A Planning Framework Employing the Cognitive Tools of Romantic Understanding

What's the Matter? States and Properties of Matter
Grades 6 - 7
By Lindsay Zebrowski

1. Identifying "heroic" qualities
What heroic human qualities are central to the topic? What emotional images do they evoke? What within the topic can best evoke wonder?

Scientific Curiosity – What happens when ___? What is ___ made of?

The heroic quality central to this topic is curiosity. A secondary quality is persistence. The heroic figures behind this topic were driven by their curiosity and persisted relentlessly in their quest for answers to big questions about the nature of things. This unit will investigate important discoveries that led to shifts in widely-held scientific beliefs and attempt to replicate some of the experiments conducted by key figures. The Scientific method will be used to tap into the students' natural curiosity as they pursue answers to their own theories on "how things work" and "what everything is made of".

2. Shaping the lesson or unit
Teaching shares some features with news reporting. Just as the reporter's aim is to select and shape events to bring out clearly their meaning and emotional importance for readers or listeners, so your aim as a teacher is to present your topic in a way that engages the emotions and imaginations of your students. To do so, consider which of the following dimensions of your students' emotional and imaginative lives can be used to shape your lesson or unit—all related to the skills the good reporter works with:

- 2.1. Finding the story or narrative:
What's "the story" on the topic? How can the narrative illustrate the heroic qualities of the topic?

- Leucippus of Miletus, 480 – 420 BC[1] (dates are approximate); "The Father of Atomism"[2]

  The Ionian Gazette
  5th Century BC, Asia Minor
  Local Philosopher Claims Discovery of "Smallest Particle on Earth"
  The students of Abdera Philosophic College will have no trouble filling out their course evaluations this semester. Their instructor, Leucippus of Miletus, claims to have made history today with a simple block of wood. The details of the experiment are secondhand as Leucippus, a notorious recluse, declined all our requests for an interview. Top student Democritus, described by classmates as the quintessential "teacher's pet", did allow us access to his class notes. The class was challenged to repeatedly split an ordinary log in half until they reached a fraction of the log no longer divisible. The students were baffled, but compliant, and eventually reached a point where they were no longer able to split the pieces any further. They turned expectantly to their teacher, eager to hear the explanation for this seemingly mundane task. This experiment, Leucippus told them, was first-hand proof that all things consist of a massive but finite quantity of indivisible particles – which he has dubbed "atoms". Naturally, student reaction was swift and in a few cases, violent, as these claims fly directly in the face

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[1] http://www-history.mcs.st-and.ac.uk/Biographies/Leucippus.html;
[2] http://www.britannica.com/EBchecked/topic/337658/Leucippus; http://www.3rd1000.com/history/ancients.htm

of the philosophic community's widely held monistic beliefs about the universe[3]. One expert (who declined to give his name) stated outright that Leucippus was "clearly delusional" and that "Parmenides must be turning over in his grave – everyone knows you can divide anything forever if you simply design a finer splitting tool". How far Leucippus plans to pursue this radical theory remains to be seen, but we do know he will have very little help on the journey – only Democritus plans to return to class tomorrow, while his peers are busy seeking more "traditional" mentors to resume their studies with.

- Read the narrative to students as if it were a "current events" piece from the local newspaper
- Have students listen to the narration from this video[4] ("Proof the earth is flat and not round")
- Give students chunks of clay to repeatedly divide in half with their rulers

The "news story" narrative on Leucippus, the flat earth video, and the clay experiment are designed create a conflicting sense of curiosity and skepticism in the students. Students will begin to understand the challenges facing Leucippus whose theory of atomism was extremely radical in his time. Thanks to the skepticism of contemporaries like Aristotle and Plato it would be 2000 years before the ideas Leucippus and his student Democritus presented would be widely accepted. The "flat earth" video is a tongue-in-cheek representation of what it might feel like to listen to someone presenting a theory that challenges widely held beliefs about what is "true" and "known". By replicating Leucippus' "wood experiment" with clay, the students can be introduced to the reasonable but flawed logic behind the critics' argument that you simply need a finer tool. Students can be prompted to think about how they might continue dividing the clay once their ruler is no longer suited for the job (e.g. if they were given microscopes and fishing lines or wires.) Together, these activities will begin to highlight the curiosity that drives a scientist and the persistence needed to pursue radical ideas. Students can then be introduced to the scientists that continued the work of Leucippus and Democritus centuries later and established what we now "know" about the properties and states of matter. Students could also be challenged to think about what we "know" that may not be true.

