EDUC 811

# The Mighty Mole – A Love Story

## Enlisting learners' emotions in the quest for understanding

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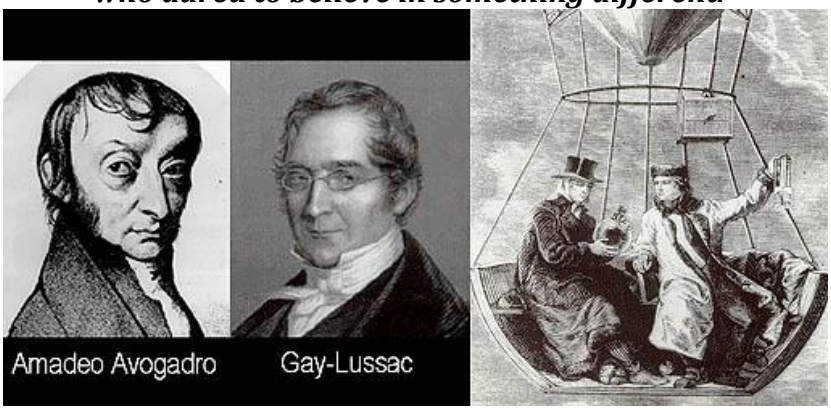
**3/31/2011**

***Dedicated to: Amadeo Avogadro and Joseph Gay-Lussac, who dared to believe in something different.***




*ABSTRACT: This study falls squarely in the 'pragmatism' style of Action Research. I specifically wanted to know if Imaginative Education is effective in helping learners understand well-established science concepts any better than they would without ImEd. I used specific mediational means ('learning engines') that, for me, had a logical fit with the concept I wanted to teach. The purpose of the research was two-fold: to investigate whether it increased emotional engagement and whether there was an increase in understanding.*

*There was a noticeable increase in learner curiosity, enthusiasm and willingness to try. There were a few learners who demonstrated understanding from the first lesson and a few who are not yet at the level of understanding that would produce competence. However, in the middle group, there was a large shift from confusion to confidence and this was borne out by strong performance on the Unit test.*

IF I COULD TURN BACK TIME (by Cher)

Dear 23-year old Judy,

You are about to embark on an interesting, challenging, lifelong career in education. You will meet some fascinating young people and you will be a strong advocate for the best interest of all the young people you encounter. The excitement you feel at the start of your career is warranted as you will definitely make a difference. However, there is always room for improvement, as nothing in this life is perfect. You will make some embarrassing blunders along the way. So I want to tell you the story of an action research I just completed that may save you from making some costly mistakes. My hope is that this will shorten the learning journey for you so that you may offer a more efficient, meaningful educational experience to your learners. This is my story.

I am tired. I'm tired, Judy, of rolling this rock up the hill every year, trying to open up the possibilities of science to whining, snivelling learners who do not love the Mole. I'm tired of trying to stop them saying it is hard to understand, impossible to love and not worthy of their time. It breaks my heart.

Do you remember when you were 14 years old and were first introduced to the Mole? You fell in love immediately and completely. It made so much sense! Suddenly, matter became organized into something you could manipulate predictably. The UNESCO Handbook for Science Teachers (1980) cited Piaget's age-stage development as the reason that you were the only one in your class of 15 girls to understand the concept of the Mole. This highly respected publication stated unequivocally that

> Abstract thinking...is beyond almost all children in primary school and the lower classes of secondary school. If teachers of young children would only realize this,

> they would suffer much less from lack of confidence in their own scientific knowledge. Since so many of the great scientific concepts are abstract, this is why the teacher of young children needs to attend much more to the processes of science than its concepts. (Lowe et al (1980) p. 191)

You were treated as somehow superior, an anomaly among 14 year olds, having acquired abstract reasoning before your peers, who were temporarily still stuck in concrete operational thinking. Pure Piagetian perniciousness! But that was the accepted educational thinking of the day. We all accepted it. Lives were changed because of it – and now those ideas are in serious doubt.

Read Vygotsky! I beg you, read Vygotsky, before it is too late. Vygotsky successfully challenged Piaget's ideas and Piaget recanted some of those ideas long before you were born (Piaget, 1962). Yet we still have Piagetian echoes in the 21st century classroom, as if Vygotsky's brilliance never existed. All your life you will be able to stand apart from the crowd and stand on the shoulders of true giants. Start doing that now, at the start of your career, with the Mole.

