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Generating questions: A key skill for the development of critical thinking

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Abstract

Students who are thinking critically in a science, engage in a four step process that begins with them collecting data and/or observations, evaluating the data/observations, using their evaluation to generate a hypothesis, which in turn must then be evaluated (Keller, 2008). This process is assumed to be cyclical until a hypothesis leads to a conclusion. A key skill identified for all steps is the ability to question. Questioning is also a hallmark of self-directed, reflective learners (Chin et.al., 2002). The literature has shown, however, that students have limited opportunities in class to raise (and learn from) their own questions and that students questions are usually infrequent, and tend to probe for basic information rather than a deeper understanding (Chin et. al., 2002, Dillon, 1988, Middlecamp et. al., 2005). The presenters are interested in creating activities that probe, hone and evaluate students questioning skills (Middlecamp et. al., 2000, Offerdahl et. al., 2014). The participants attending this presentation will be asked to experience a first day of class activity designed to probe the initial questioning skills of freshman chemistry students. It will be followed by how these students' questioning skills were also assessed at the end of term. It is hoped an interactive discussion will be sparked regarding how to best use activities, like those presented, to strategically address the development of students questioning skills.

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Generating Questions

A Key Skill For Developing Critical Thinking

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This is one model chemists use to represent the structure and bonding in

(5*Z*,8*Z*,11*Z*,14*Z*)-*N*-(2-hydroxyethyl)icosa-5,8,11,14-tetraenamide

aka anandamide.

- List as many questions as you can about this statement (10 min).
- Review your list(s) of questions.
- Identify 3 questions you believe are the most important ones.
- Your scribe should write *everything* down
- Write those questions on the poster sheet provided.

Rule 1: Ask as many questions as you can.

Rule 2: Do not stop to discuss, judge or answer any question.

Rule 3: Write down every question exactly as it is stated.

Rule 4: Change any statement into a question.

Prize for the group producing the most questions

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My questions

- Why are some balls black, red, blue and white? What is the meaning of the different colours?
- Why are the geometries/shape around different balls different?
- Why is the number of balls attached to one another not always the same?
- Why are there empty holes in some balls?
- What are the angles within the structure?
- What is the real 3D structure?
- Is the molecule "flexible" in reality?
- What are the connectors in between the balls really made of?
- Where are the electrons?
- What is a model?
- Why is this "a" model for this compound? Are there others?
- Is this model accurate? Are there any flaws?
- What is the actual size of this molecule (in real life)?
- Why a picture of chocolate?
- What are the properties of this compound?
- Is it soluble in water?
- How does the name of this compound relate to the model?
- Why two different names?

Context

Run on the first day. A segue introducing the big ideas for

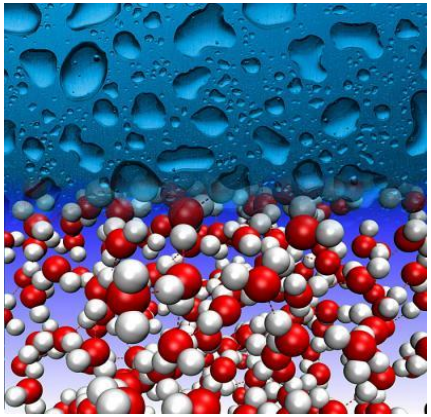
Chemistry 211
Structure & Bonding

Lecture
120 students
Laboratory
14 students max

Assessments
3 in-class assignments
term test
final exam
5 traditional experiments
5 inquiry based activities

Conceptual Big Ideas
- *Atoms*
- *Chemical Species*
- *Collections of Chemical Species*