- **Scientists as Pioneers** –Here teachers can emphasize that the science of matter is a process of discovery rather than invention. The journey begins in ancient Greece with philosophers debating the significance of the four humors, particularly water and earth – precursory versions of "solids" and "liquids". Later pioneers (in the 19th and early 20th centuries) include Antoine Lavoisier, Henry Cavendish, and Robert Boyle, whose work with gases and chemical composition paved the way for John Dalton's revival of the atomic theories left behind by Leucippus and Democritus centuries earlier. The pioneers who followed in Dalton's footsteps would continue refining the theory and establish distinctions between the different states of matter. This journey of discovery is ongoing – modern scientist continue to press into new territory – and here we venture into the realm of quantum states (plasma and condensates) beyond the realm of this unit.

- 2.2. Finding extremes and limits:

What aspects of the topic expose extremes of experience or limits of reality?
What is most exotic, bizarre or strange about the topic?

- **Is there an ultimate, indivisible unit of matter?** Our investigation of matter begins with Leucippus' and Democritus' quest for the smallest particle. Students can easily observe the changes of state that water goes through when it is heated and cooled. **This video[5]** and **also this one[6]** can be used to easily

[3] http://en.wikipedia.org/wiki/Monism
[4] http://www.youtube.com/watch?v=ul8Ik7MQqr0
[5] http://www.harcourtschool.com/activity/states_of_matter/molecules.swf

illustrate what is happening at the molecular level and spark students' curiosity about what is happening in the world beyond what the naked eye can perceive.

- **Did you know??** – Water is the only substance that occurs naturally on Earth in all three physical states of matter – solid, liquid, and gas.

- Once students have been introduced to the relationship between temperature and states of matter they could be asked to research materials with the highest and lowest boiling and freezing points. What is the largest solid object on Earth? The smallest? Students may come up with examples such as an elephant or a house for the biggest solids and ants or pebbles for the smallest. Challenge them to think about mountains, skyscrapers, ships, grains of sand, dust, and germs[7]. What is in the air that we cannot see?

- After they have gained an understanding of states of matter students can move on to other properties of different substances. They may investigate the bounciest, stretchiest, hardest, softest, stickiest, most viscous, or most corrosive materials, and other properties. (E.g. diamonds, the hardest material, can be used to cut glass).

- **Polymers**: This simple experiment[8] allows students to produce a material (oobleck) that can behave both as a solid and as a liquid. This second video is a clip of the same scientist on an episode of *Ellen* with an entire tank of oobleck and a volunteer "walking on water". Other "oddities": solids that flow or that you can pour like a liquid – tar, sand, sugar

- 2.3. Finding connections to human hopes, fears, and passions:
To what human hopes, fears, and passions does the topic connect? What ideals and/or challenges to conventions are evident in the content? Through what human emotions can students access the topic?

- **Curiosity & Persistence vs. Fear of the Unknown & Failure:** The opening narrative and initial activities are designed to spark curiosity while also exposing students to the idea of challenging widely-held beliefs and venturing into the realm of the unknown. When a scientist conducts an experiment they form a hypothesis – they have expectations about what will happen. It is not a failure if something unexpected happens – some of the greatest discoveries are made as a result of a supposed "mistake"[9]. Students are accustomed to operating under the assumption that the teacher (or the textbook) has "the right answers". They will be excited by the freedom inherent in searching for "any" answer as opposed to the "correct" answer.