A GROOVY KIND OF LOVE (by Phil Collins)

I undertook this action research on the concept of the Mole for two reasons. Firstly, it is the foundation of modern quantitative science and therefore must be mastered by everyone who aspires to a life in science. As the great equalizer, it allows comparison of all forms of matter and therefore, allows for generalizations that would be impossible without it. Secondly, the Mole is that kind of concept that changes the way you think. It gets inside your consciousness and makes connections that would otherwise be difficult to make. The Mole has the power to connect the concrete, observable world with an abstract, unseen reality that we can only imagine. In addition, my action research centred on my classroom

practice because I am convinced that the way I can make impact on the educational system is through my individual action in my classroom. This action research was undertaken to show that teaching the Mole using Imaginative Education principles, can have a powerful impact on learner engagement and learning, and in so doing can become the model for classroom instruction, thereby transforming education from the inside out, both on an individual and on a systemic level. This action research also points to the potential of transforming learners from the inside out, by helping them to access the power of abstract thinking through positive emotions.

When you are well into the sunset years of your teaching career, you will come across an intriguing book by Dr. Kieran Egan called An Imaginative Approach to Teaching, and will feel as if you had finally found your people after a lifetime of feeling like an oddball among your peers. Dr. Egan articulates a Theory of Understanding that feels so right and fits with what your experience confirms. He describes the 5 ways in which humans understand their reality and the mediational means associated with each way of understanding. These are the mediational means I used to teach the Mole concept to determine their efficacy in developing understanding in my learners. (See Appendix 1). It formed the basis of my research question: Is Imaginative Education effective in engaging learners and, in so doing, does it improve their understanding of the Mole Concept?

JUST THE TWO OF US (by Grover Washington Jr.)

The action research was conducted with 4 classes of 86 Chemistry 11 learners in all. The duration of the teaching unit was 3 weeks with 6 periods of 75 minutes each. The learners are generally well behaved and are somewhat curious about Chemistry. They are a

mixed ability group with a variety of reasons for taking the course. These reasons range from 'satisfying the high school science requirement' to 'wanting to see things blow up'. Some want to pursue tertiary studies in science and have aspirations for a career in medicine, engineering or further research. In addition, they are typical teenagers who worry about how they appear to others, have a need to belong, want to please their parents and believe they can change, as well as, have the world. They are wonderful children, mainly from immigrant families, who are the great hope for their family's success in an alien culture.

BABY I LOVE YOUR WAY (by Peter Frampton)

Imaginative Education (or ImEd, as I like to call it) is the brain child of Dr. Kieran Egan, whose seminal book, The Educated Mind, posed a radically different view of how the development of understanding works in the human mind. It is a masterful work that traces human cognitive development, albeit from a Eurocentric point of view. He postulates 33 mediational means through which understanding develops. (See ierg.net). I refer to these mediational means in my work as 'learning engines', because these are the engines of the mind that drive the way we make meaning of our experience. I liken them to the mitochondria of our cells that propel our physical actions. In a similar way, the 'learning engines' of the mind propel the way we understand our interactions with the world. I chose mainly the mediational means from the Romantic framework, while integrating some from the Somatic and Mythic ways of understanding. Towards the end of the study, I incorporated the Philosophic, urging the learners to make generalizations and detach the Mole Concept from the story we had created for it. The overarching theme of the Unit was

that the Mole is a 'superhero', with its 'superpower' being its ability to express commonality among diverse forms of matter. If I were to teach this same concept from a Philosophic framework, I would use the theme of the Mole as the great unifier of all kinds of matter. Science in general presents a challenge to trying to humanize its meaning, as by its very nature, science works to understand the physical world as something independent of humans. In objectifying the world however, we tend to lose much of the 'juiciness' that makes the physical world interesting to us, especially for children. If meaning is purely cognitive, it becomes desiccated and devoid of the richness that emotional engagement brings. Unfortunately, many science lessons can be likened to 'space food' – the nutrients are present but they are devoid of the flavour and richness of texture that water brings to the mix. In personifying the Mole I hoped to engage my learners' emotions in what is often mistakenly stereotyped as an emotionless field of study.

