Adapting a Methodology for Documenting Collective Growth to an Undergraduate Physical Chemistry Class

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Documenting Classroom Practice

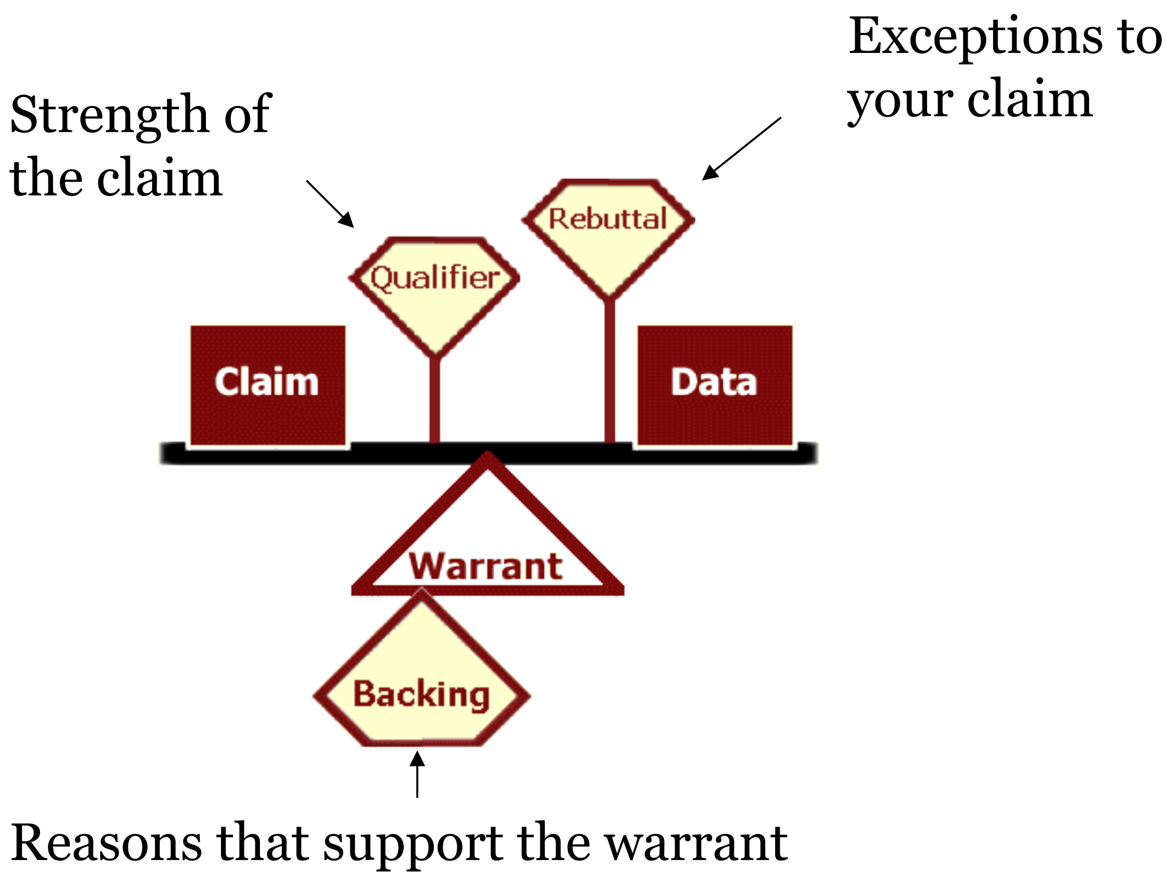
- Establish how communities of learners establish ideas
  - Growth of ideas
  - Normative ways of reasoning

Analysis of student interactions in Physical Chemistry - Goals

- To develop and adapt Toulmin analysis for use in chemistry classrooms to document the collective activity of a classroom community of learners.

- To describe student understandings of mathematical inscriptions used in Physical Chemistry via Toulmin Analysis.