  Quotes to share with students for illustrating this point:

  • "Negative results are just what I want. They're just as valuable to me as positive results. I can never find the thing that does the job best until I find the ones that don't." --- **Thomas A. Edison**

  • "Anyone who has never made a mistake has never tried anything new."--- **Albert Einstein**

  • "Science, my lad, is made up of mistakes, but they are mistakes which it is useful to make, because they lead

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[6] http://www.iknowthat.com/ScienceIllustrations/matter/science_desk.swf
[7] Pan Canadian Science Place (2004). *Matter, Matter Everywhere*: *Teacher's Guide, BC Edition*. Scholastic Canada Ltd. Toronto, Ontario. p. 21.
[8] http://www.youtube.com/watch?v=idCFb3DqWkk; http://www.youtube.com/watch?v=RUMX_b_m3Js&feature=relmfu
[9] http://science.discovery.com/brink/top-ten/accidental-inventions/inventions.html;

little by little to the truth." --- **Jules Verne**

• "Mistakes are the portals of discovery."----**James Joyce**

- **Humanization of Meaning:** This site[10] has a collection of interviews with real chemists by "Meg A. Mole – future chemist" – a goofy little character created by the American Chemistry Society to act as "spokesperson" on their websites for kids. Students will get to read about how real scientists apply their chemistry knowledge in a variety of fields. Knowing the properties of different matter is applied when designing tools and objects. Students can be challenged to think of how the properties of a material might translate into use – e.g. rubber is water repellent – use it to make raincoats. Glue is sticky – use it as an adhesive.

- 2.4. Employing additional cognitive tools of Romantic understanding:
What kinds of activities might you design to deploy other tools in your students' cognitive toolkits? Consider the following:

• **Collections and hobbies:** *What parts of the topic can students explore in exhaustive detail? What activity might engage students in learning everything they can about some aspect of the topic?*

- States of Matter: how many different materials are there on Earth? Which materials naturally occur in each physical state – solid, liquid, or gas? What would it take for a particular material to change from its natural state?

- Scavenger Hunt: what solids, liquids, and gases are there in the classroom/school/student's home/local community

- The Periodic Table of Elements – a highly ingenious device created to organize the basic "materials" that everything is made of. Here[11] is a kid-friendly version.

• **Change of context:** *What kinds of activities could change the context in the classroom? How might drama or role-play be employed or how might students engage the body's senses in learning?*

- Act like an Atom: Ask students to think about how people and animals act when they are cold (slow down, feel lethargic, hibernate, huddle for warmth). Draw this comparison to how atoms behave – when "cold" they move slowly and are packed tightly together; as they heat up they move more quickly and are spread out. ☺

- Experimenting/the Scientific Method: The "Observations" portion of the scientific method requires students to engage with their senses and describe what they see, hear, feel, and sometimes smell or taste. Students can bring in a large white button-down shirt to wear as a "lab coat" during experiments.

• **The literate eye:** *How could graphs, lists, flowcharts or other visual formats be employed in learning about the topic?*

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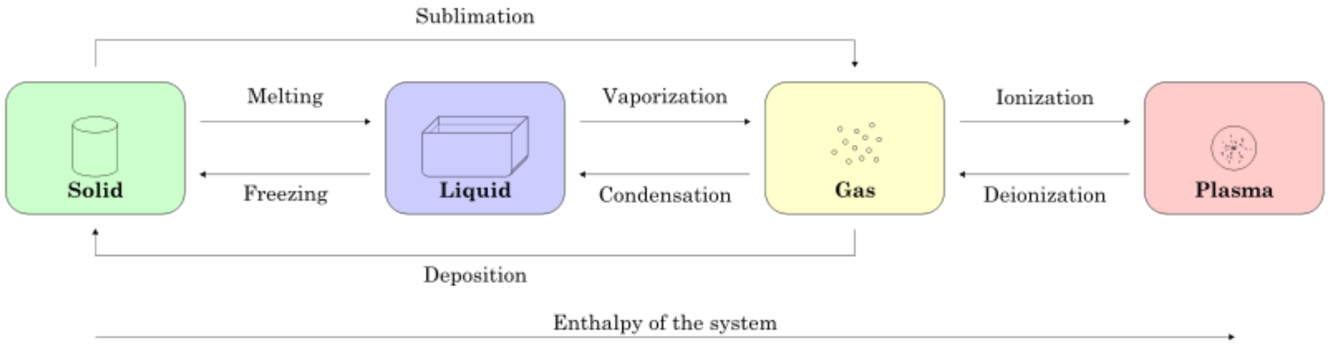
10 http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_SUPERARTICLE&node_id=906&use_sec=false&sec_url_var=region1&__uuid=39809a69-7c53-43cd-839f-a6643c04210f

