Introduction

Consider a school in a remote community several hours traveling time from the nearest metropolitan center. Regular excursions to the city are limited to a few times in the year when the weather and traveling conditions are favourable. Being an isolated community with resource-based economy, it is not large enough to support a full K-12 school system. As a result students are arranged in split-classes as follows: K – 2, 3 – 6, 7 – 9 and 10 – 12. Nonetheless, the enterprising people of the community are determined to provide the best possible education for their children.

Within this context, funds are available to design a technology-enhanced learning environment for the transition grades of 7 – 9. According to the funding agency, the primary objective of the learning environment should be to engage students in learning, improve their academic performance, maintain their scholarly interest, and prepare them for future learning. While numerous curriculum topics exist within these grades that need attention, this proposal focuses on a technology-enhanced learning environment for teaching chemistry.

Teaching chemistry does present some significant challenges. Much of chemistry is the study of intangible concepts that require models to assist with conceptualization. Necessary is the development of new ways of thinking and exploring. The teaching of abstract concepts to adolescent children is challenging because most of their earlier learning has relied primarily on exploring and coming to understand the more tangible aspects of their world. Additionally, concern exists with the ever-increasing complexity necessary to describe chemical phenomena. The development of quantum theory represents a shift in chemistry thinking and has been linked to difficulties associated with learning chemistry and keeping chemistry relevant. (Erduran, 2001) While acknowledging that older chemistry models may not stand up to quantum theory, it is believed that these models still offer a good qualitative description matter. “Models can act as interactive schemes bringing together students’ diverse experiences in science across grades K-12.” (Erduran, 2001) Models are schemes or structures that correspond to real objects. Through technology interactive models can be designed to concisely and appropriately explain the nature of matter.

Models can be visual but not always. This is an important consideration. Conceptual models utilizing formulae and mathematical formula are effective in explaining physical properties; however, they may not possess significant visuospatial properties. Visuospatial refers to the ability of an individual, in an environment, to comprehend the visual perception of the spatial relationships of that environment. The out-of-school learning of today’s students is influenced greatly by virtual technologies (video games and television) that enhance their
visuospatial ability (Habraken, 2004). Considering the significance of the visuospatial learner, the introduction of chemistry through traditional pencil and paper, or chalk and blackboard methods, may not lead to the desired student understanding and competency. Owston comments: "They [children] tend to be more visual learners than previous generations because their world is rich in visual stimuli." (Owston, 1997, p.30)

Of additional concern, the remote community is isolated from many of the learning aids that a larger center enjoys. Field trips to science museums and university laboratories are out-of-school advantages that can further understanding but are, unfortunately, unavailable to these students. Moreover, being a school in a small community means that laboratory equipment and supplies are extremely limited. Implementing technology in the classroom can provide students an experience that will further anchor and develop their understanding. It is possible to deliver interactive models that will bridge the resource gap and provide students the educational advantages they have been missing. This will result in improved understanding of chemistry and its principles.

Need
Grade 7 - 9 science curriculum requiring appropriate student competency as outlined in chemistry outcomes. The time allotted for this science unit is 6 weeks. Grade 9 students require a strong, well-anchored conception of the matter and materials upon which more advanced concepts can be developed.

The importance of learning theory, particularly as it applies to the use of technology in the classroom, will be heavily relied upon to make the limited resources as effective and efficient as possible. A blend of cognitive and constructivist theory underpins the pedagogy for this series of lessons and socio-cultural interaction will be used as a means for students to explore new information together and reinforce their understanding by articulating to one another their knowledge building.

Educational Challenge - Problem Statement
To create a technology supported environment for introductory chemistry appropriate for grade 7 - 9 students. The environment will address the difficulties faced with learning chemistry and the challenges of teaching the subject in a remote rural community.

