FLOATIES AND SINKIES
FLINKERS AND ARCHIMEDES THINKERS:
EMBODIED WRITING IN GRADE EIGHT SCIENCE CLASS

by

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Abstract

This study has emerged from concerns expressed by science students, educators, and researchers, and from my own teaching experience, that writing in school science often remains disconnected from students' experience, and rarely stimulates further learning. The purpose of this study is to explore the potential of open, expressive writing tasks to illustrate students' understanding of the phenomena of floating and sinking.

A specially selected series of seven explorations in physical properties of matter provide a rich context for Grade Eight students and I, their teacher, to experience and explore this topic. The interconnections between lab explorations and writing in school science, and the interactions in a classroom fostering science inquiry, are central to this study.

A classroom-based story is unraveled from an enactivist perspective. My analysis of students' writing tasks and reflections on learning illuminates possibilities for encouraging personal connections and embodied writing in science class. Students' insights into learning about science and about themselves through expressive ways of writing shape this story.

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Acknowledgements

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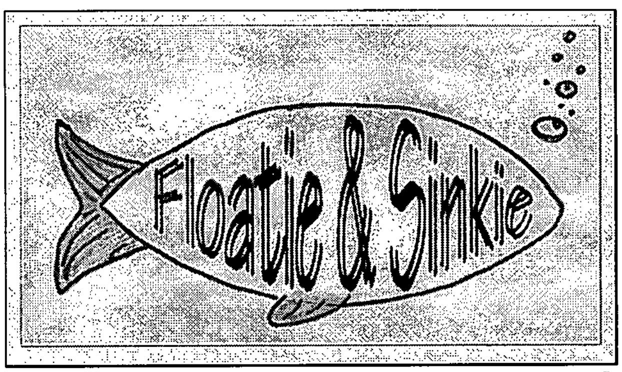
Dedication

The spirit of this writing is dedicated to those who reach out with enthusiasm for learning, passion for living, and a sense of wonder of the physical and natural world around them.



[Kristie]

Part One

INVITATION

If you are a dreamer, come in,
If you are a dreamer, a wisher, a liar,
A hope-er, a pray-er, a magic bean buyer . . .
If you're a pretender, come sit by my fire
For we have some flax-golden tales to spin.
Come in!
Come in!

(Silverstein, 1974, p. 9)

A Story

I would like to tell you a story.

It is a story about how several classes of Grade Eight students and I went on a journey together . . . learning in science, learning about ourselves, and how we expressed our learning and ourselves in writing.

This story came about as I thought deeply about my concerns as a science educator, that have emerged from experiences teaching in science classrooms and from science education literature. To write only an account about concerns in education would not be an inspiring process for me. This story is about how some concerns have been shaped into possibilities, and how the students and I experienced a possibility together. What makes this story an exciting and meaningful one, is that it illustrates how students' creativity and inquisitiveness co-emerged into some wonderful writing in science.

It is a story in the sense that it is told. Told with my senses and hopefully with a sensitive interpretation. What happens in a particular situation depends on who you ask, and what details he or she remembers. I have tried my best to keep these Grade 8 students at the center of my focus as I tell the story. It follows the line of relationships between students and learning as they are situated in an actual classroom space where curiosity, creativity, expressiveness, and risk-taking are supported. This way of being and learning in the Grade Eight classroom mirrors my own pathway in graduate school, as I have explored my own learning and expression in writing.

These students provide the language through which the story flows. Their words in the following pages are always italicized and are preserved in their original form. It is my hope that the students' *written* and *"spoken"* words (as indicated with quotation marks) will encourage their voices to be heard.

The purpose of this study has been for me to respond to students' feelings of disconnectedness from their experiences in school science, and to explore a possibility of what can be done about it. In Tennessee Williams' play, Night of the Iguana (1961), he writes that there are two worlds in which we can dwell, the realistic and the fantastic. Relating this to our science classroom, I think of the realistic as marking, lesson plans, and bells. If educators are only thinking about the realistic, then where is the passion?

This story is about living less in the realistic confines of the classroom, and playing with possibilities of writing, that strive for the world of the fantastic. I wanted to dream of what could be experienced as a learner, and what students would say about this kind of experience. The research questions that serve as a basis for the unraveling of this story are:

1. How do various writing tasks illustrate students' understanding of the phenomena of floating and sinking?

2. What are students' perceptions of their learning as they engage as writers in this way?

The writing of this story is organized into three parts. Part one outlines an orientation to the problem; part two tells of the in-class lab explorations and the early stages of the three writing tasks; and part three discusses the analysis of students' writing tasks and reflections on their learning. Hopefully it will be an exciting and meaningful experience in which you, the reader, can participate.

- *It was fun and exhilirating to be able to see exactly what you can do with your own creativeness [Anna].*

- *I really liked this project [of writing]. I feel this way because I got to combine fun with science, which usually does not happen [Simon].*

Student's day

poke, prod, trip,
get up
don't want to look like a
FOOL

what boring stuff
are we doing today
in the classroom
of my school?

note taking
paper shuffling
pencil sharpening
nose picking
text reading
chart filling
window opening
door shutting
teacher talking
teacher talking
teacher talking
teacher talking
student snoozing

character building?

(Harding, February 1998)

One of my concerns

When I think about how dynamic, energetic, and passionate many adolescents are about their own lives and their interactions in their surroundings, I wonder about how science learning can enhance and tap into this energy.

I am concerned that the teaching of science often sets students into a controlled pathway, geared to an end result previously known by the teacher. Hodson (1993) speaks about how science knowledge is often presented to students in a neatly assembled package of clear and organized facts. A friend and science educator, Chuck McFadden, is concerned that many science programs do not engage students in meaningful ways in the process of science inquiry. Rather, students participate in what he calls "definitional science" (personal communication, 1998).

"I would get bored doing fact, fact, fact" [Dani].

The paradox is that the nature of scientific inquiry is to push towards questioning and understanding phenomena in unknown frontiers. As Ramsden hopes,

> Learning [science] means a movement towards being able to solve unfamiliar problems, towards recognizing the power and elegance of concepts in a subject area, and towards being able to apply what one has learned in class to problems outside of class (1988, p. 15).

My experience as an educator in Mexico, Nova Scotia, and British Columbia is that science instruction often presents the field as a body of known facts. As a result, school science labs tend to have students performing established procedures to end results known by the teacher. Fairbrother & Hackling's (1997) research and article entitled "Is this the right answer?" echo these concerns. In my classroom, I can no longer say, "just use Johnny's data; his works nicely." Instead I ask about how students may be encouraged to be more thoroughly engaged in the process of inquiry.

Wrestling with constructivism

Two perspectives of learning, constructivism and enactivism, have significantly influenced how I have wrestled with this question of meaningful engagement. My thinking about how students participate in a science classroom was primarily influenced by a group of excellent educators in the Atlantic Science Curriculum Project. Interacting with these colleagues, I became exposed to ideas related to constructivism. The following statements represent key tenets of constructivism, which have largely influenced my classroom instruction:

- "New constructions are built through [students'] relation to prior knowledge" (Watts, 1994, p. 51).

- Students are seen as "architects of their own learning through a process of equilibration between knowledge schemes and new experiences" (Driver, 1989, p. 482).

- "If students come to lessons with ideas about their world which already make sense to them, then teaching needs to interact with these ideas, first by encouraging their declaration and then by promoting consideration of whether other ideas make better sense" (Carr et al., 1994, p. 150).

Early in my graduate studies at UBC, I found that the messages in these statements made sense to me in relation to my classroom practice. I anticipated learning more about constructivism in order to teach more effectively. Wouldn't that have been ideal?

In more careful consideration of constructivism, I began to understand some of the complexities related to this theory. For example, how do the power relations between the teacher and students affect the possibilities of student being "architects of their own learning?" I was confronted with this question when I considered Solomon's (1994) claim that students may temporarily (temporarily?) give up their conceptions of certain phenomena while in the classroom. She writes about "the power structures which urge [students'] compliance with new ways of thinking and with new concepts" (p. 11). This problematizes how a model of learning such as constructivism is carried out in the classroom.

I continue to struggle with my responsibility to encourage students in science class to adopt the right answer. Constructivism is based on the belief that merely telling students the answer would not likely bring about a deep change in understanding. Cobern (1996) problematizes the notion of conceptual change as he states that it "requires a breaking with what is essentially students' natural understanding of their world because so much of science is counterintuitive" (p. 601). This tension has surfaced throughout my classroom experiences that led to this study. While aspects of constructivism shape the design of the lab investigations guiding this study, my focus is not on conceptual change.

My interest is one of student engagement in open, expressive science inquiry. Martin and Brouwer (1993) referred to something similar as "personal science" (p. 441) and promoted the use of narratives to explore one's understanding and connection to science. These authors first introduced me to the importance of encouraging a connected and personal understanding of science. What is the value of learning if it is disconnected from one's life? This study focuses on how to enhance and tap into students' interactions with science phenomena.

Metamorphosis

Like an out of tune violin
the science teacher harped
neatly copy the facts on reptiles

vertebrates in the animal kingdom
four limbs with movable joints
lays eggs with calcareous shells
covered with protective horny plates

as the teacher continued the babbalogue
and held up Equinox photos for the visual learners
the students learned metamorphosis

now horny lizards climbing castle walls
searching for the excitement
with that special Devonian creature
only partially camouflaged in shiny armour.

(Harding, April 1998)

I feel that one of my goals is to develop a science program that encourages active exploration of scientific phenomena. Rather than pushing students to the right answer, my preferred focus is to foster students' curiosity about themselves and their environment. *I am beginning to actually understand science and think about how it affects my life [Raj].* As Cobern (1996) suggests, science class can be one more place in school where students have the opportunity to make sense of themselves and their world.

To me, these ideas highlight a sense of purpose in the subject area, and the value of turning to, and tuning into, the students' actions and voices as we think about possibilities in science class. These ideas that have emerged from my students, my own school experiences, other educators, and the literature have led me to consider the perspective of learning known as enactivism.

Turning to enactivism

An enactivist perspective guides my interpretation of this study. In setting up the environment of our classroom, I have been mindful of enactivist ideas where learners both affect and are affected by the setting. "As the learner learns, the context changes, simply because one of its components changes. Conversely, as the context changes, so does the very identity of the learner" (Davis & Sumara, 1997, p. 111). A constructivist perspective views cognition as residing in one's head. As MacDonald claims, "the constructivist [researcher] tends to neglect the role of context or setting in the construction of knowledge" (1996, p. 42). For enactivists like Davis and Sumara, "knowledge ...[is] not some sort of object that [is] created during or in the interaction;

rather, the ongoing, ever-evolving interaction [is] itself the form and substance of the collective knowledge" (1997, p. 115).

It has become apparent to me that what students seem to enjoy most about learning in a science classroom is the opportunity to explore through lab experiments. I have played around with the ways in which I organize these for students. At times, I have given students a purpose and accompanying procedures for an experiment. This seems to mirror a deductivist approach to a scientific investigation as students set out to conduct an experiment primarily to confirm a theory (Hodson, 1993). While students perform the steps themselves, the experience is to follow instructions, to complete lab techniques, and to relate this back to an original question that they may or may not understand. This kind of hands-on lab experience is more beneficial than simply receiving material transmitted in textbooks. Yet, I feel that while students may successfully follow steps and observe phenomena in this type of lab experience, they may not substantially advance their conceptual understanding.

> For too long school learning has been confined by a view that it can be represented as facts and principles to be transmitted to the student. In the case of practical activity, the role of the learner is often simply to reconstruct a known result. Consequently, students do not consider the pathways of action which they create in the process of learning to be a significant part of their learning (MacDonald, 1996, p. 34).

I believe that students' learning can be richer if they are posed a problem and then design their own solution to the problem. In this way, there is a greater connection between students' everyday science content knowledge, school-related science knowledge and their general cognitive abilities (Erickson & Meyer, 1998). If this is the way a teacher designs experimental investigations for students, then students must seek to understand the question posed. As well, when students design a process to respond to a question, they are more likely to feel a sense of responsibility to solve the problem. This also sends a message to adolescents that the process is as important as an end result in the lab experience.