11 http://elements.wlonk.com/Elements_Pics+Words_11x8.5.pdf

States of Matter:



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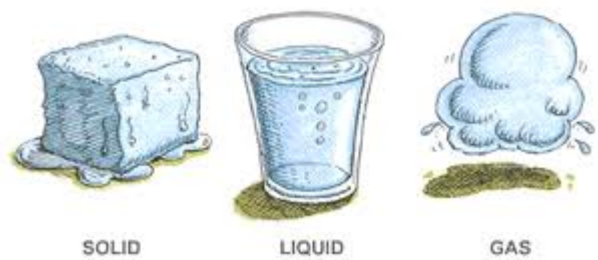

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- The Periodic Table of Elements
- Lists of materials found naturally in each physical state
- A timeline of important discoveries in chemistry and physics

• **The sense of wonder:** *What kind of activity might evoke students' sense of wonder? How could you use that sense of wonder to draw students forward in thinking about further dimensions of the topic?*

- Provoke students' scientific curiosity through experimentation – what happens when ___? (e.g. – dissolve salt in water – to the students the salt seems to "disappear". Then allow the water to evaporate and the salt "reappears". A similar experiment can be done with sugar water – suspend a string in the solution to make rock candy. Students can make ice cream with plastic bags or coffee cans with cream, sugar, vanilla, rock salt and ice.)

• **Embryonic tools of philosophic understanding:** *Consider how to frame the topic in terms of a general idea or theory. How can students begin to move from the particular aspects of what they have been learning to a more general explanation? How can students' sense of agency be engaged?*

- **Ethical experimentation:** Draw students attention to the fact that further experimentation with atoms led to "splitting the atom" and the discoveries in nuclear fission and radioactivity that resulted in the creation of the atomic bomb. Ask students to consider the ethical implications of scientific exploration. What happens when scientists are busy wondering "can we ___?" without asking "should we ____?" Whose responsibility is it to monitor what is being discovered?

- 2.5. Drawing on tools of previous kinds of understanding:

[12] http://1.bp.blogspot.com/-d4cIEEeeVck/T36Dixhpt1I/AAAAAAAAF_o/X4PHOdRX-dw/s1600/Science-Physics_Matter-States-Transitions-Explained-Solid-Liquid-Gas-Plasma-Omni.png
[13] https://encrypted-tbn3.gstatic.com/images?q=tbn:ANd9GcThTT-_FSCsKpnYv6-FG0J-QuPg8X-PD69r6EjOTx1Y6Xvdpj6-

- **Somatic understanding -** *How might students use some of the toolkit of Somatic Understanding in learning the topic? How might their senses, emotions, humor, musicality, and so on, be deployed?*

  - **Expectation & Satisfaction** is inherent in the Scientific Process. Scientists, driven by their natural curiosity about the world, conduct experiments with expectations about the outcome. They either receive satisfaction when their expectations are met and their predictions confirmed, or they encounter **Incongruities** that require further experimentation.

  - Also key to the Scientific Process is **Sensory Observation**. Students must engage with their senses, record what they see, hear, feel, smell, and taste as observations. Curiosity provides the **emotional engagement** as students attempt to explain what they observed and justify their conclusions.