I used a Wiki as an indicator of learner understanding as they generated their own collaborative story of how we learned to love The Mighty Mole. I started the Wiki with a challenge to the learners to create a back story for our superhero. With minimal guidance from me, the story took on a life of its own and provided evidence of deep understanding of the concept which we were learning.

I also used an 'Emo-meter' to make manifest learners' emotions about their learning process as they worked through this concept. It was a grid for learners' self-reporting of their feelings at the end of selected classes. It involved metacognition as learners needed to make a judgement about their comfort level with the concept, as well as take the 'temperature' of their internal environment.

At the end of the unit, we did a traditional test that probed knowledge and understanding of the Mole concept. This took the form of both multiple choice questions and written, problem solving questions.

HERE WE ARE (by Gloria Estefan)

Although many writers acknowledge the Mole as a foundation idea in science, only a few sources offer suggestions about ways to make it more accessible to learners. Padilla and Furio-Mas (2007) make a compelling case for preserving the history and philosophy of the Mole as necessary for meaningful learning. Without these, they contend, learners are merely memorizing facts and details devoid of the significance of what they are learning, especially when it is something abstract. This echoes Egan's call to make the 'story' of a concept the core of teaching. Turner and Peck (2009) identify the issue of engagement as a key component in doing school science better. Two interesting findings in their article are that (1) there is a negative correlation between the prosperity of a country and its young people liking science and (2) "degree of achievement is *negatively* correlated with positive attitudes towards school science" (p. 54). This suggests a strained relationship between learner and science – in other words, learners will do science, but they do not have to love it. Turner and Peck contend that science education robs learners of a "sense of awe" and develops an attitude that school science is "confusing, trivial, depersonalized, irrelevant and decidedly uncool" (p. 55). Thus seeking to engage learners through the narrative of the Mole concept may address both of these concerns.

Another barrier to a deep emotional connection with scientific concepts like the Mole is their abstract, non-linguistic nature. It is hard to love a symbolic construct that

seems devoid of human reality, no matter how useful it is. Gabel (1999) points out that Chemistry functions on three levels – macro, sub-macro (particulate) and symbolic. Learners lose the connection between concepts and their lived experience when Chemistry education centres too much on the symbolic. This action research seeks to bridge that disconnect as learners are invited to access understanding through bodily senses, rhythm & pattern, humour, the literate eye and transcendent human qualities. Imaginative Education seeks the human connection to the non-human world, which has the potential to bring to life scientific concepts like the Mole.

As the debate continues to oscillate among Chemistry educators, some suggest that stripping the Mole concept to its essence would result in effective teaching. Yin and Ochs (2001) propose "a radical shift: strip the concept to its essence. Eschew nonessential facts... One barrier to learner understanding of the mole is the pedantic insistence on burdening the concept with needless detail." One problem I see with this approach, however, is that the detail is what gives the concept its richness and flavour. It was my experience in this action research that learners wanted more detail and asked many questions about the peripheral issues that gave them the depth of understanding about the Mole that they craved. All in all, the literature on teaching the Mole suggests that the state of Chemistry education is unsatisfactory and learners develop many misconceptions that befuddle rather than enlighten.