In most science classrooms writing a lab report is part of the learning process. A lab report typically includes:

1. purpose
2. hypothesis
3. methods/materials
4. observations/results
5. discussion

Rowell (1997) reports that teachers primarily have students write in science class for the standard practice of accumulating facts through notes and describing experiments. This corresponds with what Anthony and colleagues (1996) suggest is the "science-appropriate genre of writing," which is limited to description, explanation, instruction, and argumentation. In my experience, this is a formal and disconnected task for science students. Sue expresses this eloquently: *The o'll boring hypothesis, conclusion, materials stuff. . . is always so boring --- that is the stuff you want to just put a metal pot over your head and bang it with a wooden spoon [Sue].*

If my goal is to encourage a personalized understanding of science, then how should students be writing?

At the National Science Teachers Association's 1997 convention, I had the opportunity to attend a session where thirty national award-winning teachers presented their best teaching idea in an open forum. Inspired by their ideas, I asked many of them how they had students write about these science activities and maintain a sense of enthusiasm. I was not really satisfied with their responses. My concern was that few educators were focusing on students' loss of enthusiasm and spirit of investigation as they moved from lab experience to lab write-up.

Explorations shaped in words

I have considered the idea of whether we should get students to write at all. Among many reasons for writing in science, two stand out for me. First, I think it is important to document our pathway of learning for future reference. Second, I believe that the act of writing helps shape our learning of science. In a lab experience, students are involved in a social act of learning where questions are posed and ideas are discussed and debated. My interest is to explore how writing can be an extension of this journey of learning from the lab experiences. In six years of teaching, I have been delighted to discover the potential for learning through writing from students as they have come to exciting and unexpected places, shaping their experiences in words.

I became oblivious of our own human time, and zeroed in on geological time. I realized that a decade of life on earth is barely a breath in geological time, and the long hours of class time in our days are less than a wink [Nicola].

Nicola's words embody an understanding of science as it is connected to her own place in the world. "When writing is for learning science, in the sense of transforming understanding, it will be less tied to reporting experimental investigations and more oriented to explicating ideas, both personal and those expressed by others" (Sutton, 1989, p. 154).

Literature around constructivism has addressed how students' writing can augment their learning of scientific concepts (Anthony et al., 1996; Appleton, 1993; Hand & Prain, 1997; Needham, 1987). The purpose of writing from this perspective is to facilitate students' conceptual change about a reality that actually exists. Conversely, Hildebrand (1998) argues that we need to disrupt the hegemonic writing practices in science class. She suggests that science should involve the logical and the intuitive, as well as the objective and the subjective.

Davis, Sumara and Kieren (1996) challenge assumptions that "learning outcomes should be pre-specified and that, once such objectives are selected, learning sequences can be devised to ensure that they are effectively achieved" (p. 152). Goldberg (1986) heightens this issue of endpoint when she suggests that the pleasure and power of writing is in open engagement in a process that may lead to unexpected places. Encouraging openness might enable students to explore what they understand and even who they are. For this reason, this study does not push towards an end-point of conceptual change.

I wonder if teachers are hesitant to get students to write in an open, expressive way because of challenges to grading, perceptions that the writing is "fun and games", or that it might not focus adequately on science facts. But how might it affect their classroom practice if they were aware of Sutton's (1996 & 1989) research of Robert Boyle and Charles Darwin's initial writing? Sutton realized that when in the process of discovery, they did not write with authority. Instead their language was speculative and interpretive, as one would expect of a scientific claim not yet encultured by the scientific community as fact.

This gives further support for students to write in an interpretive tone (narratives) as it more closely aligns with the investigation process of scientific inquiry. This fuels my passion to encourage students to use their own words as they interpret science phenomena. Martin and Brouwer (1993) promote scientific exploration through narratives because of its "potential of engaging students more personally in the lives of others [scientists] and of more fully exploring their own understandings" (p. 441). Ogborn et al. (1996) also encourage the use of "story-forms, not merely to add to its 'liveliness' or 'interest' and not merely to show it applied to some real context, but more fundamentally to act as an involving, memorable and efficient knowledge carrier" (p. 67-68).

Poets such as Anne Michaels and William New inspire me in their abilities to seek connections between science phenomena and other realms of life. Consider the following:

> "A family is a study in plate-tectonics, flow-folding.
> Something inside shifts; suddenly we're closer or apart."
>
> (Michaels, 1991, p. 59)

The old seesaw beside the barn
stands at an angle, plank half in the air,
half in the long grass, lodged in weed.
sometimes they pry it loose, playing for precedence,
command of the fulcrum, nudge and flail, spurning
old weighted games for single access
to the balance beam.

(New, 1996, p. 40)

Connecting families and plate tectonics, or properties of physics and men's work in the barn create vivid images which are so much more vivid than encyclopedic explanations. These examples inspire possibilities for combining science with writing. In our classroom, I have tried to encourage students to maintain their natural voices as they write about their experiences with science inside and outside of the classroom.

I don't see molecules or particles, I see little people, each with their own personalities and traits [Des].

Teaching and learning school science might be influenced by adopting a "hunkering perspective" which celebrates "the interests, motivations, passions, and ways of being inherent in children themselves" (Cummings, 1998, p. iii). An idea is to see how this can be generated and embodied in words.

If students are active as writers in science class, then will this encourage them to develop a personal and meaningful understanding of science? If they write in ways that are expressive, what is the potential for their learning? These questions guide this study in addition to Sutton's call "to know more about how pupils use language when they try to re-tell in their own words the story within which a particular investigation is situated" (1996, p. 17).

To review, the research questions that are the basis of this study are:

1. How do various writing tasks illustrate students' understanding of the phenomena floating and sinking?

2. What are students' perceptions of their learning as they engage as writers in this way?

Part Two

Our classroom space

I have outlined my philosophy about engaging adolescents in science in order to provide background for how this study has developed. The most central part of this story is the students. I move now to students' reflections of our classroom space. I asked them to respond to the following:

If someone was trying to understand what it was like for you to be a learner in this science classroom, what would you say? Describe what learning in this classroom is like. How would you describe what science as a subject is like for you?

What is this classroom space like for some students . . .

- *It is very fun, and at the same time we are learning [Grant].*
- *I always thought science was dissecting frogs [Julian].*
- *learning in this classroom is like working in a scientist's room [Rietta].*

Their learning, I believe, is personal and expands horizons . . .

- *I'm beginning to actually understand science and think about its affect on my life [Claire].*

- *In science, not only do you learn, but you also understand how what you're learning, effects you [Tanner].*

- *Overall, I find science to be not only a class, but a sort of understanding to life, and how it works [Garth].*

For one, the classroom environment is akin to an invitation . . .

- *It gives me a chance or an opportunity to open my mind and think into more possibilities and more solutions. We get to have fun and open up to a whole new world [Devon].*

And students appreciate the social aspect of learning . . .

- *It's good that we can get into groups and do experimenting so you can be with friends and work well, and two heads are better than one [Sophia].*

- *I personally love science because of the open conversation in the classroom and everyone can share their ideas about what they think and it doesn't matter if it's wrong [Sally].*

- *Each day varies . . . this year we have more ideas that are being expressed [Kristie].*

And the journey of learning moves forward with carefully created questions for students to ponder.

- *I like the class discussions that we have because we get to think and use our brains rather than just filling in easy worksheets [Cam].*

- *We are asked interesting questions where you actually have to think and give your opinion and no one is right or wrong necessarily. Also, when we give an opinion we are asked why. This way you always have to be logical, as are the ways of science [Fiona].*

Density daze

If we look up this way
if we look up *this* way
please, facing the front *now*,
we can see the formula
a mathematical *representation*
or an equation

stools flat . . . safety reasons
the formula for calculating
any guesses?
there is no title but look at the terms
put your thinking caps on
hands, hands,

yes
density.

Who can say what density means?
don't be shy
the meaning of density
the meaning of density,
come on folks, the amount of matter
remember matter?
matter
turn around please
if you cannot remember
an even better reason to be *listening*
listening, density

You must divide the mass by the volume
to get the density *put the ruler down, please*
it should be obvious
the units should be obvious
see where they come from?
the numerator and the denominator?
some simple math blended with science
like twins friendly twins
that talk to one another,
the units of density. . . anyone, anyone?

the units are grams per milliliter

follow along please,
less chit chat at the back
grams per mil

the question you must be asking
where is this calculation useful
where *is* this useful?
no, you should have gone at recess
let's consider an example
similar to one in your text

if the density of water is one gram per milliliter
and
if we have two hundred and fifty milliliters
what would its mass be?

yes you are right.
two hundred and fifty grams
head up please

two hundred and fifty grams is the mass of the water
not weight, remember graMs where M is for mass
excellent
now if we knew the mass of the water
how could we find the *keep your hands to yourself*
the volume of it?
is it not just the reverse?

It is.

Now, here's a trick
magic for mastery learning
and always be correct on a test, *shhh*
shhh . . . here's the secret

make a triangle with m on the top,
d on the bottom left and v on the bottom right
take your hand and cover the one you need to find
see what's left.
just fill in your known values
understand?

understand?
works here with density

and for those *sit straight* going on in science
works with displacement, velocity and time
replace mystery with mastery folks
easy mastery
made easy
Any questions?
Any questions?
Let's turn to our textbooks.

(Harding, November 1998)

Writing as an exploratory endeavour

Field notes – Nov. 15

> What do I want this experience to be like? Is it going to be connected to their lives? Will this [unit] increase their awareness of the beauty of science as a way of experiencing the physical and natural world? Am I encouraging students to explore their interpretation of science? Am I pushing them toward the correct answer?

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I had been exploring the ways that I asked students to express their thoughts in words. The possibility existed that the act of writing itself could become more than showing the teacher that all is understood. I wanted students to be excited at the idea of writing, rather than it being an assignment that is only valuable because it receives a mark once completed. The tone of writing as interpretive should be as important as writing to just show one's comprehension. Too often, writing like reading, is for the purpose of an "excavation of meaning" (Sumara, 1996, p. 10). Whose meaning? Whose life? Whose purpose?

We played with our writing in class earlier in the year during our geology lessons with questions such as:

> <u>Holy Prospector!!</u> – Pretend that you are a geologist on an exploration in the Canadian arctic and you come across what you think is the most rare and beautiful mineral. Write about it.

I think "Holy Prospector was an inviting way for students to explore their ideas and use of language in science class. It had a catchy title, was open-ended and they could use as many or as few science words as they wished. The act of writing in science was about dwelling in our classroom space now, rather than practicing for life later.

We had an exciting beginning to the topic area of physical properties of matter with a lab investigation entitled "Particles on the Move". Students worked in pairs at various stations, followed short procedures and witnessed some interesting changes (often colour and shape). In each station, students were asked to describe what happened and write an explanation of what they imagined was happening at the particle level. The stations included: (a) diffusion of potassium permanganate in hot and cold water; (b) expansion and contraction of a balloon when attached to a flask containing a small amount of methanol; (c) boiling point of water compared to methanol; (d) vapourization and solidification of iodine inside a sealed tube; (e) melting and solidification of parafin wax; and (f) condensation of water vapour from one's breath.

One of the follow-up exercises after Particles on the Move was for students to think of an analogy of what particles behave like as a solid, liquid and gas. Students came up with ideas of particles crowded onto an elevator and hardly able to move (solid), or slipping down a water slide (liquid), or bouncing up and down on a double bed (gas). These fascinating and playful analogies seemed to allow students to express their understanding in a unique way that they could identify with, and perhaps help them remember their learning at a later time. They enjoyed sharing their creations and I was excited to hear how they had conceived of the particle level in this open format.

Field notes – Nov. 16

I seem to be somewhat reluctant to follow up the lab experience with "ok folks, now let's look at the correct answers".

- - - - - - - - - - - - - -

Students were asked to provide some feedback about how they felt the initial Particles on the Move experience contributed to their understanding of the microscopic world. I was delighted to see how they connected their in-class learning to their experience outside of the classroom, and how their awareness of particles was changing.

