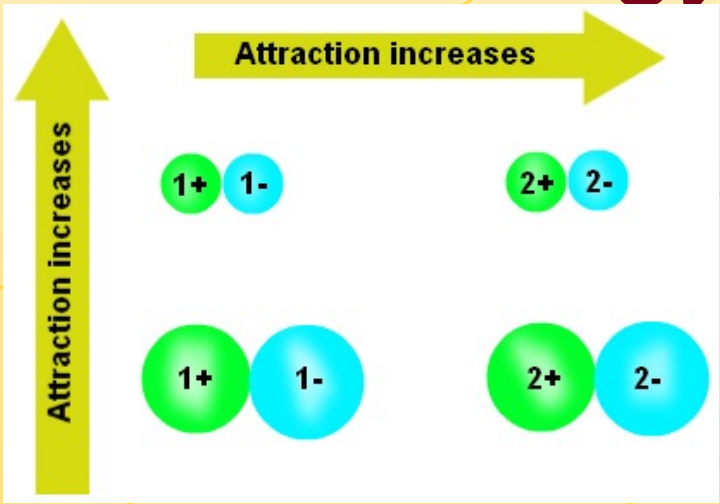
→Students cannot build the CVS but they have understood the trend and can successfully answer the ranking

The same it's true for the effect of mass and shape

Example 1: Boiling point of molecules



Using ChemEdXData Example 2: Ionic lattice energy of crystal solids



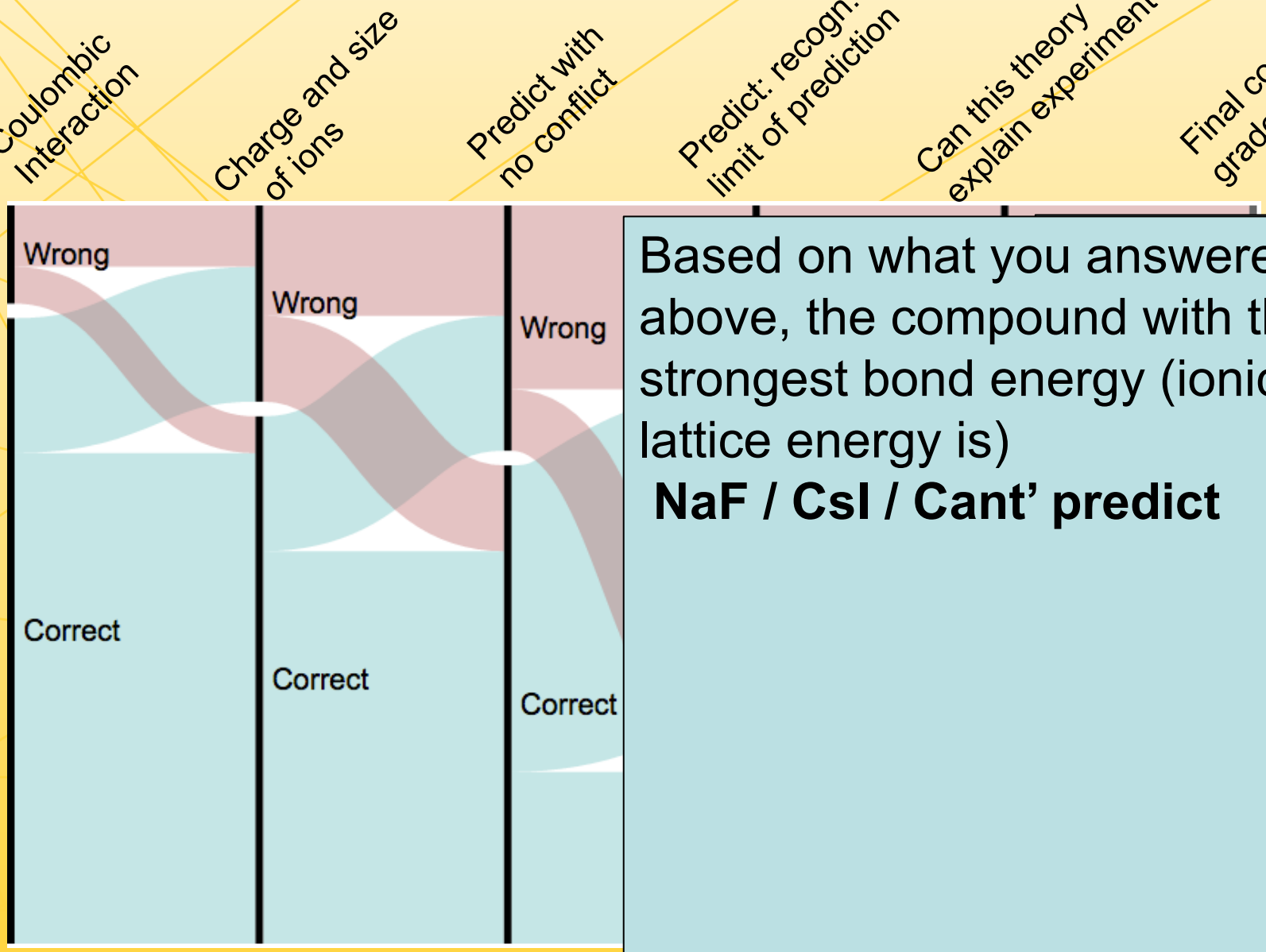
The exercise had several questions classified here according to its cognitive level