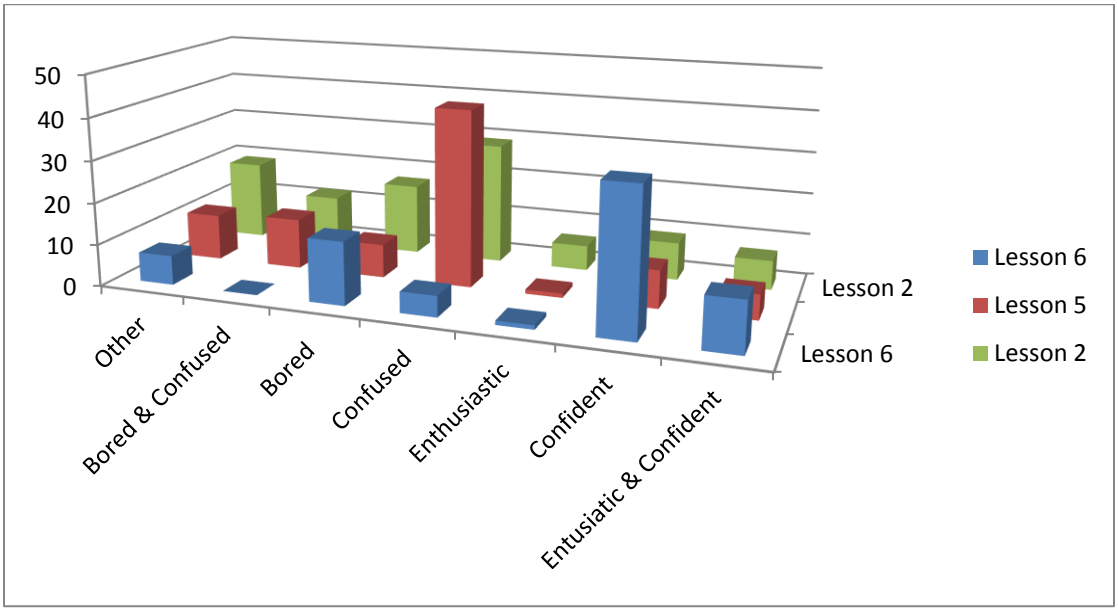
## I DON'T WANNA MISS A THING (by Aerosmith)

The analysis of our Mole experience brought out some interesting insights. The learners reported more engagement, deeper understanding and were able to demonstrate

their understanding on a traditional test. Of the 86 participants in the project, 8 of them did not demonstrate efficacy with this concept. These learners have been underperforming all year and struggle with school in general. There may be other factors that are contributing to their lack of success other than the way concepts are taught.

*(a) Let Love Lead The Way (by Spice Girls)*

The 'Emo-meter' was a chart that learners completed at the end of Lessons 2, 5 and 6, where they each placed a sticker at the emotion that most closely represented what they were feeling. The results were as follows:




Lessons 2, 3, 4: learners reported high levels of confusion but were not frustrated enough to give up. Lesson 4 was a traditional 'cookbook' type lab exercise. Learners were fully engaged in the activity, but reported much frustration with the Lab Report requirement. On a deeper look at the lab, I realized it was too prescriptive and did not allow learners to solve the problem for themselves. However, they persisted with their work of

understanding and by Lesson 5 saw some clarity emerge and then Lesson 6 saw a sudden breakthrough from confusion to confidence. In all 3 'emo-meters', but particularly in the last 'emo-meter' there were 7 learners who placed their stickers in between the identified emotions and reported that they felt that the categories on the chart did not quite match what they were feeling. One learner went so far as to create his own category – 'annoyed'!

*(b) Making Love out of Nothing at All (by Air Supply)*

Did the Wiki induce engagement or did the engagement find voice on the Wiki? I do not know if I can answer that question successfully this time around. I probably have to do this again to fine tune the distinction between what was actually engaging for the learners. I do know that 80 learners registered 150 views on the story page. So although there were only 115 contributions to the story, there were multiple readings of the story. One girl noted that at first she did not understand, but on reading over the story a few times, she finally 'got it'. One learner started a separate discussion page to encourage others to lift the level of the narrative. He had 103 views of his comments with 3 other learners overtly endorsing his comments. The discussion pages generated far more activity than the actual back story page. When the learners were asked to discuss their feelings there were 107 entries and 786 views. The tone of the feelings described were generally hopeful, with comments like "I know what I'm doing most of the time, I just get confused when I'm trying to find the number of particles." being a typical comment.

An eye-opener for me was to discover that the learners understood the concept of the mole far more readily than I anticipated. Their difficulty was really with the constraints of expressing their understanding in a restrictive pre-determined academic format and

language. They seemed to rebel against the desire to write out a formal algorithm of their thinking and they particularly detested units, for some reason. That's an interesting question for further study. Why do learners deem working and units beneath their dignity and an utter waste of their time?

I have a few oddly fascinating learners, who have ministry-designated learning challenges. I find these learners of more interest to me because they often have a unique perspective that enriches classroom discussions and enliven us with thoughts that may not otherwise enter the mainstream area of concern. One such learner, in the first lesson, drew in his book a tiny image of what the Mighty Mole looks like. I complemented him on his drawing and asked him to put it on the Wiki.