- *After breathing on a beaker of cold water, I compared that to the frost on the windows of a house [Tim].*
- *I learned that particles are really small, but they can make a big difference [Kathy].*
- *I see the stations in my head when I say "particles" and I have a different understanding on everything because everything is particles [Ty].*

Next, I wanted to create an exciting and active series of investigations that were pieces of a puzzle . . . the puzzle, or King's Query, stimulated us to draw connections between what was previously learned, or known, and what was presently being experienced. Hopefully, the whole experience of learning in the King's Query, would create a very rich context that would allow for many possibilities when students were asked to write. The experiential medium for students to investigate physical properties of matter progressed as follows:

Sequence of lab explorations

Title of activity	**Focus**	**Time allotted**
Particles on the Move	To become familiar with how particles can "behave" and how this can be observed with the naked eye.	one period (77 min.)
The King's Query	To pose a puzzling question that provides a context to think about properties of matter.	half period
Conniving Clay	To explore how clay sinks and floats depending on the volume of space it takes up in water.	one period
Peel me a Grape	To uncover how grapes with CO_2 bubbles attached are less in overall density which affects buoyancy.	half period
What do You Think Al?	To figure out how to calculate density, which is applied to a cube and a cylinder (both aluminum).	one period
It's not all Heavy Metal to Me	To determine that various materials differ in density which is related to their particle make-up.	one period
Our Density Cocktail	To see how the relative density of an object in a liquid will determine whether it floats or sinks in that liquid.	one period
Flinkers Challenge	To build an object that has neutral buoyancy in water and see how materials are each uniquely buoyant.	one period

The King's Query

The puzzling question that provided a context of learning for the four Grade Eight classes (110 students) was this:

<u>Archimedes' Problem – Is it gold or not?</u> There is an amusing tale about a Greek mathematician and physicist named Archimedes. He was born in the town of Syracuse, on the island of Sicily, in about 287 BC. Hiero II, the ruler of Syracuse, had a fantastic crown of gold made for himself. But Hiero did not trust the goldsmith who made the crown. After the crown was made, he wanted to make sure that it was pure gold and not alloyed (mixed) with silver by the goldsmith. Hiero asked Archimedes to find out without destroying the beautiful crown. But how was he to do this?

(McFadden et al., 1988, p.100)

I learn the best when I have some sort of story to go along with the problem [Jamie].

Students each responded to the question by writing a response on paper. We did not discuss possible methods or solutions, but only if they understood what the question was. When students came to class the next period, volunteers shared their responses. People listened to one another, and a smattering of methods came up such as, scratching the crown, biting it, looking at its colour, viewing it with a hand-lens, making an exact replica of the crown and see if it was lighter, and seeing what temperature it melted at.

Students seemed to be very engaged in the question, and did not appear uncomfortable with being left with various possibilities and not knowing the right answer. When one boy said that his father explained it to him last night, he understood, but now that he was trying to tell it to us, he could not quite figure it out. I told students that the series of activities we were going to be doing in the King's Query would help us respond to King Hiero with greater understanding.

I fashioned a simple crown from yellow construction paper and wrote the name "King Hiero II" on it. On various occasions during the class, a student would go up to my desk and don the crown. Some word, or thought, or moment spurred them to go and wear it. Was this one way that the King's Query was being enacted by students?

Thoughtful play with grapes and clay

The next activity was entitled "Conniving Clay". It began simply with the question: does clay sink or float? I liked its simplicity, and how the response <u>it depends</u>, became apparent once students started listening to each other. Students were given a 400 ml beaker and a lump of modeling clay and pondered the question. The time together had quite an open feeling to it, as there was no specific endpoint for students to arrive at.

Field notes – Nov. 21

How will students play with words after playing with clay?

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During thoughtful play, students shaped the clay to make it float in the water. Then I asked them: What was changed and how could it be measured? Students were given overflow cans and graduated cylinders and on their own, they quickly came up with an idea! Use water and fill up the overflow can to the brim of the spout, lower the boat into the can, and measure the water that spills into the graduated cylinder. Students might understand in Conniving Clay that volume plays a role in density, and whether things sink or float. Also, another aim was for students to learn how to measure volume. I did not feel that as a class, we were ready to tackle what density is. A clay boat is not an easy example to fully understand density, because of relative densities of air and clay that come together and influence overall buoyancy of the clay boat in water.

Relative density of different substances was an aspect that needed to be brought to the forefront with another investigation. This was achieved by stimulating students to think about particle spacing in an exciting demonstration with green grapes. We "hunkered" (Cummings, 1998) together at the front lab bench and considered the question: "What will happen when these two grapes (one with the peel on, one with the peel off) are put in a glass of 7 up?" While the appropriate jazz music "Peel me a Grape" (Diana Krall, 1997) was playing, we shared our predictions. The music seemed to generate more excitement and enthusiasm; possibly it contributed to a special environment where it seemed natural to take risks in one's thinking.

I sense that the language in and around these explorations has a positive effect in how students feel invited to explore their understanding. "Why might this be happening" compared to "what is happening". How could particle spacing in a solid compared to a gas help explain why these grapes are behaving as such? Even the title alone "Peel me a Grape" might capture students' interest more than "A Demonstration with Grapes".

One student wrote: *Having weird titles for experiments has helped me remember things well and . . . has kept my memory fresh on this subject [Bev].*

Field notes – Dec. 1

Students were engaged because of how neat it was. Take some everyday thing like grapes and pop and do something unlike every other day. Put a grape in the pop, peel a grape and put it in the pop too. One student did not know that a grape could be peeled. Play with the unexpected. Do the unordinary.

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After having participated in thoughtful play with grapes and clay, our story of learning was not written with definitions, numbers or formulae. Students had been forging a pathway of science learning, and we were now considering more components at once. Our analysis was becoming more developed as we looked at bubbles in a gaseous state and how this affected the overall density of a grape. Our pondering of what might be happening to the peeled and unpeeled grape had an open feel to it. I was not pushing all of my students to grab hold of the most accurate scientific explanation of why the grapes were moving as such.

Most of the things we do in science are not to see something cool, but to find out what it is that makes it like that [Jamshid].

Finding density in numbers

The next investigation, "What do You Think Al?", encouraged a shift of students' understanding to a numerical plane. The focus question of this activity was this: Does the density of aluminum change when in the shape of a cube compared to a cylinder? We had seen the effects of the density of an object compared to a liquid medium, when the clay boat floated in Conniving Clay and the peeled grape sunk in Peel me a Grape. Yet, no student had been given a formal definition and formula for density. To ease any anxiety from the focus question of the exploration, we discussed that density can be described as how heavy something is for its size. In Conniving Clay, students measured the volume of water displaced by the clay boat. In this investigation, they saw that the same lab materials were available, as well as something new - electronic balances. They quickly recognized that this instrument was for measuring how heavy something was. In partners, they measured, recorded, pondered, asked, and realized what to do with the numbers. They learned <u>how</u> to calculate the density of a little cube and the cylinder, both made of aluminum. Apart from responding with confidence to the focus question, they enjoyed comparing their results with the accepted value of density.

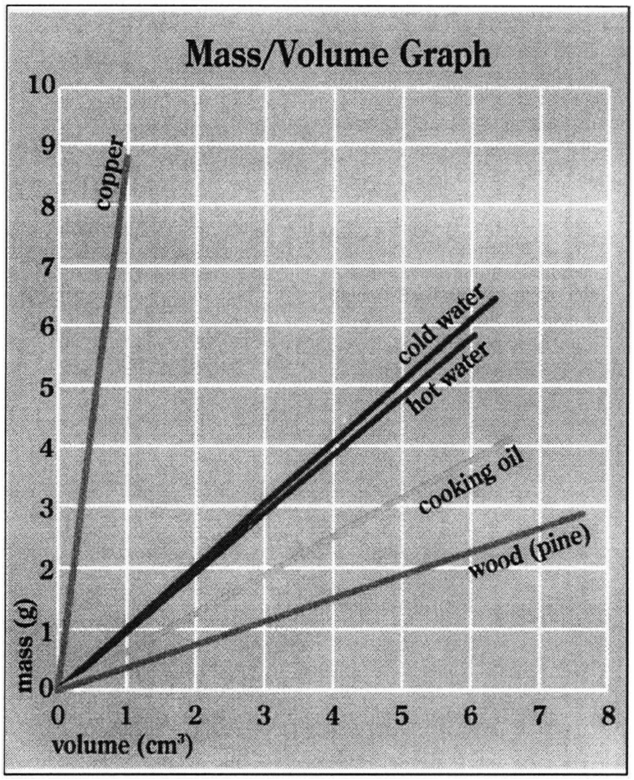
In the next lab exploration "It's not all Heavy Metal to Me", students had the opportunity to practice measuring volume and mass, and calculating the densities of various materials (brass, iron, copper, glass, plastic). This helped students realize that different materials had different densities, which is a physical property of a substance. Students were encouraged to refer to the periodic table of the elements and see if this could help them in their explanation of why the densities might differ.

The three follow-up questions that students were given (see below) were extremely valuable as this gave them an opportunity to extend their understanding from the doing of the lab to a situation where they could see this information represented graphically. This perhaps encouraged them to see that one substance had the same density, even if there was more of it present; in contrast, they could see that each material has its own unique density, which is a physical property of matter. When students analysed this graph, they would also see how various mass/volume lines related to a substance's tendency to float or sink in water, as pictured on the graph.

1. Why should 1 cm^3 of copper have a mass of 8.9 grams while 2 cm^3 have a mass of 17.8 grams?

2. Why should the mass of 5 cm^3 of water be less than the mass of the same volume of copper?

3. Why do certain materials float in water and how is it related to density of the substance compared to water?



Field notes – Dec. 3

Today was a neat day of pulling things together. We had a close look at the relationship between density and mass; most students were able to infer from a given density and figure out the mass, for example. We had a close look at the graph and I feel that students had a good sense that density largely depends on how closely particles are packed together and what the individual particles' mass is. I feel that there have been good reasons to look at the periodic table and use it in context.

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Density to buoyancy

When we come into class and see a bright yellow crown, or a grad cylinder filled with different coloured liquids it makes you think, why are those there? What are they for? I wonder what experiments we will be doing today [Fiona]?

This large graduated cylinder notoriously became known as "The Density Cocktail". It was filled with corn syrup, glycerin, water and cooking oil. Students were in awe of such a cool looking concoction! We had looked at the mass/volume lines for the various materials on the graph and now we were able to make thoughtful predictions of what would float in and on what. Using a collection of objects like a cork, a plastic washer, an iron bolt, a metal washer, a wooden cube, a plastic cube, and a rubber stopper, we explored relative densities and their relationship to buoyancy. How these objects remained suspended in, or rested in between layers impressed and influenced students' understanding of the phenomena floating and sinking.

I learn best by examples. If someone gave me a sheet saying about densities and different volumes and masses, I wouldn't understand. My favourite was density cocktail because I understood why certain things floated. It made density make sense. I never thought that I could find the density of something but that was before I understood. If I was given a formula I would never have understood how to find the density of something. I don't think I'm a genius now that I know these things, but I do understand [Jamshid].

The final learning activity that contributed to students' understanding of the concepts involved in The King's Query was "Flinkers". Students would be given the task of building an object from a variety of materials, which together would contribute to the object's neutral buoyancy, and therefore hover in a large beaker of water. I had a sense that it would be an exciting finale before students began their writing tasks, and an exhilarating way to spend a Monday with young teenagers.

Students would soon be hearing about details of the various writing tasks; they knew about the research study we had embarked upon and the consent letter and permission form had just been explained. I wanted to encourage students to explore openly in their writing, yet I did not want to be too suggestive with words like <u>work</u> or <u>creative</u>. To me, work implied that the task would be arduous, and possibly laden with drudgery. So, I referred to the writing as "tasks or pieces". As well, I did not want students to feel that they had to be creative for me, nor for this study. I wanted students to write in a way that is comfortable, expressive and personal to their own scientific understanding.

With a Dr. Seuss feel, students learned about the Flinkers Challenge!:

Mondays yes Mondays can flink!

The challenge is clear
like the water you drink
be the greatest class architects
build a contraption to flink!