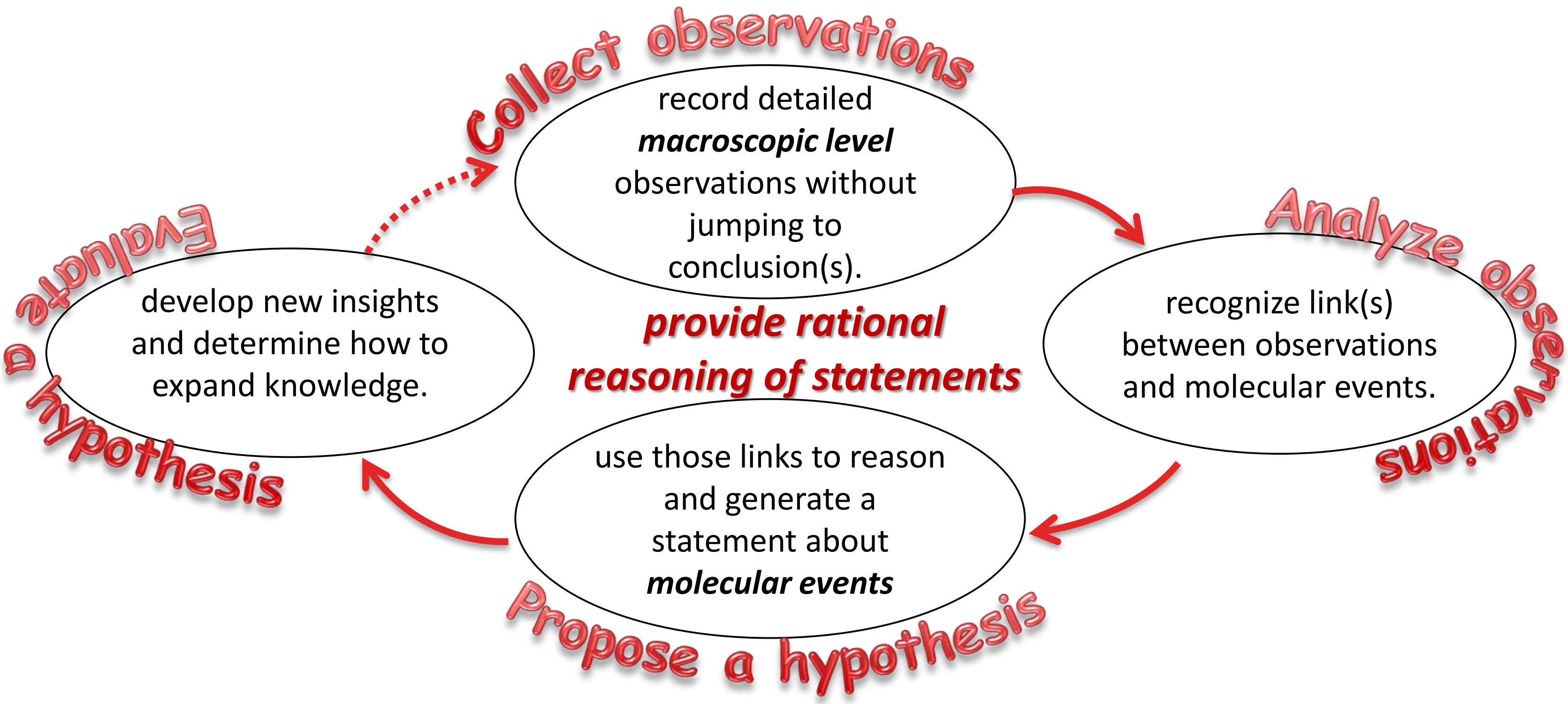
O. Akin-Ojo D. Barczak



Overarching Big Idea
Critical Thinking

Context

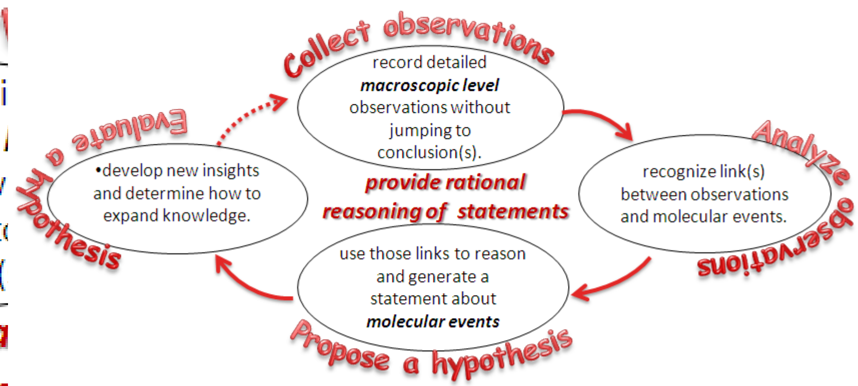
A student thinking critically in chemistry will:



Adapted from:
Dr. Rebecca W. Keller Gravitas Publications, 2008 **Chemistry 1A Chemistry Connects to Critical Thinking**
Access research network Real Science 4 Kids, Kogs for Kids,

Why improve students' questioning?

- The elements of the critical thinking cycle were integrated into the experiential activities in all course components but by the end of an academic term students still struggled to demonstrate these elements.