Although this was his only contribution to the 'back story', I think it was significant as he was able to articulate a mole as a superhero in a non-linguistic way. His test scores were among the highest in the group and he told me afterwards that he found the test particularly easy. His tone as he reported this to me was one that suggested that I might be losing my 'touch' as the test might not have been challenging enough! He is the same learner that placed his star on the Emo-meter at "Other" because he was "both confident *and* confused!"

*(c) If You Don't Know Me by Now (by Simply Red)*

86 learners participated in the study. 85 learners took the test.

| CLASS | MODE | | MEDIAN | | STANDARD DEVIATION | |
|---|---|---|---|---|---|---|
| | /18 | /14 | /18 | /14 | /18 | /14 |
| 1 – 1 (17learners) | 14 | 13.5 | 12.75 | 11.75 | 4.36 | 2.93 |
| 1 – 2 (20learners) | 11 | 13.5 | 12 | 12.5 | 2.72 | 4.12 |
| 1 – 3 (27learners) | 9 | 13 | 12 | 12 | 3.04 | 2.17 |
| 1 – 4 (22learners) | 12 | 13 | 14 | 13 | 2.00 | 1.90 |
| TOTAL | 15 | 13.5 | 12.5 | 12.5 | 3.19 | 2.88 |

On first glance it appears that Class 1 – 4 performed better on the test than their peers. On deeper examination, the 22 learners involved in the project were the ones that had been performing at a very high level; the learners in that class who were not performing well simply did not participate in the study. Thus, the marks were skewed to the higher end. The learners in this class were also quite enthusiastic about the study and committed themselves wholeheartedly to personal and group success.

On the other hand, in Class 1 – 3 I had all the learners give permission to participate in the project but they did not participate in the Wiki to the same extent. There was more of an atmosphere of scepticism in this class and less desire to participate as a group. Seeing the mole as a superhero does require a suspension of disbelief, which a significant number

of learners in this class were not willing to do. The atmosphere of whimsy that was present in Class 1 – 4 was definitely absent in this class. One learner went so far as to say that she was already "successful" in her studies and therefore did not need to change her methods. I interpreted this to mean that she is a good test taker earning marks she is happy with and therefore was not inclined to try something new.

VIVA LA VIDA (by Coldplay)

I found myself analyzing my own beliefs and values about science education far more than I did those of the learners, in this action research. I went as far back as to ask why I value science education at all. I rediscovered the joys of rational thought and the internal dialectic that goes on in all of us as we wrestle with the questions of what are our fundamental truths. I changed a significant belief because of this research – I no longer believe that the Mole is, by its very nature, difficult to understand. The prevailing theme in the literature on this topic is that science concepts are difficult because they are abstract. I found the opposite to be true. In using the principles of Imaginative Education to target my lessons at the confluence of emotion and imagination, learners became engaged in both the process and the content. It is difficult to say which was more influential, so when I do this Unit again, I will be more careful to differentiate what is having the greater impact. My observations of learners' efficacy with the concept could be summed up by one young man who looked at me suspiciously and said "It can't be that easy!"

I also found myself convinced on a practical level that Imaginative Education works for the majority of learners in a wide variety of circumstances. Only 8 of the 86 project participants did not develop significant competence in the short time frame given for the

Unit. Perhaps, with more time these learners will be able to develop their fledgling understanding of the Mole concept.

A surprising finding for me was that the thing that learners disliked most about this Unit was the way they were required to demonstrate their understanding. The rigours of a set format for 'working' proved to be too much of a challenge for some. Whereas, they could express their understanding orally, being constrained to a written algorithm developed by someone else, was too much to bear. Some refused to conform to the standard practice but were unable to demonstrate their understanding in any other written format. I find this intriguing and may investigate other ways of ferreting out learner understanding and perhaps develop other formats for written work.

All in all, my findings suggest that this mixed ability, mixed motivation group of learners were engaged and understood the Mole Concept with greater ease than I had previously encountered. There was an energized atmosphere in the class and learners participated enthusiastically, with very few exceptions. It was time well spent for me as well as for the learners.