Flinkers are real
like an unusual boat
they don't stay on the bottom
nor do they float

These flinkers they flink
no one's getting your goater
flinkers are <u>floating</u> <u>sinkers</u>
remarkable <u>sinking</u> <u>floaters</u>

Don't fret nor sweat
just devise clever plans
with such creative minds
build with your hands

Using a cork as the core
please use quite a bit more
like wooden splints
washers
clay
styrofoam
straws
pins
plastic pegs
paper clips
and last but not least
tacks
not tasty tic tacs
just tacks!

It's a class contest
one you can win
use as many different materials
and make a flinker that's trim!

(Harding, December 1998)

Field notes – Dec. 7

Flinkers was a big success today! It was amazing to see them build in such an open and investigative manner. I wonder if this will be reflected in their writing task if they choose that one. The order of explorations was pretty crucial in terms of heightening students' understanding of the concepts. It was so neat to see Greg building away, pull his arms out of the water, turn to the class and exuberantly exclaim: THIS IS SO FUN!!

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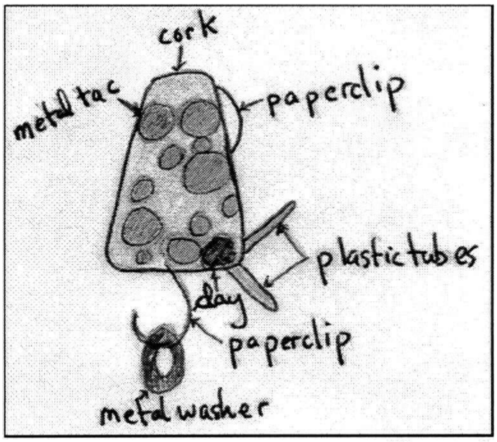
A Flinker



[Ramin]

Students' reflections on learning in and around the King's Query

Our thinking of 'properties of matter' began with the King's Query. For a few moments, think about your learning over the last several classes as we have done the assortment of explorations, follow-up questions and reflections. Do you feel our pathway of investigating properties of matter has made a connection with how you learn the best? Please respond and try to give some specific examples from class that help illustrate what you have written.

Two students' responses have encouraged me to think about how they were interacting with science phenomena and how this resonates with some ideas in enactivism. I think of <u>embodied</u> science learning when I re-read these students' reflections.

- *Doing hands on things are also helpful because you experience things through many of your senses, not just your eyes [Dimitri].*

- *I think that I learn best by doing experiments or watching experiments because I am not very good at reading things and remembering what I've read. For example, I could tell you how I did an experiment in class, like the density of aluminum experiment or the boat one, but I couldn't tell you much of what I had just read in a social studies textbook to prepare for a test [Elliot].*

At a loss for words

To be honest, I find it very difficult to describe what happens when I teach students about a particular science phenomena, like physical properties of matter. How can I make sense of such a complex web of interactions when there are so many things going on concurrently? Numerous times I have asked my students to explain what they saw, and it was so different than what I had expected.

I also hesitate that some people may attempt to translate what went on with these students at this particular time in our relationship as teacher-students, to their own situations. We dwelled in our classroom space in ways that were both unexpected and likely unrepeatable . . . students wearing the yellow construction paper crown or asking for that jazz song again.

As I try to make sense of what went on during these special minutes in our classroom, I ask how can I so cleanly write what is going on with students' experiencing selves? Do people really believe that teaching can be understood in terms of doing more of <u>this</u> will bring about more of <u>that</u>? "You can observe behaviour, you can observe the organism, but you cannot observe the flow of information" (Marton, 1993, p. 234). To gain some insight on the possible influences of experiencing science phenomena, I think of the collection of influencing and interrelated aspects . . .

context or
story alongside
the explorations

order of
explorations

open-entry to the
focus questions

experiencing
science phenomena

medium rich
in interpretation

classroom setting
rich in the senses

correct answer
is diminished

variety of ways for
students to record their
learning in their notes

- - - - - - - - - - - - - -

I selected the lens of enactivism to guide this research study because of the positioning of subject and object, when someone is experiencing something. These are not two distinct and separate entities. The experiencing subject is not receiving sensory inputs from watching or participating in experiments that are void of meaning. These Grade Eight students were manipulating and interpreting these science scenarios and were being shaped by them at the same time. Their experience was an experience of something, "and it says as much about the experienced object as about the experiencing subject" (Marton, 1993, p. 236).

Let the writing tasks begin

Students were given the following outline and it was discussed so that they could extend their learning by writing with the greatest possible confidence.

Grade 8 Science: the King's Query and physical properties of matter

In your final writing task, explore your understanding of the following:

- density and its relationship to volume and mass
- how properties of matter affects density
- how relative densities are related to an object's tendency to float or sink
- how "behaviour" of particles is related to all of this
- other concepts . . .

Some suggestions:

Attempt to write in a way that is meaningful for you, and is the best way for you to show your learning of the ideas and concepts touched on above. This is relevant for any of the three writing tasks you select. The descriptions of the writing tasks are to serve as a starting point from which you can begin your writing journey. Have fun!!

Flinkers

Write a personal and informative account of what it was like to successfully (or almost) build a Flinker. Explain how you did it and why it worked (or almost worked).

Eureka – I've got it!

Pretend that you are Archimedes and as you were sitting in the bathtub, you finally figured out that the King's crown was indeed a fake. Your writing task is a formal letter to King Hiero II explaining your findings.

Floatie and Sinkie

Write a conversation, a script or a short story, about two characters named *Floatie & Sinkie*. You may want to take on the character of either *Floatie* or *Sinkie*, or you can narrate their story.

Workshops on writing

My intention was that each of the writing tasks seem equally appealing, and that each would have the same amount of detail in the description. With very little further discussion, students began in whatever way they chose to begin their task. It was fascinating to see what transpired in this open design of the "Workshop on Writing." Students began the following things: made mind-maps of the various science ideas on chart paper; drew models of Flinkers and how they looked at the particle level; sifted through their notes; highlighted key areas in their notebooks; talked in pairs about what their story line was going to be like; asked me for some help about concepts they did not understand; made lists of terms in their notebook; drew pictures of who the characters were going to be; talked about the upcoming vacation plans.

A good friend, Jackie, who is also a graduate student at UBC participated with us on our day of initial exploration in writing. Jackie was enthusiastic to work with students and me as they drew connections from the lab explorations, played with ideas of having characters tell the story, stumbled with how to get started. Jackie made a wonderful contribution by sharing her ideas and encouraging students to write in a way that seemed natural to them. Students responded well to her assistance and asked if she would be coming back on the next day for another hour of help. I was relieved and appreciative that Jackie was excited to participate in our workshop, especially since there were aspects of this day that I was not used to.

Field notes – Dec. 9

It was a neat day. It was a hard day. It was a day when I felt that I hit the wall of what I am best at, or most confident at, or most familiar with. What I am asking them to do is terribly difficult for some students. Incorporate an understanding of science in your story . . . how much do I want them to be incorporating appropriate science language? If they gain very little, what is the purpose of having them write in science class then?

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The final class before the writing tasks were to be handed in needed to be more structured. I had the sense that saying "make sure you show an understanding of terms and concepts in your writing" was not sufficient. I had been thinking about this for a very long time, yet I had not explicitly illustrated what I meant by this. What might serve as a useful activity on this second day of our writing workshop, would be to give students a sample writing passage that could be analysed together. Then the learning from this, could be extended to their own writing, whatever stage it is in. The following instructions were given, which accompanied the sample writing passage, shown below.

Writing example (from Flinkers)

To the side of the cork (and other materials), we added two tacks which are pretty light because they are made of metal. This was not enough to make the object sink, so we added a small volume of modeling clay. This was too much and our object (named Hereby) sank. When we took off one of the tacks, it was perfect and could almost flinch. This had to do with buoyancy.

1. Read the following example paragraph.

2. Do you feel that your understanding is enhanced after reading this paragraph? Why or why not?

3. What science terms has the writer used and are relationships between these terms developed so that you better understand a science concept?

4. Re-write this paragraph so that the main concept is explained much better.

5. Exchange your rough copy of your writing task with a person of your choice and have them do the same analysis on all or some of your writing.

6. Share your analysis with each other – how are you doing?

7. Look back at your own writing – what is your sense? Continue writing; remember that your writing is due next science class.

Field notes – Dec. 11

Then students got back with the [peer] editor and they talked about each other's writing. It seemed to go very well. Then they hopefully wrote with renewed vigour. Some students changed which one [writing task] they were doing because it just didn't seem to allow them to incorporate their science understanding. Other students realized that they had a lot of work to do; others were still organizing their rough notes, which says a lot too.

Between lab explorations and writing

The open, expressive writing tasks were unique as they encouraged students to be creative, and hopefully fostered connections with in-class investigations relating to physical properties of matter and their own personal experiences. These Grade Eight students' writing responds to the call for further research by Rivard as he states that "classroom-based studies investigating how teachers can use writing-to-learn strategies within instructional situations should be a high priority on any agenda for future research" (1994, p. 978). In this review of writing in school science, Rivard states that expressive writing appears useful, but important mediating variables are still not sufficiently understood" (p. 975). Can the effect of mediating variables be understood? Can mediating variables be pinpointed down, or are they like ripe dandelion seeds that dance in the wind?

I think that a number of these dancing influences, or mediating variables, played a role in our classroom space, and these probably shaped students and their experience of writing. One influence that students expressed to me was they were quite relieved to be given choice of which assignment they could use to demonstrate their understanding of physical properties of matter. This may help their confidence as they set about the task of writing; as well, it may contribute to an environment where students are encouraged to take risks and be openly expressive.

I think the main thing that influenced my writing was that, for one thing we had permission to have fun with our project [writing]. Also, we always want to write about what we enjoy and when we can expand and change things to make them what you enjoy writing and reading, then it is so much better [Claire].

Natural tendencies like doodling, or drawing or reading, were seen as starting points to their writing, instead of hindrances that should be put away for after class. Students were excited to create the character on paper first, which could be the one to tell the story of density. I think that this was one of my first times where I saw this as part of their writing, and in the past, I believe I would have told my students to "do the hard part first, and then the fun stuff can always be added later". I feel that my writing of this story has helped me get a better view of what motivates students to be active participants in connected, personal science.

One student wrote about his understanding of density with unique old English language, and he reflects on why this was.

What influenced me the most when I wrote my story, or casual report, was the book Robin Hood [The Outlaws of Sherwood]. It gave me a character to build on, and to express what I thought of a floating character and a sinking character . . . yes, I think this way of writing better improves my understanding of science [Juan].

Even before the writing was handed in to me, I believed there was significant educational value that could be linked to the relationship between experiencing science phenomena and creating the writing tasks. This surrounded students' attitudes toward expressing their learning and understanding of science in writing. It appeared that they celebrated having this opportunity to show their knowledge compared to completing a regular unit test. I observed this as students orally shared their writing.

Dancing connections

doodling and
drawing

feeling a crescendo
in the lab activities

a story to go alongside
the lab investigations

talking

**experiencing
science phenomena**

**writing in
school science**

reading

being

open classroom
environment

fun feeling to
a school assignment

influence
of a teacher

Field notes – Dec. 15

Today the writing tasks were due. Yes, it was an important day, but so were all the others. It was a day for celebration – of students' writing, of students' understanding and for students' voice. For once, we were not rushing off to the next component . . . students shared their writing in small groups – the class was buzzing with laughs and conversation. After 5-10 minutes, students assembled in their seats again and I asked if there were any volunteers to read aloud. Some very interesting things happened . . . the readers' voices just came alive; students were so engaged as listeners. They were in awe of each other's work . . . saying things like "I never knew he could write like that!". It was an incredible celebration of the end of the King's Query.