Level 1: (*remember*) Coulomb's law, size and charge of ions

Level 2-3: (*understand/apply*) Predict substances with highest ionic lattice energy

Level 4: (*evaluation*) Recognize limit of prediction when there is a conflict between factors

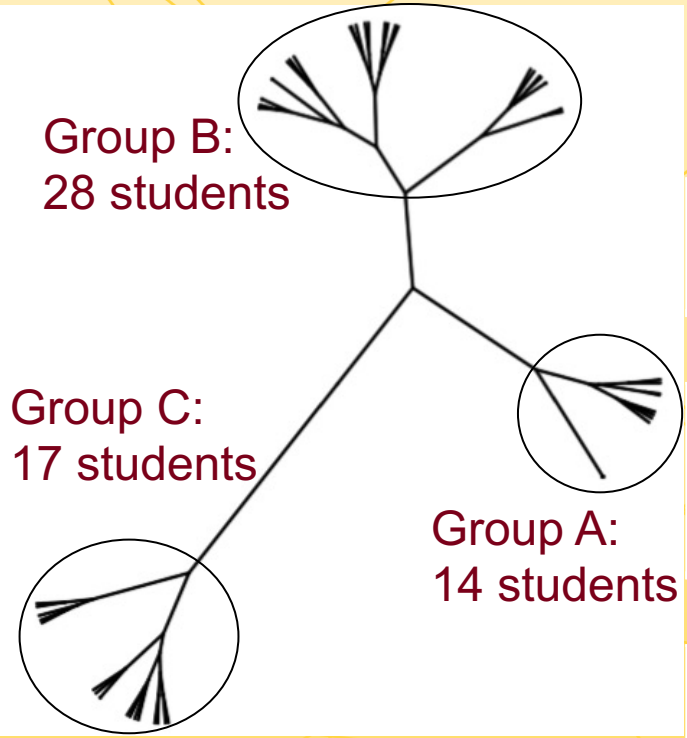
Example 2: Ionic lattice energy of crystal solids



Based on what you answered above, the compound with the strongest bond energy (ionic lattice energy is)

NaF / CsI / Cant' predict

Example 2: Ionic lattice energy of crystal solids



	Group B n = 28	Group C n = 17	Group A n = 14
Course Grade	81.0±9.2	79.0±6.2	88.0±5.5
Ionic energy survey	62.7±14.2	31.7±9.3	88.1±12.9
Conflicting factors questions	14.3±26.2	8.8±19.1	85.7±22.6

Hierarchical cluster analysis (Ward's minimum variance method) using the results for the "Ionic lattice energy" survey

Conclusions

- ChemEd X Data was used to practice higher-level cognitive skills in introductory courses and collect student data for its analysis.
  - Using data-first students learn by themselves
- We have identified several activities as higher-level such as:
  - Learning “Control of variable strategies” in boiling point of molecules and identifying the limit of predictability in ionic bond models.
  - Students who do well in identifying ”limits of predictability” obtain the highest course grades

ChemEdXData on GSpreadsheets