Rationale / Learning Theory
Teaching styles are based on theoretical frameworks of learning from which educational practices have been developed. Pratt (2002) describes the personal teaching theory as “an inter-related set of beliefs and intentions that give direction and justification to our actions’ and as a ‘lens through which we view teaching and learning’. The teacher of the grade 7 – 9 class in our remote
school community has a challenging assignment; that of providing curricular learning outcomes to a range of three grades, with students of differing learning styles and abilities, while fostering excitement for the material. He is aware that his didactic teaching model is not the best practice and has taken several courses recently to upgrade his skills. He believes that collaborative type learning situations are the perfect fit for integrating the curriculum in his multi-grade classroom. The teacher’s goal is to enhance the grade 7 – 9 chemistry curriculum with learning activities based on social constructivist theory. He realizes that previously his science classes were notoriously non-inclusive of inquiry practices. He further believes that his prior connectivity to his students has helped them build self-esteem. Now his goal is to branch out towards challenging his students to bring their personal knowledge to their learning situations. This opportunity will allow students to share and collaborate with others. Motivated, the teacher realizes learning with technology provides an opportunity for creative discovery “because computers are pervasive, they facilitate an easy flow of information that allows kids to put forth theories, receive constructive feedback, and mold new theories relatively easy.” (Ferguson, 2003) Perhaps more significantly, the students all bring differing levels of scientific knowledge to the classroom environment. This represents what the teacher wants to build upon; the varied knowledge levels that will help students construct understanding of science topics and phenomena.

In this multi-grade classroom, the teacher is setting the stage for the developing learners to share and work together through hands-on activities, experimentation, communication and ultimately act as co-participants in their personal development. Knowing that Vygotsky, “was deeply interested in the role of the social environment, included tools and cultural objects, as well as people, as agents in developing thinking.” (Bransford, Brown, & Cocking, 1999), the teacher considers Vygotsky’s research and methodological developments in the area of social learning. Vygotsky’s ‘Zone of Proximal Development’ – “when an observable difference exists between a mentor’s and a learner’s stock of knowledge, and leading activities support the acquisition of knowledge or skills by the less-experienced from the more-experienced learner” popularized the concept of a ‘community of learners’. (ETEC 512 course notes and Driscoll 2000)

The tools utilized in the teacher’s technology rich lessons have the “potential to enhance children’s learning and opportunity”. (Blanton, 2003) Through the computer programs, simulations, and visual demonstrations the learners are enabled to enrich their life experiences and knowledge. Within the five lessons on chemistry principles, technologies are varied and the learning is shared through class and teacher accessible e-folios. Sharing is further enhanced through student presentation and video conferencing technologies. The teacher plays an important role in helping shape the pairing of the students and guiding the students in critiquing and revising each other’s ideas. (Linn, Clark, & Slotta, 2003)
A series of chemistry lessons culminates in a large problem based learning (PBL) project that ties all of the learning activities together. PBL has been considered a successful way of furthering understanding. “Designing contexts for problems that connect to students’ personal concerns can motivate students to reconsider and revisit their ideas long after science class is over.” (Linn et al, 2003) The students will consider chemistry in the environment of the real world.

### Classroom context

The teacher needs to structure the learning environment so that students feel comfortable to respond, acquire information and construct new knowledge. (Mayer 1993) This need and desire for structure in a learning environment, as an important principle of learning, stems primarily from constructivist theory. Constructivist environments demonstrate the need to develop environments that promote cognitive understanding. The technology enhanced science environment that the teacher is implementing provides the impetus for students to move forward in their learning.

The resources available to the teacher in this context are limited although computers connected to the internet are at their disposal. The school has been provided with a sufficient number of computers each with high-speed satellite internet links. Students have become proficient with the computers.

The physical classroom is a large open-plan room with large windows providing most of the required lighting. Twenty-four laptop computers are stored in the same number of study cubicles found against the two opposite walls adjacent to the windows. The notebooks are wirelessly connected to the internet allowing for greater flexibility and mobility about the classroom. The center of the room has 6 round tables large enough to accommodate 5 students each and small experimental apparatus. Students may work individually or in groups at the tables depending on the task at hand. The room is equipped with a projector connected to a computer for presentations viewable from the tables. The teacher also has access to a student response system (SRS) that will help facilitate student discussion and allow the teacher and students to assess understanding. Finally, the room is equipped with video conferencing unit also connected to the projector that allows for two-way communication between the classroom and external resources.