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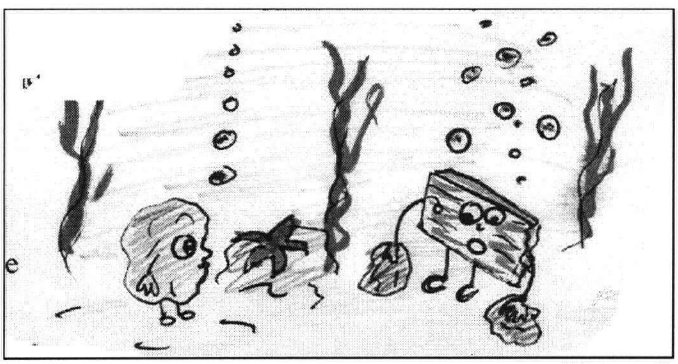


[Kristie]

Part Three

Analysis of students' writing in light of two research questions

After reading the students' writing several times, I began to look for any emerging themes in their creations. I did this, keeping in mind that the two research questions pointed to different things. My first research question (How do various writing tasks illustrate students' understanding of the phenomena floating and sinking?) enabled me to make an in-depth analysis of how words were used to demonstrate students' comprehension of this particular science phenomena. The two emergent themes discussed in relation to this are: experiential versus explanatory tones in students' writing, and use of terms and relationships between terms.

My second research question (What are students' perceptions of their learning as they engage as writers in this way?) adds another dimension to this study as it centers around students' understanding of their own learning. The two themes that have emerged in this analysis are: students' voices of themselves as learners in science class, and students' perceptions of their world. It is important to recognize that other themes could emerge from another person's analysis, however, the themes that I have highlighted resonate deep within me because of my personal experience and what I hear most distinctly when I tune to students' writing. It is my hope that through the interpretation of students' words, some pedagogical contributions to science educators and teachers can be heard.

Experiential and explanatory tones

Students were asked to demonstrate in their writing tasks, their understanding of the science concepts learned in the physical properties of matter unit. But what does the word concept mean to an eighth grader? Is a scientific fact the same as a scientific concept? By showing how to make a Flinker - is that sufficient for some students to demonstrate their understanding? Is that less valuable than an elaboration on how overflow cans and electronic balances are used to distinguish aluminum's density from that of brass?

As a teacher, I was wrestling with how three writing tasks could allow for a multitude of personal understandings to be explored and developed. Maybe just the mere process of writing serves as a limitation for some students to express their understanding? My intention was to address this by having a choice of three writing tasks which were different enough from one another, so students might find one an appealing way for them to write about their understanding from the King's Query.

Upon reading and re-reading seventy writing samples between one and four pages in length, I coded some interesting themes that had emerged. In their writing, some sentences serve the purpose of explaining an understanding about a given concept, or word, like density or volume. By doing so, students fulfill the purpose of showing what they now are coming to understand. Yet in contrast, other sentences provide an account of what and how they experienced with lab materials and sometimes this extends into a student's own thought experiment. These sentences sound very different tone than the other ones.

I shall refer to these two tones as experiential and explanatory. In Flinkers!, Sandy begins with the sentences: *Flinkers are objects that will not float or sink in H20. An ideal flinker, when placed in H20, will fall until it is about halfway down and then it will suspend itself due to the similar density and mass. An object's density is how heavy is it for its size and you can find this out by dividing it's mass by its volume.*

In the second paragraph, Sandy writes: *We were allowed to use cork (as a base) and thumbtacks, play-doh, wooden stir-sticks, metal washers, pins, straws, plastic bits, and paperclips (which were used to add mass) to make our flinker. I decided to use cork and on the top and bottom, I fastened two washers with two thumbtacks, next I stuck some pins on top and on the side, I stuck a straw with a plastic bit on it.*

In the first three sentences, Sandy defined what a Flinker is and then explained how such an object can exist with an appropriate use of terms. She shows that she understood the objective of the task, and a certain level of scientific understanding. In the first sentence of the second stanza, the tone appears to shift and become experiential by giving an account of what could be used and what she did in this investigation. Even the phrase within parenthesis "which were used to add mass" illustrates a break in an experiential tone, back to one that is explanatory.

This clear break from an experiential tone to an explanatory tone can also be heard in Alexandra's writing as she writes in one paragraph: *We knew that if it hovered for a bit, then we would have to make only the slightest adjustment to make it flink.* Compare this to the next paragraph: *The reason some objects floated is because the density level was less then the water's density level, and they sank because they were more dense than water.*

Cam starts off his Flinkers writing task with *When I tried to build a Flinker (a floater, sinker) I learned a lot about the physical properties of matter. The purpose of my project was to build an object that had neutral buoyancy, meaning it would hover below the surface of a container of water, but not sink to the bottom.* This is the most experiential Cam's writing ever tends to be. The explanatory tone is pervasive throughout his three-page report with sentences such as: *Refer to the table.*

	Density = Mass / Volume
	1.0 = 1 / 1
	2.0 = 2 / 1
	0.5 = 1 / 2
	1.0 = 2 / 2

Line one shows a sample object with a density of one. When the mass in increased but the volume stays the same [as shown in line two] the density becomes bigger . . .

this brings up the subject of liquid water density . . .

this leads me to the topic of physical properties of matter and their densities . . .

For Cam, writing in this explanatory and factual way may allow him to best express himself and what he has learned. His experiences in class help improve his understanding, but what he finds most important to demonstrate is an explanation of the concepts and terms, in the table that he designed.

Certain conditions and/or tendencies might influence a student to frame most of their writing task in an experiential tone. Even though they were explicitly asked to demonstrate their understanding of science terms and relationships between terms, this may be difficult for some. What might be more natural and thus easier for some adolescents is to maintain an account of what was physically done in class. Consider

Matthias' writing which is appropriately represented by these first sentences: *When we first started I thougt it would be easy to make an object or vehicule that wouldn't float or sink , it had to flink . Like I said , I thought it would be easy but I admit it was incredibly dificult.*

Sandy, Alexandra, Cam and Matthias all selected to write about the Flinkers activity. This writing piece was primarily a descriptive writing task. It likely appealed to students who were less inclined to write creatively or from another character's perspective. By following the guidelines on the handout about the writing tasks, both an explanatory and an experiential tone could be fostered and the balance of this depended on the student.

However, the Archimedes letter and the Floatie & Sinkie writing task were different than the Flinkers writing task. They had a different entry point for the writer. Students could pretend that they were Archimedes, or Floatie, or Sinkie. What does this do to the nature of writing in science when one is telling as if one is experiencing something firsthand?

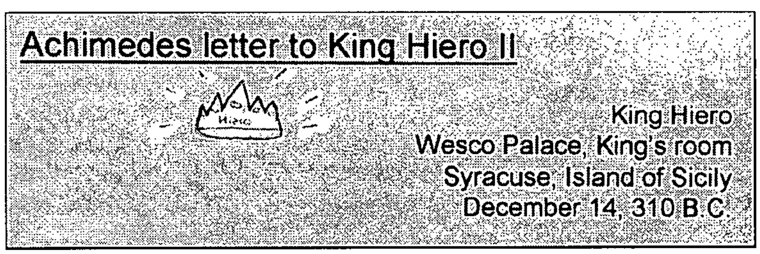
A fine blend in the narratives

These two narrative writing tasks most often have a much subtler and finer blend of experiential and explanatory tones. This overlap can be heard in Sophia's writing as she writes in a voice possibly akin to Archimedes: *I knew for a fact that silver had a much smaller mass than gold [when comparing the same size], so I weighed the original crown and a crown made with the same supposed volume of gold on a balance. This* *method proved me right and it also proved that your goldsmith was wrong . . . but just for evidence sake, I measured the volume of both crowns by taking two large liquid measuring cups and two overflow cans filled with water, then watching how much water poured into the liquid measuring cups beside each can.*

Sophia communicates a thoughtful understanding of what volume is, how to measure it and also, how this is relevant to the King's Query. Sophia may not only be writing to learn science, but she might be participating in the story as if she is was Archimedes . . . *If you would like me to order the imitation goldsmith to be hung, then I shall do it upon command, or I will simply order another goldsmith to fix you the most beautiful pure gold crown ever made!*

Sincerely yours,

Your trustworthy companion Archimedes



[Sophia]

The experiential nature of a few Archimedes letters even became more than the printed word. When Devon volunteered to share his letter, he began doing so by showing the class the red wax seal he had made on his letter to King Hiero.

"You burn hot wax, and then drip it on the page, and then you stamp it. They used it a long time ago in the olden days and they called it the King's seal . . . that's how they kept the secret business between the King and the source coming from the King. I made

one of these and it was coming from Archimedes to King Hiero when he was telling him the news of his findings and the research of the golden crown. And it's a G for the Golden seal and I'm going to take it off now to unseal it." Devon breaks the seal as students watch intently . . .

In Devon's writing, a unique blend of experiential and explanatory can be heard, rarely evident in the Flinkers writing tasks. *Not wanting to lose this precious idea, I jumped out of the nice warm cozy hot tub and wrote it down . . . I was about to solve this problem. I took the cm3 of the pure gold and found its mass on a balance.*

Depending on the student's ability and interest to play with language, an interesting connection can develop between the experiential and the explanatory tones of language. It might be that the experiential language of the day (~250 BC) augments the power of a scientific explanation. *I have but one last term to define for you, my liege, and then the answer shall be unveiled. The final term is density. Density is a confusing culmination of the other terms, mass and volume. Density is a strange concept, one which I spent many nights pondering. Density can be found by dividing mass by volume . . . a piece of iron the size of a pea has the same density as an iron longsword.*

How inspirational! How does it feel to be able to write like this, show an understanding of scientific concepts and have great fun playing with words? This, I feel, is not possible to encourage from students when there is a prescribed endpoint and method in how the writing should occur. This would likely not occur unless students had a dynamic and experiential sequence of investigations to stimulate them. As well, students' feelings of freedom as they select which writing task to learn by, must influence how they enter the process of writing.

It is not to say that a narrative writing task leads to a wonderful blend of experiential and explanatory tones. The teacher as evaluator still inevitably loomed. Students communicated during interviews that this school assignment was even more important because they did not want to disappoint anyone as the writing was going to be used for their teacher's research study. This may have led to the occasions where flowing writing was interrupted with statements of science facts that students felt should be included. Consider Sally's story: *Once upon a time, on a far away planet there was a vast and beautiful kingdom named Aichtoowoe. This kingdom consisted of, well, water . . the Floaters floated because they were not as dense as water, the Sinkers sank because they were denser than the water, and the Flinkers flunk because they either had the same or an extremely close density to the water. Anyway back to the story.* Even the structure of the middle definitional sentences is repetitive and indicates the function of providing scientific rationale to their names.

Yet, later in Sally's writing piece, a blend of experiential and explanatory tones is creatively shown. *'I don't understand why your density would change when new materials were added to you. You're still the same [you] aren't you?' inquired Corky dumbfounded. 'As I said, it changed my overall density as an object, not as a substance. In other words, it didn't change the density of the cork, but it added to my density as a whole.'*

Embodied writing in science

After our in-class workshops on writing, I encouraged students to push their understanding and writing further than just telling what was done in an activity or writing a fun story line. I believe some students have illustrated how an enhanced understanding comes when science stories are felt, while they are being written. This can be heard in students' writing pieces when there is a rich and exciting blend of explanatory and experiential tones.

Think of the active, personal involvement in the following actions that all share the prefix "em", as in embody . . .

embrace

embellish

embarrass

embroider

embody.

When an understanding of science terms and concepts resonates deeply within making personal connections, experiential and explanatory tones of writing co-emerge.

Use of terms in the writing samples

Grade Eight students were encouraged to demonstrate their understanding of floating and sinking using science terms to enhance their writing. In response to the first research question, I wish to explore how students' use of science terms, and relationships developed between terms, illustrates their understanding.

Students differ in their ability to use science terms in a way that is deemed as acceptable in the scientific community. In many if not all cases, when students veer from the scientifically encultured meaning of various terms, their understanding should not be seen as less valuable, but as a differing interpretation. From numerous writing samples, I see how students' understandings of terms and concepts relating to the phenomena of floating and sinking is deeply understood by the choice and way that the various science terms are used. How did a lab exploration in the physical properties of matter unit influence their understanding as shown in the writing task? Can this point to a possible origin of enhanced meaning of some of those science terms?