Toulmin argumentation scheme



Toulmin, 1969; Rasmussen & Stephan, 2008

Toulmin analysis requires discourse

- Use POGIL (Process Oriented Guided Inquiry Learning) classrooms where the physical chemistry curriculum encourages students to explore data, mathematics, and the physical meaning of mathematics.

A POGIL Classroom

- uses guided inquiry
  - activities focus on core concepts and encourage a deep understanding of the course material while developing higher-order thinking skills.
- students work in small groups
- instructor serves as facilitator, observing and addressing individual and classroom-wide needs.

Spencer & Moog, 2008

Two levels of analysis

- Small Group Discussion
  - Focused on one target group
- Whole Class Discussion
  - Reporting out of small group discussion
  - Elaboration of concepts by instructor

3-Phase Methodology

- Phase I
  - Analyzing class transcripts for argumentation schemes
  - Creation of argumentation logs
- Phase II
  - Look across multiple class sessions to see what ideas expressed in the arguments become part of the group's normative ways of reasoning.
- Phase III
  - Take the list of as-if-shared ideas and organize them according to the general activity in which the students were engaged when these ideas emerged and became established.

What functions "as if shared"

- Criterion 1 - When the backings and/or warrants for a particular claim drop off
- Criterion 2 - When any of the four parts of an argument (the data, warrant, claim, or backing) shifts position within subsequent arguments.

Establishing Classroom Practice

- Ideas that function as-if-shared are grouped into clusters of related ideas
- Each cluster is then given a theme that indicates the common thread
- Each of these themed clusters is referred to as a classroom disciplinary practice

Adapting the methodology – the setup

- Undergraduate POGIL physical chemistry class
- 5 week unit on thermodynamics
- Created transcripts of each class session
- Used Toulmin's model to create sequence of argumentation schemes

WCD Data Example

Students were provided the question prompt below:

Consider one mole samples of Ne and N_2 at the same temperature, T. Equal amounts of heat are added to each sample under otherwise identical conditions.

Predict whether the final temperature of the two samples will be the same or different. If different, predict which will have the higher final temperature. Explain clearly.

POGIL ChemActivity T4 (Heat Capacity)
Critical Thinking Question 2
(Spencer, Moog, & Farrell, 2004)