- **Mythic understanding –** *How might students use some of the toolkit of Mythic Understanding in learning the topic? How might abstract and affective binary oppositions, metaphor, vivid mental imagery, puzzles and sense of mystery, and so on, be deployed?*

  - **Binary Opposites:** risk taking and safety – driven by their curiosity, scientists push past fear of the unknown, skepticism, fear of failure, and other challenges in the pursuit of knowledge. Leucippus and Democritus were proposing a theory that was in radical opposition to the widely-held beliefs of their time. Another example to use with students - Marie Curie's death from radiation poisoning.

  - **Mystery and Puzzles:** Leucippus and Democritus were seeking answers to the "ultimate mystery" – that is, a guiding theory to explain the nature of the universe and everything in it. With each new discovery the scientists behind what we know about properties and states of matter refined their questions and sought answers to new mysteries. It should be emphasized that scientists never consider their work "finished" simply because one mystery has been solved. While students are only expected to gain a foundation in the three basic states of matter – solids, liquids, and gases, - some basic facts on plasma and Bose-Einstein condensates[14] can be introduced to emphasize the importance of continued studies.

    Students could also be challenged to invent riddles for the different states of matter or for different materials, based on their properties.

    Example:
    "Come one, come all, and guess my name.
    I have three forms, but I'm still the same.
    In solid form I'm smooth and cold.
    In liquid form I'm hard to hold.
    When you feel dry, I'm good to drink.
    If you want to skate, I make the rink.
    I'm tough to see when I'm a gas.
    But even so, I still have mass.
    In all the world, I'm always found
    Above, below, and on the ground."[15]

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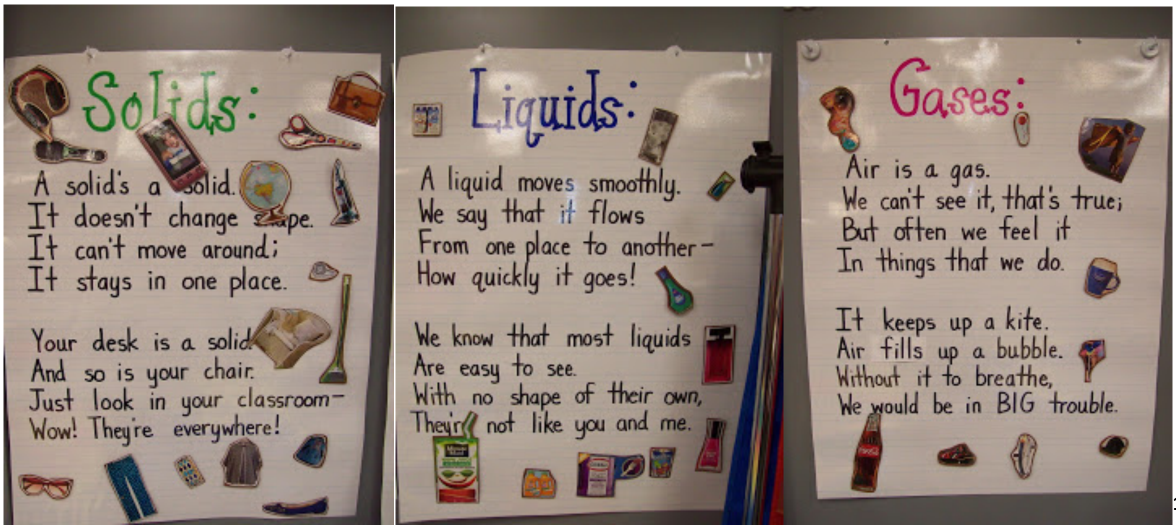
[14] A good source of "student friendly" information: http://www.chem4kids.com/files/matter_states.html

[15] Pan Canadian Science Place (2004). *Matter, Matter Everywhere*: *Teacher's Guide, BC Edition*. Scholastic Canada Ltd. Toronto, Ontario. p. 64.

- **Rhyme and Rhythm:** poems about the three states – (from blog in footnote)



[16]

- **Jokes and Humour:** Similar to their "riddle" challenge, once students have gained enough knowledge about states and properties of matter they may begin to play with their knowledge to create jokes. Some terrible examples:
  Q: What's brown and sticky?
  A: A stick.