Erin writes about her understanding of mass, volume and density in her Flinkers piece. *Mass plays a part [in density], but not as much as you would think. If you had 1 cm3 of aluminum and 18 cm3 of wood, the mass and volume would be greater for the latter, but the density would still be greater in 1 cm3 of aluminum.* This understanding tightly links back to the exploration, It's not all Heavy Metal to Me, where students measured and compared the densities of various materials. This lab investigation provided the experiential base and hence tone, as Erin explains her understanding. Without the experiential nature of this event, quite possibly Erin may not have been able to make this clever application of a smaller mass' larger density.

In Lara's writing of Floatie and Sinkie, her understanding of density reflects the learning in Conniving Clay. *If you take the ball of clay and break it so one piece is bigger than the other, the density is still the same because each ball is made of the same stuff. Oh, [replied the fish], I think I get it. If you take different amounts of the same substance the density is equal per cm3, right?* This investigation was critical at getting students like Lara familiar with how density does not change when one material is just broken into a smaller piece. In this story form, Lara uses a familiar voice and words, and then makes a crescendo to science terms. Notice how "stuff" is replaced by "substance", and "amount" is replaced with "cm3".

The topic of particles has been a prevalent thread in the series of lab explorations in the entire unit. Tanner eloquently demonstrates his understanding of particles as he refers to atomic mass in a relevant context. *Materials with particles that have more of an atomic mass as an individual and are composed of many particles that are closer together will weigh more for their size (volume), and will be more dense.*

Tanner weaves his scientific understanding (which strongly overlaps with the scientifically encultured view) into all of the sentences he writes. This highlights differences in understandings of science terms and concepts compared to that shown in Kathy and Claire's writing. Their writing centers around the demonstration, Peel me a Grape. In their writing, Kathy has taken on the grape character Rob (*who had his skin removed by an evil being known as Mr. Harding*) and Claire has embodied the character and writes as Val, a grape with his skin still on.

Rob

[Kathy & Claire]

Although not contrary to what has occurred scientifically, does Claire articulate the differences between mass, volume and density? *My brother, Rob, was brutally skinned, which decreased his density, mass and volume considerably . . . then he was thrown in the 7up, which actually went inside of him increasing his mass and density again.* Compared to Tanner's writing, the level of understanding in Kathy and Claire's writing is not as developed.

These two writers structured their science stories by underlining various words and then a definition/meaning was supplied at the end of the story. For example, the explanation of density was written at the end of Kathy and Claire's story "The 7up Catastrophe":

Density

-The quantity of something per unit measure, especially per unit length, area, or volume.
-The mass per unit volume of a substance under specified conditions of pressure and temperature.
-Less dense means that the object will float in water/liquid
-More dense means that the object will sink in water/liquid
-Volume plays a big role in density

[Kathy & Claire]

The tone of language in these five sentences or statements is fascinating, as I think about their possible origin. The first two sentences sound like a dictionary definition, with phrases such as "per unit measure" and "under specified conditions". At no time in our classroom learning, had we talked about how pressure can have an effect on density. The last three statements (that do not have a period at the end of each) suggest the meaning that Kathy and Claire have attached to density. What is stated is correct, but it indicates a different level of understanding as the questions why or how, with respect to density are not explored. As well, the phrase "plays a big role" is something that I have heard myself say in class, and it lacks the formality and explicitness that usually accompanies a dictionary definition.

Upon reflection, I sense that there is a difference in openness of the three writing tasks. Flinkers is quite linear or purposeful in its format of responding – what did you do? Were you successful or not? What did you learn about the various science concepts? Students were excited by the Flinkers activity and this encouraged a number of them to write about it; however, some students commented on the fact that they were not successful in creating an actual Flinker that worked, so this did not encourage them to choose this writing task.

The Archimedes letter also had an endpoint of explaining how the crown was found to be impure gold, but it allowed for more exploration of voice and language as students could take on Archimedes' character. The stories and scripts with Floatie and Sinkie likely encouraged the most creativity in terms of what adventures or events the characters experienced, and possibly even the probing of scientific explanations. By taking on a character, this might lessen the risk in exploring tentative understandings. Listen to Rob the grape in Claire's writing: *Bubbles were coming into me then rushing out and I wished I had my protective skin. This happened because of the acidic reaction my insides had with the awful fizz in the 7up. As my body let the liquid in, my density changed and I was more dense than the liquid. I sank because there was no oxygen or air bubbles attatched to me.*

If the primary purpose in any writing exercise was to induce conceptual change, then analysis of these writing samples would lead to different findings. I would have needed to design a project that identified prior knowledge before the classroom explorations, and how these changed as a result of the classroom activities. I believe that an important thrust is that students come away from the classroom activities with a clear (and as accurate as possible) picture of what is happening scientifically. This I attempted to achieve by paying particular attention to which lab experiences were selected and what order they would occur in. In this way, by not introducing too many concepts at once, it would help students understand why certain things were happening.

Yet, it is very likely that students will hold onto certain beliefs, or have a particular, favourite explanation to use when it might seem feasible. This study is about tuning into the possibilities that can exist in open, expressive writing; however, at the same time, I was working with students in the classroom, largely through demonstration and discussion, to develop the most reasonable scientific understanding.

Conceptual development as the focal point of analyzing students' writing would narrow my (the researcher's) perspective of how the science terms are used. This would negate the value of one's personal understanding that can grow from this process of writing. In Brady's writing on Flinkers, he tells of his learning from a conversation with his lab partner during one of the workshops on writing:

A boy in are class [Bob] whent swimming one day and found a log thet was beread in the mud under water. The crent must of pushed it down into the water because when he poled it out of the sand it floted up a bit. Than he pushed it up out of the water and let some of the water drain out. After that he than put it back into the water and it floted cloce to the middle for about 10 minets but than something happened and the log sunk back down to the botem. What acrsholy happened was the log became water-logged and it's density changed and became hever than the water's density and it sunck.

In Brady's reflections on his writing, he tells of how he was inspired by a story that Bob told him about a log, and if he was to help other students with their writing, he would give them an example like Bob's. Is the social act of learning part of a teacher's focus when much of the literature on conceptual change suggests that cognition is an individual act? I do not believe that writing for demonstrating a change (as in an improvement) will encourage stories like Bob's to be re-told, as the structured model of constructivism will not promote this style of learning. Rather, students will still be reminded of the right answer as a goal, while other stories (interpretations?) lack merit.

The value of the act of writing would not be reinforced if students were pushed to seek the correct answer. This does not mean that writing-to-learn science should not push students to make sense of things with certain words to be used in their writing. By using relevant science terms, and having explanations that are grounded in one's experience, an embodied understanding may transpire.

Ah yes. The water displacement theory was discovered by this Archimedes fellow quite a long time ago, when he had a bath. Archimedes filled his bathtub to the brim and discovered when he got in that some water poured over the edge of the tub. He pondered at this and then discovered a new theory: water displacement . . . if an object was put in a liquid for example, that the liquid would rise up in the exact amount of the object, and it proved to be an accurate way of measuring volume [Fiona].

It is evident to me that these excerpts from the writing tasks are excellent, concrete examples of the ways in which students were able to express their understanding of concepts about physical properties of matter. They demonstrated deeper extensions in their thinking by interpreting the periodic table, elaborating on the lab investigations, and clarifying their understanding in their own words. What a wonderful situation for a teacher to experience – a classroom where students explore their ideas and understandings of sophisticated science content in their own language and writing styles. Compare this to copying facts out of a textbook, or off of the board! Promoting a sense of wonder and openness in the classroom offers possibilities for learning in school science.

Students' voices of themselves as learners

Students' powerful comprehension of concepts relating to physical properties of matter was illustrated in light of the first research question. The analysis about to be unraveled comes from seventy students' one-page reflections on the writing process and the audio-taped interviews of the twelve students who conversed for approximately forty-five minutes. Emerging themes are linked to the second research question: What are students' perceptions of their learning as they engage as writers in this way?

From my own lingering in and about the space of these science classes, some of the rich learning that transpired was not solely a result of the openness of the writing tasks. Other notable influences are heard in Tanner's reflections: *You gave us many choices about what we could write about and how we would write it and this let us write freely and creativly.*

The openness of the writing task mirrored that of how the students participated in the journey of scientific exploration. "If science is seen as facts to be learnt and right answers to problems and experiments, then the pupils expect a right answer to exist and if they get the wrong one, then they think *they* [emphasis in original] have gone wrong" (Fairbrother & Hackling, 1997, p. 891-2).

Influences such as being given choice of which writing task, encouraging students to write expressively and openly, having various interactive investigations act as the springboard for learning, reinforcing that the teacher does not hold the right answer, all contribute to an encouraging classroom climate for exploring one's own science ideas. What are students' views of the learning that went on?

Tanner includes in his writing piece: *Trying to build a flinker was very interesting and I found it to be a fun experience. It tested my brain by trying to get the object to flink, and thinking about why it wasn't. Here's what I discovered in my thinking* . . . From the excitement students generated in the classroom on the day they created Flinkers, it was clear that students had a lot of fun. For Tanner, it likely influenced his interest in writing and the extent to which he might dig into and remember some of the science concepts.

During audio-taped conversations, one student, Sally, spoke about how this type of writing task encouraged her to think about the words she was using in her science writing and if she truly understood their meanings. What she realized was learning was synonymous with "*going back and asking questions . . . and you think about it [the words] and then it helps you learn better because you ask yourself 'Do I really know this?'.*"

These types of writing tasks where students had to record their ideas in their own words was pedagogically better than other less personalized forms of writing. If students are just required to copy the teacher's definition or that from a textbook, the learning will have little to do with them, and not show their understanding of science terms. And a teacher may not see students' confusion over somebody else's words . . . *"We [students] get lost totally. Kids are really good at that – just making themselves look like they understand" [Carrie].*

My belief in the need for this research study arose from the disconnectedness that I sensed in many adolescents as their science learning and writing was far removed from them. The connection can grow, as students of this age are passionate beings. One goal is to create a science experience that is exciting, close to the learner, and for them to be thinking back on how their understanding is taking shape. Not only will this help them make sense of their experience, but it will also encourage students to be reflective of their own learning. Mitchell (1992) outlines the extreme importance of this (internal reflective and external reflective thinking) to overcome poor learning tendencies, and improve students' learning.

How adolescents speak compared to how those persons clad with science knowledge, is usually different. During interviews, I asked students what it would be like if they were listening to a group of scientists all talking together. Carrie responds: *"it would be like reading a really hard book or something; it would be like reading Shakespeare, we could understand some of it, but not all of it."*

It should not be surprising that, for many students, the language of science is less accessible compared to how adolescents naturally speak. Most people, including scientists, might also feel this way when they pick up a textbook or journal outside of their area of specialization. Kelsey and Carrie speak about what learning to use science terms feels like: "*The science stuff [words, facts] feels artificial a little bit [Kelsey] . . . because it is not as if we are talking, we're talking to get a grade, not the way we understand it" [Carrie].*

"A lot of it [the words] you sort of understand, but not really. Like it's not the type of language that you would normally use, so it's sort of like learning a different language. It's like learning how to be more scientific" [Carrie].

Carrie is sending out four valuable pedagogical messages: (a) she uses science words, even if she does not understand all of what she is saying; (b) she knows that being graded is a reality of her life in school; (c) she feels that regular conversation is very different than science language; and (d) she perceives being scientific requires speaking scientifically.

It is my belief that science educators should attempt to erode this barrier between the two distinct languages. If this was the case, students might feel invited to become expressive and scientific all at once. They are naturally curious and capable at designing experiments, so can this not be transformed into accessible, felt, scientific language? This may have been what occurred for some students as they fashioned a unique blend of experiential and explanatory tones. In the audio-taped interviews, participants speak about how the use of science words in class has influenced them. *"This year it's like starting out easy and building up, as if more scientific" [Carrie].*

"It's better . . . not saying any of the scientific words before. You just say that the bubbles are all tightly packed and . . . they move in slow motion. And afterwards you say this is called solidification, for example . . . It feels good kind of, you know when you are talking and then all of a sudden one of these words [like solidification] pops in here and you're like 'hey!' I learned that . . ." [Sally].