IMAGINE (by John Lennon)

Children love what they understand. Imagine classrooms all over the world with young minds fully engaged in the work of making meaning about everything under the sun. As teachers, we have the power to engineer that engagement. We also have the privilege to witness the occasions when an individual makes an unforeseen connection. I believe we can make that rare occurrence more commonplace for our learners by trying something different. Imaginative Education comes at classroom experience from a different point of

view, allowing all aspects of human understanding to mingle and merge into a transformative experience both for the individual and for humanity.

Like my heroes, Amadeo Avogadro and Joseph Gay-Lussac, I am willing to try something different in the pursuit of deeper understanding. I may not be prepared to go up 7000 feet in the air in a hot air balloon, as Gay-Lussac did to find the truth, but I am prepared to follow my learners wherever their emotions and imaginations lead them in the pursuit of the 'story' of everything. I believe we have the capacity – now all we need is the willingness.

Oh, by the way, Judy, in your first year of teaching, when you get the urge to throw that chalk at the inattentive learner, don't do it! You will feel like a jerk for the rest of your career if you do. Throw a metaphor at him instead – it may well be all that he needs to become engaged. To be continued...

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*APPENDIX 1: THE MOLE UNIT*

**LESSON 1: THE MOLE AS SUPERHERO**

Romantic – (Change of Context) Dress up as your favourite superhero.

I dressed up in a sweater with Green Lantern, Superman and Robin and played the theme from the Spiderman cartoon as learners entered the room. There was a definite sense of curiosity as the learners entered the classroom. I introduced the mole as the 'spiderman' of units - misunderstood and mistrusted.

Somatic – (Sense of Touch)

Learners were asked to measure flour, sugar and oil by the handful. The Purpose of this was 2-fold. 1. It got learners to feel the things we often don't think of as 'chemical' and 2. To recognize that all handfuls are not created equal – it is not a standard measure.

Mythic – (The oral story)

I told the story of Avogadro and Gay-Lussac's work that led to the concept of the Mole. They were presented as superheroes – scientists as hardcore, seekers willing to do dangerous things to uncover the truth.

Assessment strategy: Contribute to the back story of The Mighty Mole on the Wiki. On the discussion page, explain how you are feeling as you go through the process of understanding the Mole concept.

**LESSON 2: THE MIGHTY MOLE – THE SUPERPOWER EMERGES**

Somatic – Measurement of moles of different substances, using an electronic balance.

Romantic – (Extremes and Limits) Calculating large # of particles and seeing what it looks like in the beaker.

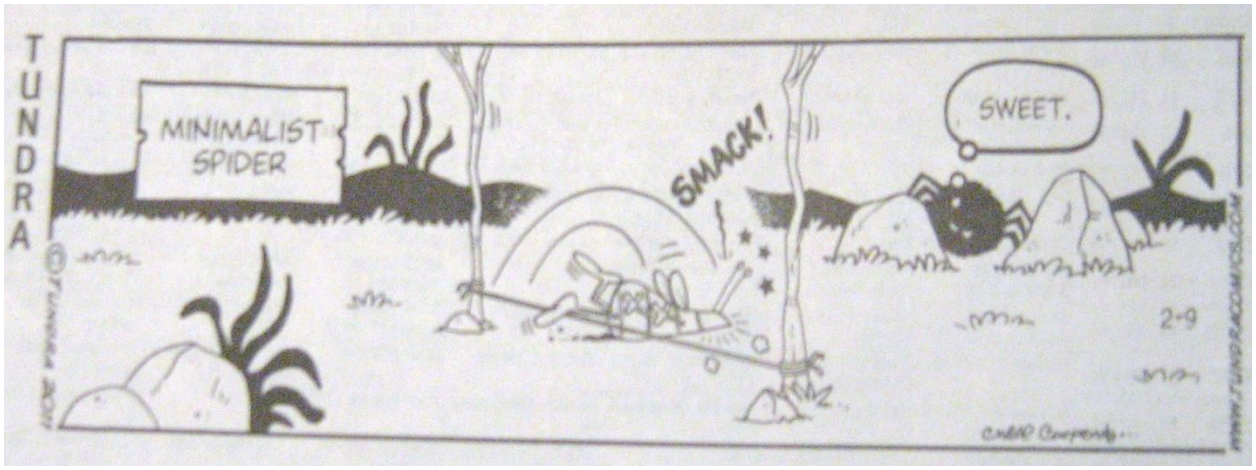
Philosophic – (Making Generalizations) The same number of moles looks about the same, no matter what the substance is.