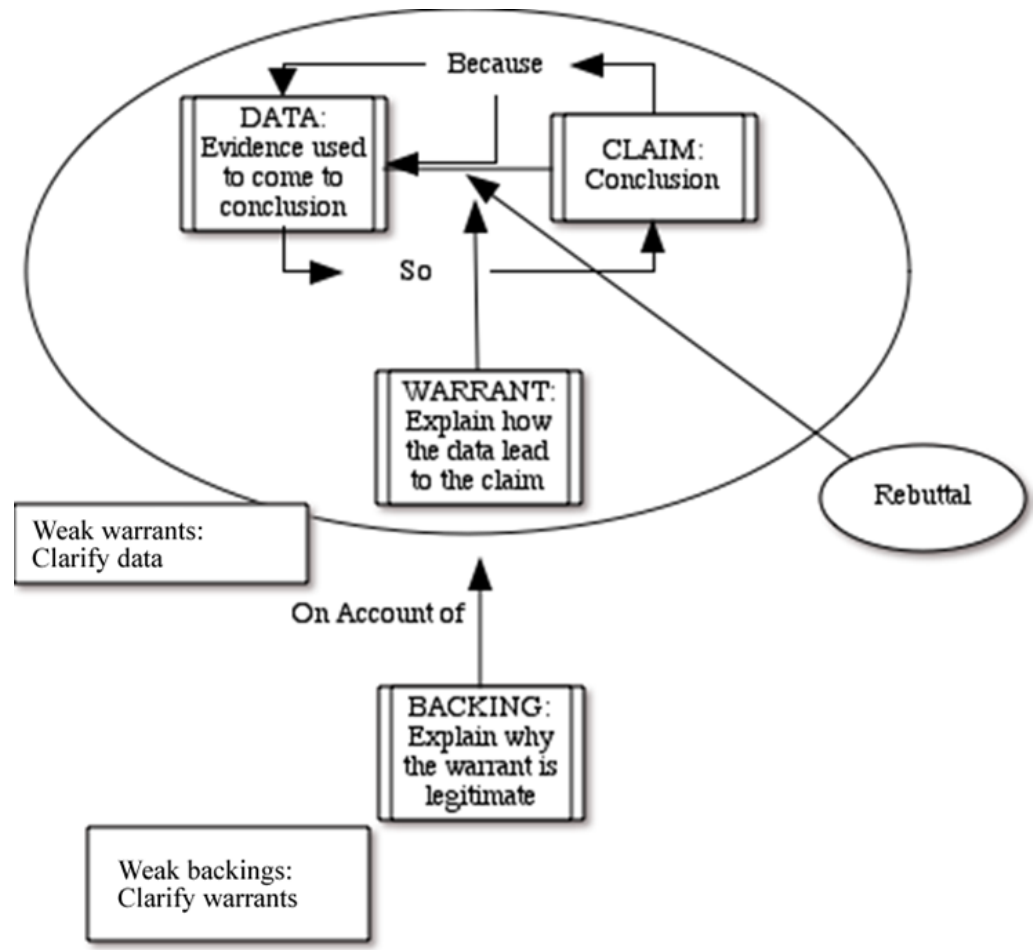
Video

Whole Class Discussion

Instructor:	Any one want to venture a reason why they're gonna be different?
B:	We said because the N_2 is gonna be bigger and take more heat to move. It would be like the mass will be larger....
Instructor:	No, so it's not just size, cause those are different sizes. What is it that nitrogen has that neon doesn't?
H:	It has rotation.
Instructor:	It has rotations. Cause here when we were talking about kinetic energy, what are, what types of motion we're talking about?...
H:	Translation.
Instructor:	We're talking about translational motion... So when I look at N_2, it has a bond, so it can rotate. What else can it do?
Multiple Students:	Vibrate.
Instructor:	And it can vibrate. So I look at N_2, it can take some of that q [heat energy] and put it into rotational motion and vibrational motion...

Creating Argumentation Schemes

- Had to carefully define "data"
- Look for key phrases



Whole Class Argument Log

Argument 1	
Claim	Neon and nitrogen will have two different temperatures even if the same amount of energy is added (Group)
Data	N_2 is bigger (B)
Warrant	Bigger molecules take more heat to move (B)
Rebuttal	The bigger the molecule doesn't have to do with the amount of energy (Instructor) [rebuttal to the warrant]
Argument 2	
Claim	Nitrogen can rotate and neon can't (Instructor/H)
Data	Nitrogen has a bond (Instructor)
Argument 3	
Claim	Nitrogen has a lower temperature than neon (Instructor)
Data	It can vibrate and rotate [and neon can't] (Instructor/Students)
Warrant	Some of the heat energy can be put into rotational and vibrational motion (Instructor)
Backing	Only the translational energy is kinetic energy (Instructor/H)

Adapting the methodology

- Undergraduate POGIL physical chemistry class
- 5 week unit on thermodynamics
- Created transcripts of each class session
- Used Toulmin's model to create sequence of argumentation schemes
- Looked for criteria 1 (warrants/backings drop off) and 2 (parts of the argument shift)

Example of Criterion 2

Argument 1	***(2/16)***
Claim	Gas has the most entropy (multiple students)
Data	There aren't any restrictions on where to put the gas molecules (instructor)
Warrant	It has the least interactions (L/H)
Argument 2	***(2/23)***
Claim	[illegible]rS will be positive (B)
Data 1	*The sum of the products would be greater than the sum of the reactants (B)*
Data 2	The reaction is going from solids to gases (B)
Warrant	Gases have more entropy than solids (B/Instructor)

Need for adaptations

- Structure of POGIL materials created an "artificial" framework for reasoning
  - Some questions provide "data" and ask for claim (and sometimes warrant)
  - Some questions provide "claim" and ask for data (and sometimes warrant)
  - Some questions provide "claim" and "data" and ask for warrant.
  - Request for backings is typically missing in questions.