In a different way, Richard indicates his depth of learning from the Flinkers activity. Consider his words: *The flinker was childish looking, but had a challenging task . . . The neutral buoyancy task would involve a lot of previous lab knowledge such as density, mass, etc . . . there are still many un-explored ideas to Flinkie, but till then 'The Truth is out there' with density, buoyancy and mass.*

If this is as deep as he probes, what does Richard understand about density? How does it change from material to material? How does overall density of a Flinker affect its buoyancy in water? What is he really saying about his learning and understanding when he concludes his writing piece with *The Truth is out there*? By having students write from their own understanding, rather than repeat a myriad of detached facts, it will be quite evident in students' writing when they have not elaborated upon their understanding.

When students are given an open, as compared to a directed writing task, they can probe their own understanding and follow a path of exploration that is unique to them. I believe this is how personalized learning might be . . . students leading themselves in writing to explore themselves and their understanding concurrently. This open, expressive style of writing allows them to draw their own connections, or make their own extensions at the same time as discovering their voice as learners.

The following three students (Sophia, Jamshid and Ernest) all illustrate how they have probed their understanding, made their own unique connections or extensions from the King's Query, and evidently what they are capable of as learners. They all differ in academic performance in science, beginning with an A student, then a B student and then a student who has consistently and seriously struggled this year in many subjects.

In Sophia's Archimedes letter, she writes: *Both crowns sunk to past the glycerine and cornsyrup and the original crown stopped in the center of the bromine, though the pure gold crown continued on till it reached a bit before the border of the bromine and mercury (which was at the bottom because of its heavy atomic mass of 200.6 grams per certain number of atoms).* In her writing, she has elaborated on The Density Cocktail by adding elements that exist as a liquid at room temperature. Could we not put the crowns into these additional layers of the density cocktail? Has she minimized the feeling of getting the right answer? I believe that here, Sophia is illustrating that she can extend her understanding of physical properties of matter, to a unique thought experiment that she has created. In a sense, she illustrates what and how personal, connected science can look like, as she makes connections that are specific to her understanding.

Jamshid makes a connection to his learning in math class that is unique when compared to other students' writing. *I then found out what the surface area of the bucket was . . . measuring the diameter, which was 30 cm, dividing that by 2, squared it and multiplying that by 3.14 [706.5 square cm]. I then took the height of the bucket with the crown and subtracted the height of the bucket without the crown and found that it was 5 cm. I then multiplied . . .* What an impressive cross-curricular connection, reinforcing the value of learning in both of those subjects! I wonder if he actually performed this calculation at home, given some of his measurements?

Ernest has done something very important with his writing assignment. He has achieved the goal of completing the assignment, collectively set by him, his mother and his teachers at the end of an unsuccessful term one. Here is an excerpt from his Flinkers poem that he submitted:

I put in some tight particled bolts
With some loose particled foam,
It was so hard that I wanted to go home.
But I stayed and made my flinkers mass,
Whose flotation was in the center of the glass.
So it happened I learned a lot about mass,
Flotation, density and flinkers that day in class.

What is Ernest showing about the potential for open, expressive writing in science? His interest and ability to be creative has resulted in the bending of boundaries, at the same time as showing himself and others that he is bright. The question is about creating an opportunity which allows a student like Ernest to show his potential in writing.

Another way that students illustrate their cleverness is when they incorporate the use of humour or playfulness into their writing. It does make them distinct. Not only did it come into Ernest's writing on Flinkers, but throughout numerous of the Archimedes letters and the Floatie & Sinkie stories. Students might believe that their learning from writing is far more than showing an understanding of scientific facts. Listen how Sally playfully incorporates her sense of humour with an understanding of properties of matter.

King Onecent was a small and flat, but heavy piece of copper. The many particles that made him up were heavy and tightly packed making him sink. He had his mother, the queen tattooed on his back and the two maple leaves on his front. He was very attractive with his shiny read luster and slim figure. His good looks were probably the only reason why he was king because he didn't have much else to speak of in the way of personality".

What an insightful, refreshing change! Clean humour that is not derogatory…an example for adolescents and adults alike to consider.

Students' perceptions of their world

What is it like to be thirteen years old and dwelling in this classroom, as well as other classrooms? Do students communicate their concerns, joys or passions in their writing? Do these styles of writing allow them to be passionate?

A few interesting commentaries about students' perceptions of their world emerge from writing tasks. One commentary is their concern for the ecological crisis that humans have created. This is lightly broached as one Sinky character says *"Well, for a short while I was a floater like you, tossed into the ocean by some careless human" [Fiona].* In Kristie's writing, a stronger environmental message is coupled with a wise proverb about being satisfied with what you have: *'Well', said Sinkie, 'down here where I live People only come sometimes, and quite rarely drop pollutants into the lake'. . . Sinkie never did visit the world above [land], but sometimes Floatie would visit him. After what Floatie told him that day, he appreciated living at the bottom of the lake, his mass, and most of all the fact that he never went into the dangerous world that Floatie called home.*

The theme of good versus evil adapted to an ecological setting is seen in William's story entitled "Max the Cricket". This tale is unique as it is lived through the cricket's perspective as physical properties of matter are elaborated upon. In the tale, Max the Cricket cleverly escapes destruction from the evil empire of Ursila *(a large group of terrorizing animals such as crabs, hawks, dragon flies, spiders, rats and other nasty creatures)* by building a flinking boat. *After the evil creatures realized that they could not reach Max's boat, they eventually gave up and left. It was so peaceful now and happy here now, the perfect life for most animals. But, not for Max. He decided to take his boat and move to the seaside to study the buoyancy of fish [William].*

What complex thinking! Making sense of the Flinkers activity, but having it retold in a setting that has come alive for the student. It has become more than communicating the terms and concepts involved in floating and sinking, as it is an adventure where a flinking boat was needed for survival.

Another prevalent thought that permeates adolescents' worlds is the idea of love. Quite elaborately, the biochemical aspect of love (or lust) saturates one part of Tim's writing. *Being an average teenager Sinkie [the lobster] was chalk full of hormones and the day he saw Floatie his hormones said 'Hubba, Hubba' and his mouth acted accordingly. As Sinkie stared up through the crystal clear water at Floatie's long delicate tentacles and her lovely translucent body with purple veins he thought, 'if I could get her some fish she would be forever mine'.*

Pamela highlights the procedural side of love in a story "Floaty and Sinky Get Married". In it she writes: *they fell madly in love and decided to get married, but they had to fill out marriage documents . . . as follows:*

Marriage thing		
Sex	**M**	**F___**
Mass		
Volume		
Density		
Name		
Partner		
Age		

They had the wedding and it was wonderful and they just had a baby. It was slightly unfortunate though because the baby did not sink and did not float all it did was flink, because the baby was a combonation of a sinker and a floater [Pamela].

Sally plays with the romantic notion of love in her writing. '*I love you Jiggy [as in Thingymajig, as in a Flinker]. With all my heart and soul'. She pondered the words she had just said and realized that they were true. She loved that funny looking boy . . . she had found true love.* Yet, Sally ends her story with a punchy twist . . . *to make a long* *story short, the two lovers run away, leaving the greedy king and the evil father angry . . . don't ever try this at home kids, you'll get in big trouble. Love stinks'.*

Each of these students give readers a window into how they perceive their world and it is done with a sense of humour. This takes talent! The openness of the writing tasks encouraged personal expression; yet it did not always lead to this. I believe that it does illustrate what writing can sound like when it is a connected, meaningful and embodied endeavour. This open, expressive type of writing encourages one more space in today's schools for adolescents to explore who they are and how they express themselves in the world. It is exciting to see various students' voices come alive in their science writing as they demonstrate their creativity with ideas and playfulness with words.

This can be seen in Flinkers . . .

- *My flinking-deprived creation was then left dismantled and now only its memory lives on in this <u>Writing task</u> [Sandy].*

and Archimedes letters . . .

- *When I stepped into my bathtub I noticed that the water overflowed. The first thing I thought was, 'Damn, now I'm gonna have to wipe up the water' [Gavin].*

and Floatie & Sinkie stories . . .

- *Well sire . . . unfortunately the densities differed, meaning only one thing, thou hast been had by the vile, corrupt creator of counterfeit crowns! . . . Off with the head of the fraudulent fink! [Jamie].*

- *He [the pebble Sinkie Sunk] wanted to see the world. He wanted to be out of the lake, to breathe the air and to smell the flowers, and not be water logged, but he had a problem . . . his weight. He wasn't fat or anything, but his mass was much greater than that of water, making him sink [Kristie].*

Pamela also plays with her Floatie and Sinkie short story in a unique way. It is my belief that here she is pushing the boundaries of writing in science class, while also exploring her own voice.

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Pamela Pierce

In an interview after the writing pieces had been completed, Dani said *"I will keep this story forever. I may lose my notebook, but I always keep my stories."* When asked about this style of writing in science, she said *"I need to be more entertaining in my writing . . . that way it keeps <u>me</u> interested . . . I feel that my writing is both entertaining and informative."*

As students had demonstrated such creativity in their science writing tasks, I wondered whether or not they felt that scientific inquiry was itself a creative endeavour. This led to some interesting discussion during interviews.

Tom: Do you feel that scientists are creative and use imagination? Or do you see the terms scientist and creativity as separated?

Dani: Well, they have to be creative or else they wouldn't have tried to prove something wrong. They would have had to be interested in a little tiny bit at least and it gets you thinking creatively and, or else they wouldn't be able to figure out what makes that water, right? Because you have to be able to guess and test in a little way and you have to be creative with what you are thinking of.

Fiona: I think that scientists are creative in that they have to think about what are the possibilities and stuff to discover things. But the part that is not, it still is pretty creative but not as creative, is when they relay all the information. Because information doesn't become knowledge until you know about it, and you can talk about it, right? So they have knowledge and they refer to information and information isn't really creative unless you incorporate into something like a story, where people can read it and think 'Oh! Wow, now I understand', right? And also the good thing about a story is it keeps people interested.

Fiona has suggested how to incorporate *"information which can be hard and cold"* (her words) and transform it into a story which is a more inviting form. By doing so, is not the spirit of scientific inquiry, which is creative in itself, fostered? Is not the interpretive nature of scientific understanding maintained when it is written in a personalized and expressive way?

Exploring students' perceptions of their learning, in addition to their impressive understanding of science content, was an exciting process. In this study, students demonstrated that they could engage fully in an expressive and exploratory approach to science learning. From my observations in class, conversations with students, and their written reflections, I feel that our learning was indeed special. The care and respect of a supportive classroom environment encouraged students to write about things including and beyond science that were connected to their lives. These connections, combined with a demonstrated understanding of scientific language and concepts, reflect what I have called embodied writing in science. This, I believe, enhances students' learning far beyond any traditional lab report.

A Sinking thought

Although a repetitive call in the literature (Hand & Prain, 1997; Hildebrand, 1998; Rivard, 1994; Rowell, 1997; Sutton, 1996) sounds on for more writing studies to occur in science classrooms, several limitations of this particular study need to be outlined.

The interpretation of this study is from my point of view. It is laced with my beliefs, my biases, my current views that may skew what is reported of what went on. "The present is thus seen through the past, but the past is always seen from the point of view of our current situatedness" (Marton, 1993, p. 236). This is of concern for any qualitative research.

It is extremely unlikely that these results could be replicated by following the procedures outlined in this study. Too many unique elements exist that influence the kinds of writing that were created. For example, the socio-economic status of many of these students makes education a high priority by parents, and this is a very well-equipped school with an abundance of lab materials. A significant influence on the results of this study was that these students knew that their writing was going to be part of a University study, and this strongly pushed them to do their best. Since this is a community where University is an encouraged endeavour, this would have a lingering effect even on Grade Eight students' writing pieces.

Rivard (1994) writes that "research on writing-to-learn has been hindered because studies have not always been well designed or clearly reported, and few have been conducted in authentic learning environments" [emphasis added] (p.969). My sense is that this is an authentic learning environment, but do people realize how much of an influence a teacher has on students and the act of writing? This does not negate the writing that students created, but when their teacher also plays the role of University researcher, this might have a synergistic effect on how students engaged as writers. From conversations I have had with various educators, I strongly believe that the teacher has a sizeable influence on the classroom atmosphere, activities and how students feel about writing.