A large number of particles can fit into a beaker because individual particles are extremely small.

Assessment strategies: The Emo-meter and the Wiki

**LESSON 3: FINDING YOUR OWN SUPERPOWER**

Somatic – (Humour):




Romantic – (Literate eye) Small group practice. Reading questions together and coming up with algorithms to solve problems. Problems with the style of questions. The language distracted the learners from the problem solving methodology.

Assessment strategy: Design a spiderweb to organize the different ways we calculate the mole.

**LESSON 4: LAB - CALCULATE MOLES BY MEASURING MASS (COUNTING BY WEIGHING)**

Learners worked in small groups to calculate the mole ratio of water of crystallization to salt in copper(II) sulphate crystals. This was done by measuring a sample of the hydrate, heating it to produce the anhydrous salt and then comparing the moles of the two, to calculate the moles of water removed. At first, I thought this was a somatic experience, but now I am not so sure.

This lab was a mistake. In retrospect, asking them to follow someone else's algorithm for mole ratios denied them the opportunity of thinking it through for themselves. They had already identified for me in the narrative that thinking the problem through in a step-by-step manner was very effective for them to solve word problems. These traditional cookbook type lab exercises have been discredited repeatedly and I am ashamed that I fell into this trap of thinking this lab would be a useful somatic experience for my learners. Now I realize that what I need to do is rewrite this lab as a quest for a relationship between a salt and its water of crystallization and let the learners come up with their own algorithm.

Assessment strategy – a traditional lab report. Should have done a Vee diagram and allow the learners to form their own conclusions.

**LESSON 5 – MOLARITY: DEMONSTRATION OF THE MAKING OF A STANDARD SOLUTION**

Somatic – (Senses) Seeing the blue copper(II) sulphate crystals disappear into a blue solution.

Mythic – (Humour) Relating the dissolution of a salt to the dissolution of a relationship.

Romantic – (Extremes and Limits) Large moles small moles and everything in-between moles. 1 molar solutions of everything, everywhere are comparable.

I narrated this demonstration as a melodrama about the break-up of a supposedly strong relationship (ionic bond). Water is cast as the interloper that comes between the partners (ions), causing them to drift away from each other and disappear into solution.

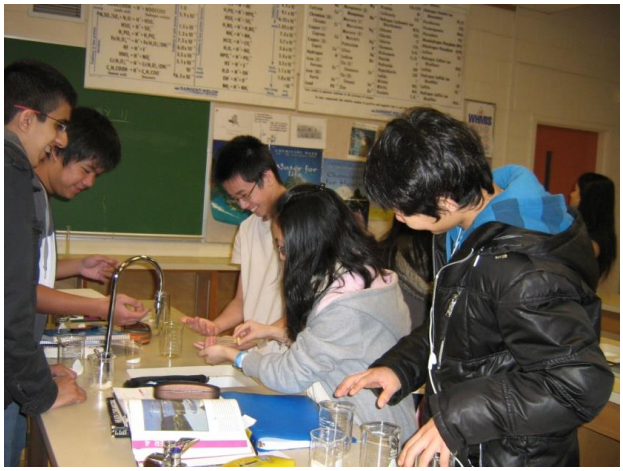
**LESSON 6 – MOLAR GAS VOLUME: MOLES, MOLES EVERYWHERE**

Mythic – (Rhyme & Rhythm) The Mole Song – A summary of the major ideas sung to a familiar tune. About 25 learners rewrote their own versions of the Mole Song.