  Q: What did Leucippus say to the people who thought his theory was crazy?
  A: Let me atom!

  Q: What happens when electrons lose their energy?
  A: They get Bohr'ed.[17]

  Groooaaaan.

3. Resources

What resources can you use to learn more about the topic and to shape your story? What resources are useful in creating activities?

Pan Canadian Science Place (2004). *Matter, Matter Everywhere*. Scholastic Canada Ltd. Toronto, Ontario. (Includes a set of non-fiction student books and a teacher's guide with accompanying lessons and activities about properties of matter. Intended for grade two, but the activities can be adapted for higher grades).

Historical Background:
http://www-history.mcs.st-and.ac.uk/Biographies/Leucippus.html

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[16] http://mrsterhune.blogspot.ca/search/label/Matter
[17] http://www.juliantrubin.com/physicsjokes.html

http://www.britannica.com/EBchecked/topic/337658/Leucippus
http://www.3rd1000.com/history/ancients.htm
http://en.wikipedia.org/wiki/Monism
http://science.discovery.com/brink/top-ten/accidental-inventions/inventions.html;
Videos
http://www.youtube.com/watch?v=ul8Ik7MQqr0 (proof the earth is flat)
http://www.youtube.com/watch?v=RUMX_b_m3Js&feature=relmfu (Oobleck "walk on water")
Student-Friendly Sites
http://elements.wlonk.com/Elements_Pics+Words_11x8.5.pdf (Periodic Table – kid-friendly version)
http://www.chem4kids.com/files/matter_states.html (Chem4Kids - states of matter info.)
http://tlc.howstuffworks.com/family/science-projects-for-kids-states-of-matter.htm (Science projects, mostly involving water, to help students understand the different states of matter)
http://idahoptv.org/dialogue4kids/season7/matter/facts.cfm (more student-friendly facts)
http://www.harcourtschool.com/activity/states_of_matter/molecules.swf (microscopic view)
http://www.iknowthat.com/ScienceIllustrations/matter/science_desk.swf (microscopic view of water)
http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_TRANSITIONMAIN&node_id=878&use_sec=false&sec_url_var=region1&__uuid=d77d4383-516f-4d81-a023-b8485c4baafb (American Chemical Society's Kid site)
http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_SUPERARTICLE&node_id=906&use_sec=false&sec_url_var=region1&__uuid=1d2bb618-5808-4dfe-ae75-122d6dc778a1 (ACS Kid Site – Meg A. Mole interviews chemists)

4. Conclusion

How does the narrative end? How can one best bring the topic to a satisfactory closure and how can students feel this satisfaction? Alternatively, what new questions can draw students to think more deeply about the topic? How can you extend students' sense of wonder?

By opening with the narrative about Leucippus and Democritus' theory students will likely want the satisfaction of hearing how the theory of atomism was eventually established. Any number of experiments (see "Resources" can be conducted to help demonstrate the basic ideas about the three main states of matter, properties of different materials, and how different materials interact with each other. By engaging the students' scientific curiosity with experiments and highlighting some significant discoveries in chemistry and physics, students should feel some satisfaction about the way these fields of study produce "answers". At the same time, informing students about current research in these fields will help them extend their curiosity beyond the scope of this unit.

5. Evaluation

How can one know that the content has been learned and understood and has engaged and stimulated students' imaginations?

Students will be asked to create visual representations demonstrating their understand of the states of matter – solid, liquid, and gas – by illustrating the changes water goes through as it is heated and cooled. They will be expected to represent what they can observe with the naked eye, as well as explaining what is occurring at the molecular level. Students will also be conducting research on a topic of their choice – exploring a particular state of matter and the materials that are found naturally in that state, or a selected material and its behavior in each state. They will be assessed on their research skills and their ability to demonstrate their learning in a manner of their choice. During classroom activities involving experiments students will be expected to follow the scientific process and produce reports detailing their question, hypothesis, materials, observations, and conclusions.