In response to Rivard's statement, I do not know whether the analysis of this study has been well designed. I feel that there is a lack of triangulation for the first research question, as it was just one person looking for emergent themes in students' writing pieces. This is where I have one sinking feeling. Emergent themes for the analysis of the second research question comes from reading students' writing pieces, reflections on writing and from interviews; here I feel that there has been a more professional and balanced analysis in response to this question.

Is this research study clearly reported? I have written it over a period of ten months, while working in the dynamic, enthusiastic, chaotic, living space of a Grade Eight classroom. One of the challenges for me has been to make some sense from the multitude of interactions of what might be going on. When I read some other reports and studies of writing in school science, I feel that they are oversimplified. For example, "students are encouraged to be imaginative, which will reveal whether or not they are comfortable enough with the vocabulary to express themselves freely and intelligently" (Johnston, 1985, p. 94). How were students encouraged to be imaginative? How can one tell if students are actually comfortable using certain science vocabulary? Intelligently . . .

A natural question that could be asked because of the design of this study would be: what can be learned about various genre in science writing? I have not attempted to respond to this question. Studying genre would include an in-depth analysis and discussion of organizational patterns and diction in the writing, as well as how the specific type of text is used and by whom (Kalnin, 1998). In this study, students were not made explicitly aware of the different genres that the writing tasks could be deemed to be an example of, nor did the analysis encourage a comparison of the merits between writing samples.

This is an exploratory study of how students engaged as writers in science class and the learning that transpired. Another sinking limitation is that it is not a long-term study, but rather a brief six-week snapshot of writing around one scientific phenomenon, with one grade level, in one school, with one teacher-researcher. Amidst these limitations, hopefully its few ripples may be sensed in some near and far places.

Flinking and thinking

In the midst of a scientific and technological revolution, it is fascinating to consider how the chapter "Experience and Thinking" in John Dewey's (1916) book Democracy and Education sheds some light on this study. I believe that the possible contribution made here comes from how the lab experiences in the King's Query contributed to students' writing in science. Dewey's writing in this book serves as a helpful and timeless account of how the doing or flinking might shape students' thinking.

It was very apparent that students enjoyed and felt they learned the best when they were doing the various lab explorations in the King's Query. It is interesting to see that some of the statements that Dewey makes, are values about experience and learning that enactivists today might support. For example:

> The very word pupil has almost come to mean one who is engaged not in having fruitful experiences but in absorbing knowledge directly . . . the intimate union of activity and undergoing its consequences which leads to recognition of meaning is broken; instead we have two fragments: mere 'bodily' action of one side, and meaning directly grasped by 'spiritual' activity on the other (Dewey, 1916, p. 140-141).

I believe that in the learning events of the King's Query, students participated in a setting which engaged the whole person, in body and mind.

There was purpose in their activity. Not the sole purpose of conceptual change, nor the purpose of creating a hands-on learning experience, but an inquisitive splashing in the learning medium and attending to the waves, sound and ripple patterns of the experience. Students would be shaped by this as Dewey suggests, "we do something to the thing and then it does something to us in return" (p. 139).

The experiences in the King's Query were put together to encourage more than school science entertainment, but an attempt was made to create an exploratory space with relevant questions that stimulated students' thinking. With each lab experience, a step was hopefully made in the students' journey of learning, as one piece of a puzzle could be better understood. In this way, the activity was reflected upon and the learning made from the experience would be steeped with significance (Dewey, 1916). How the lab experiences, the students' actions, the reflections of learning came together could be viewed as the learning space between flinking and thinking. "Thinking, in other words, is the intentional endeavour to discover specific connections between something which we do and the consequences which result, so that the two become continuous" (p. 145). My sense is that the learning from students' participation in the lab experiences, and the articulation of science terms and relationships between terms, is where the value of students' writing tasks comes from.

Eureka – a contribution?

In her review of current writing practices in school science, Rowell (1997) makes a claim that writing in science classes is not generally perceived as a socially situated activity. It is my belief that this research study has the potential for science educators and researchers to see how the students' writing was influenced by their own actions, the involvement of their peers and the teacher, and how it would be very difficult to separate one aspect from another. Rowell summarizes that there are three dimensions about writing in school science that can be understood: (a) the writing allows for personal interpretation; (b) the writing is transformative as students make the knowledge their own; and (c) the conventions of writing become more aware to students as they write more. It is my sense that students' writing samples, and their reflections of their learning as they engaged as writers validate Rowell's summary of personal interpretation, transformation, and conventions of writing.

- *I think that we should do more of these writing pieces at the end of a unit because it's kind of like a summary of everything that we learned. Also we get a chance to use our own words to explain how we understand a topic that was just taught. I wish that we had learned this way last year because I probably would have been inspired to write more and do more than what was required [Sally].*

- *I'm afraid I mostly had fun with words on this project, but I also learned how to entwine science into my writing [Jasmine].*

Another contribution this research study makes could be how it illustrates the importance of the learning context as students engage as writers. Moore writes that in the 1990s, "contexts for literacy [also] were said to include entities such as teachers' instructional goals, the resources made available for accomplishing the goals, the participation structures of teacher-student and student-student conversations, and participants' stated orientations toward literacy events" (1998, p. 265). I believe that this research study is far from exceptional in responding to these various components of context, but the students' lab and classroom experience that led toward the writing tasks was carefully designed. The atmosphere was rich in providing cues in which to begin writing about, and the timeless story of Archimedes and the crown that went alongside the classroom investigations, was stimulating for students. One student, Tanner reflected upon what was different for him . . . *most of the time we are just given a page long assignment and told "Just Write!"*

I think this is such an important component of any study – what were students doing or not doing that encouraged them to become writers? This is illustrated by default in Levine and Geldman-Caspar's empirical study on informal science writing preferences, as they, the researchers worked with students who had little familiarity of informal writing. Grade 7 students were given five choices of writing tasks to pick and write about for half an hour; tasks 1 – 3 included the expressive, descriptive, and narrative mode, whereas tasks 4 and 5 were a dialogue and a free-writing task. "Task 4 and task 5 were not analyzed due to the limited number of students who chose them" (1996, p. 425). It is interesting to see that the dialogue and the free-writing task were not chosen, but for all of the possible writing choices, what was lacking was the development and relationship between student, science phenomena, teacher and writing. The context needs to be understood as the underpinning of students' writing, and preference for that matter.

Eureka – I have an idea! If the idea makes sense and I am able to communicate it, to whom is it most relevant? The possible contributions from this research study are towards three different, although interconnected areas: the research community, to science teachers, and to me personally. In the previous paragraphs, I have outlined the possible contributions to the research community.

For science teachers, I believe this study sheds some light on what Donald Schon describes as "reflective teaching: listening to kids and responding to them, inventing and testing responses likely to help them get over their particular difficulties in understanding something . . . helping them discover what they already know but cannot say, help them co-ordinate their own spontaneous knowing-in-action with the privileged knowledge of the school" (1988, p. 19). Teachers can easily use the collection of lab experiences that give students a story and a reason to study physical properties of matter, and if teachers are interested in having students experiment in writing, then three different writing tasks (Flinkers, an Archimedes letter, and Floatie & Sinkie stories) have been outlined that accompany the King's Query. This experience with students and writing may linger on and have pedagogical implications similar to that discussed by Anthony Pare (1994): having students write as part of ongoing activities, or write in many different roles or voices, or write collaboratively.

The implications of this research study to me, personally, run deep. It is a meaningful endeavour as I have watched students be engaged in their learning, and demonstrate that it is connected to them. Where are they and who are they and how do they create themselves in this picture? It is through their voices that I have developed a slightly better sense of what learning and writing in science might look like. As I near the end of my Masters program, I reflect upon one major thing that I have become more aware of and how it permeates thought, action and being.

This is language.

To describe its effect or influence is to undermine what it is.

Can we ever come freshly to language?

Children have already acquired natural ways of language that may be powerful or clash in a school setting (Kress, 1989). This makes me begin to think about how I use language, the diversity of students' language and how this shapes their roles, and how we collectively engage in any form of communication. My role as a teacher does not become easier, but much more lively. "A sensitivity to language coupled with conscious attention and discussion in the classroom seems particularly important to educators of adolescents today as what it means to be literate shifts and changes" (Kalnin, 1998, p. 280).

In the excitement and chaos of the classroom, I attempt to be careful about how I select my words, largely for pedagogical reasons. Scientific language can be an exclusive tool, and it is my aim that students have equal access to the learning in science regardless of what their family background and language use is like. I want to encourage the opportunity that students under my care can become scientists if they desire. Hence, I try to use language that embraces the idea that science is "something that real people actually do as members of a social community in the course of ordinary working days" (Lemke, 1989, p. 33). At the same time, I do not want there to be conceptual limitations (a bond becoming a real entity that actually exists between hydrogen and oxygen in water) in my use of language, which is probably persuasive because of my role as a teacher. Lemke (1989) comments on a study where students were three to four times more likely to pay attention to teachers when they broke from the official language of science and used more familiar language. The message to students was that the serious business of the lesson became recognizable through the scientific language that was more important and dehumanized. How we speak and shape meaning in an open and expressive environment needs to be done with care.

Finally floating freely!

At times I feel that the discussion of what is learned as someone writes is virtually too big to respond to. How can it be answered with much confidence, as so much influences the web of relationships between writing and learning? From students' voices regarding their learning in this research study, some value can be attributed to their experience in writing, although it cannot likely be pinpointed as such. If one of the goals of schooling is for students to gain an understanding of who they are, then there is value in having students to write expressively in science class. "By reading and writing the texts of their lives, they [adolescents] are reading and writing themselves" (Neilsen, 1998, p. 4).

I think that writing freely (almost) was fun because we were allowed to use imagination along with scientific facts. It's a lot different from writing reports, because writing freely is much more fun to read, and everyone gets to pick what they do best [Kristie].

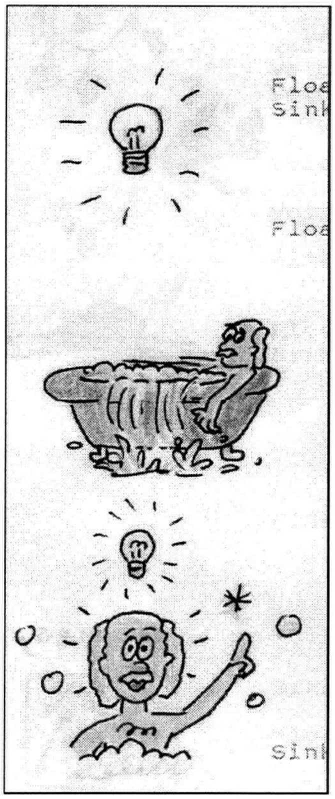
After reading students' writing – Flinkers passages, letters by Archimedes, and Floating and Sinking stories, I felt that some students might have had a floating or a free-ing feeling as they played with words. It may have allowed them to experience science writing as they had never participated in it, and with it, before.

> Adolescents need spaces in school to explore multiple literacies, to experiment . . . to receive feedback and guidance from peers and adults. Such spaces are not provided by schools and curricula that are designed to teach an idealized (technical) literacy to idealized (adept and compliant) adolescents via the medium of idealized (canonical) texts" (Phelps, 1998, p. 4).

I found it [the Archimedes letter] was a lot more fun than writing an essay because just by calling something an essay makes it hard to write [Gavin].

Maybe this story can encourage more discussion of what it means for adolescents to write in a personal, and scientific way. If learning feels most connected when it is entwined in students' experiencing selves, then their expression of themselves and their learning of science might create a wonderful freeing feeling. Then, embodied writing in school science <u>would</u> approach the world of the fantastic.

Well, the reason I felt better and was more enthousiastic about this writing assignment was the fact that we had more freedom and I could go out on a limb and start writing and writing and writing. [Usually] you have to follow very strict guidelines. So my imagination is all caged up. But with Science we can unlock that cage, think of every little option and probability and improbability . . . If I was to give a tip to another grade 8 I would say "don't be afraid to put down an idea that seems stupid. And never stop with the minimum, always try to go the extra mile and make it fun. Because it is more interesting that way believe me" [Devon].



[Fiona]

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