Emerging philosophic: A useful generalization

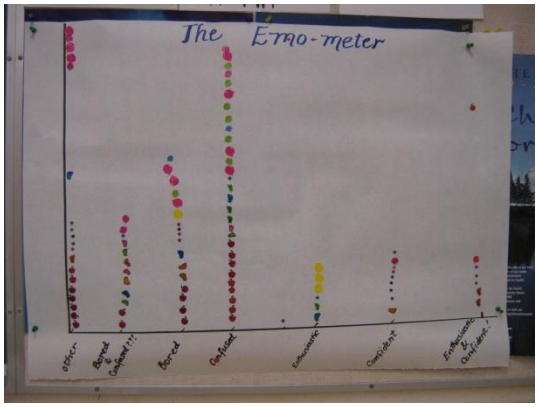
Solids, solutions, gases, elements, compounds can now be compared using the unifier, the mole. Circling back to Avogadro and Gay-Lussac who both independently experimented with gases, we come back to the emerging generalization that all gases, no matter what they are, have $6.02 \times 10^{23}$ molecules. This generalization helps us to optimally predict and weigh out small and large amounts of all different kinds of matter to interact with each other.

*APPENDIX 2:*



Looking decidedly engaged...The ‘face’ emo-meter

Lesson 2

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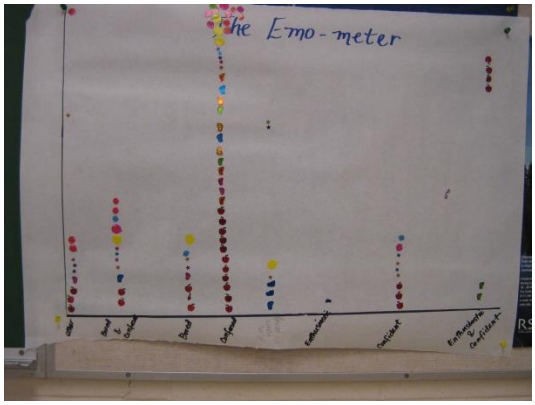
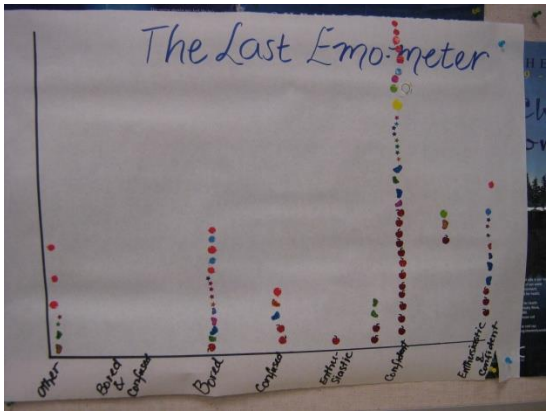



Lesson 6



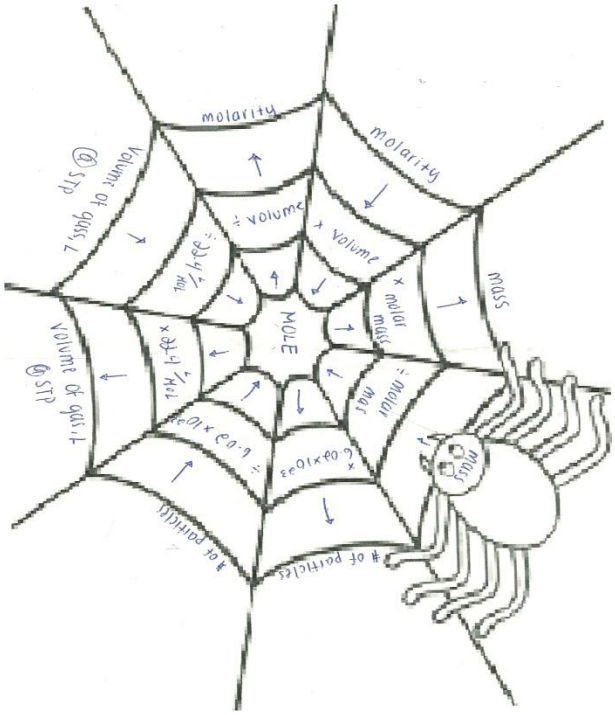
*APPENDIX 3:*

http://mightymole.wikispaces.com/

Created by Ryan Jiang (Class 1 – 2)

Original design and computer graphic by Maxime Deslauriers (Class 1 – 4)

*APPENDIX 4:*




The Spiderweb Created by Jasmin Cruz (Class 1 – 3)