Observation: All elements of the cycle require students to ask good and relevant questions.

Hypothesis: As students ability to question improves, their ability to analyze observations and come up with hypotheses should improve.

Context

What does the Literature say?

If students are to learn to think, they should be encouraged to ask questions (Mason 2007).

Question Formulation Technique helps students learn how to produce/improve questions, and strategize on how to use them (Rothstein & Santana 2011).

Student-generated questions range from probing for basic information to deeper understanding (Chin & Brown 2002) depending on familiarity with a topic (Scardamalia & Bereiter 1992)

Deeper Questions can be diagnostic of routes through which students seek understanding (Watts & Alsop 1995).

The relation between question generation and construction of conceptual knowledge is sparse (Offerdahl & Montplaisir 2014).

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Pre-Assessment Class of 2014

Back to the First Day's Activity

Relevance to Statement and/or Items	Classification*	STEP 1 % of 682	STEP 2 % of 125
Occurrence/Identity of species	Basic	**16**	**14**
	Deep Understanding	**2**	**0**
Structure/Model of species	Basic	**21**	**41**
	Deep Understanding	**4**	**2**
Naming of species	Basic	**12**	**23**
	Deep Understanding	**1**	**0**
Chemical and Physical Properties of species	Basic	**30**	**38**
	Deep Understanding	**1**	**0**
Safety Issues of species	Basic	**7**	**8**
	Deep Understanding	**0**	**0**
Miscellaneous e.g. History of species, Is this examinable?	Basic	**5**	**0**
	Deep Understanding	**1**	**0**
Not Relevant e.g. Why is Calgary cold?	Basic	**2**	**0**
	Deep Understanding	**~0**	**0**

*Basic - factual or procedural questions that required a single unambiguous answer.

Deep Understanding - questions for comprehension, prediction, anomaly detection, or application that required answers involving reflection and deeper understanding.

Pre-Assessment Class of 2014

Analysis

STEP 1

- A significant number of questions were similar to one another.
- Questions often contained erroneous information, misconceptions or were unclear.
- Students primarily generated relevant questions, which probed at a basic level.

STEP 2

- Many students combined questions to create new questions.
- Deeper level questions disappeared.
- Questions related to structure/bonding, physical properties acknowledged as important.

Post-Assessment Class of 2014

Final Exam

Question production related to the demonstration performed for Part I of the final exam. Students in groups of 25 for demonstration.

<u>Section 1:</u> Student controlled demonstration that involves dropping an Alka-Seltzer tablet into a cylindrical flask containing two layered solutions (bottom: water/dye, top: oil ($C_{16}H_{34}$)).

Accompanying information
Possible reaction (also studied in Experiment 1):

$NaHCO_3(aq) \rightarrow NaOH(aq) + CO_2(g)$

Post-Assessment Class of 2014

Final Exam

Next two sections students did individually (in unknown order). Section 3 was framed as a BONUS question.

Section 2: Exam questions where students must
- critique/compare given observations with their own.
- critique/explain given hypotheses about the molecules involved, and the intermolecular forces.
- calculate the final concentration of NaOH.
- explain the structure and bonding of $NaHCO_3$.

Section 3: Students asked for question production.

PROMPT: **Write down up to 3 *thoughtful* questions about the chemical species involved in this demonstration. The answers to those questions should allow a student to better understand the demonstration.**

Post-Assessment Class of 2014

Analysis

Total of 115 student-generated questions assessed*	% yes
Question is *thoughtful* (dealt with relevant aspects of demonstration).	**100**
Question addresses a chemical species directly involved.	**89**
Question is relevant to understanding the reaction.	**21**
Question is relevant to understanding what was seen.	**61**
Question is more for further inquiry rather than understanding.	**34**

* Sometimes questions dealt with only the reaction, sometimes only about what was seen, sometimes both.

- Questions were thoughtful.
- Significant number addressed concepts rather than chemical species
- Most preferred to deal with understanding of what was seen versus what was proposed to be occurring.
- Significant number wanted to further their own understanding.

Conclusions

Data Collected Generated the Research Question

How should experiential activities be structured and assessed to best introduce the importance of, and help students develop, questioning skills?

Future Considerations:

Activities should

- have students reflect on
  - the importance of what is desired from question prompts.
  - the need for both good and relevant questions.
  - the difference between, and importance of questioning for basic information or for deeper understanding.
- increase the number of expectations in question prompts and/or question selection as the term progresses.

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Time for discussion!

Acknowledgements

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You!