Need for adaptation to phase II

- Structure of activities proved prohibitive to seeing criterion 1 (drop off of warrants/ backings)
- See some evidence of criterion 2 (parts of argument shift)
- **Noticed repeated use of particular ideas as either data or warrants**

Entropy - 2/16/09

Claim: Liquids are in between (Instructor)

Data: *They're moving around a little bit, but not as far as in gases* (M/Instructor)

Warrant: *They can't just go moving off, we still have forces and interactions*. (Instructor)

Entropy changes as a function of temperature – 2/18/09

Claim: Enthalpy of reaction is positive for the melting of ice (Textbook/Instructor

Data: *Because it's going from a solid to a liquid* (Z)

Warrant1: going from a solid to a liquid requires heat because *it* [the solid] *breaks down* (Z)

Warrant2: *We put energy in to go from solid to the liquid so we give the molecules enough energy to move around* (Instructor)

Backing: *Liquids are a more high entropy state than solids are* (Instructor)
[Backing comes in as a response to some misconceptions involving "breaking bonds" related to warrant2]

Third Law of Thermodynamics – 2/20/09

Claim: All materials must be solid at absolute zero (Text)

Data: *There is no motion* (A)

Warrant 1: *The way its compact* (A)

Rebuttal 1: *ok you're sure dancing around it* (Instructor)

Warrant 2: *There's no room to move* (A)

Rebuttal 2: *It doesn't have to do with space available* (Instructor)

Warrant 3: *the particles move in a crystal structure* (T)

New Criterion

- Criterion 3 – An idea functions “as if shared” when the same concept is used as a data/warrant for different claims on different days.

Establishing Classroom practice

- Noticed common themes for explanations – another way to document classroom practice

Heat Capacity - **2/11**

Claim: The temperature of the system increases if energy is absorbed. (B)

Data: *Kinetic energy is increasing* (B)

Warrant: *Temperature is a measure of kinetic energy* (B)

Third Law of Thermodynamics - 2/20

Claim: The entropy of the system increases as T increases (Text)

Data: The T is raised above zero Kelvin. (Text)

Warrant: Because if you increase the T then things can move again they have motion (J)

Backing 1: It increases the kinetic energy (M)

Backing 2: *Causes more disorder* (M)

Classroom Practices

- Reasoning using phase states
- Reasoning using the relationship between temperature and kinetic energy.
- Reasoning using the relationship between the number of bonds and possible energy modes
- Reasoning about spontaneous processes
- Reasoning about equilibrium processes

Analysis Provides Insights

- into what is happening in the classroom
- into student understanding
- into structure of activities

Facilitation leads to classroom culture of reasoning

- C: So we're saying the gas is less, the molar heat capacity of the gas is less than the water that's a liquid?
- A: Yes. I dunno, that's what makes sense to me but probably..
- B: So what's our reasoning behind that? Cause it's in gas form that…

Insights into student understanding

Claim: All entropies are positive (Instructor/ Text)

Data: Tables of entropies in the text (Instructor)

Warrant: *If it's negative it's not spontaneous (A)*

Rebuttal: *I thought entropy could be spontaneous or non-spontaneous* (M)

Backing: The assumption in the back of the book is that the reaction is spontaneous (A)

Insights into materials

- Portions of activities that focus on deriving equations result in weak argumentation patterns
- Future analysis will focus on characteristics of materials that result in rich argumentation vs poor argumentation

Future work

- Finish coding small group discussions
- Compare practice/learning between small group discussion and whole class discussion
- Expand study to include additional classrooms
- Look at impact of curricular modifications based on initial Toulmin analysis

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