### Preliminary activity – Establishing an eFolio

The students are asked to keep a weblog (blog) of many of their activities in this environment. This web based applications allows students to upload text, images and video. This blog will be referred to as a learning portfolio or eFolio. The eFolio will serve as a repository for the information gathered throughout the units and can be contributed to by either the student or the teacher. The eFolio serves as a social medium, as maintained by Vygotsky for its importance to learning, to assist students in their cognitive development. A specific advantage
of the eFolio is the promotion of active interaction by all students with the learning - not only the vocal, outgoing students. The eFolio additionally serves as a reference that the students may review both inside and outside of the classroom.

Lesson 1 – Particle Theory and Phase / Chemical Changes

Learning Outcomes

Students will learn and use important scientific procedures for collecting, observing and measuring characteristics of matter.

- Record textual information into a web-based portfolio.
- Plan and organize observations, records and measurements.
- Exhibit proper techniques for measurement and data recording.

The particle (or kinetic theory) of matter will be researched and discussed with peers. Specifically, students will investigate and formulate explanations for:

- properties of liquids, solids and gases.
- relationships of physical states of matter with temperature.
- differentiating between state changes and chemical changes.
- characteristics of substances in each physical state.
- comparing the properties of various substances in the same physical state.
- explaining changes in volume and/or shape of matter with temperature.

Students will verify and differentiate the behavior of particles in the solid, liquid, and gas phases through direct experimentation and observation.

Part 1 - Introduction

The introduction to the module begins by reviewing and capturing students’ existing knowledge and understanding of mass and materials. The students are given the task of identifying 5 substances that are found in each of the physical states (gas, liquid, solid) at room temperature, creating a table for this information on the computer, and outlining two principles they understand about matter and materials. A teacher led discussion follows the exercise where specific ideas and understanding associated with mass and materials are probed. This discussion and the ideas forthcoming are summarized by the teacher and added to each students’ eFolio as “Initial Theory of Mass and Matter”. The objective here is to uncover students’ previously anchored ideas related to the subject to which new learning and concepts can be attached. Ausubel explains, “Anchorings ideas are the specific, relevant ideas in the learner’s cognitive structure that provide entry points for new information.” (Driscoll, 2005)

In order to ensure a good understanding and basis upon which further learning can take place, this introduction also serves to reveal student misconceptions, both to the students themselves and to the teacher.
stage these misconceptions are simply noted and recorded in the electronic portfolio but not corrected. In summarizing research literature Clark and Jorde (2004) point out that “…students’ experientially based ideas (that) are tangential but disruptive to instructed ideas.” and that “By first helping students revise their experientially disruptive ideas and then helping students connect these revised ideas to the instructed ideas, we increase student understanding”. The intention of bringing student misconceptions to the surface is to force students to confront these misconceptions through experimentation and observation.

Part 2 - Particle Theory and the Properties of Matter

After reviewing and summarizing student conceptions of matter and materials the students are directed to the web site: http://www.le.ac.uk/se/centres/sci/selfstudy/particle01.html#propertiesofmatter and then to the following animation: http://www.dac.neu.edu/physics/b.maheswaran/phy1121/data/ch04/anim/anim0402.htm.

These animations help students to create visual representations of the concepts being learned thereby assisting the learning process. “Mental representations of the world are real and necessary for cognition. Rather than “pictures in the head,” these might now be thought of in terms of associative networks, which have a neurological basis and which are activated by sensory inputs.” (Winn, 2002, p.6)

While visiting these two web sites students are required to make notes in their eFolio summarizing the information they have discovered on these web sites. An on-line form guides the students with specific questions to help them ascertain the important points.

Once the students have completed their research into particle theory and the properties of matter the teacher then brings the class together to discuss the readings and concepts discovered. A brief, concise summary of particle theory and properties of materials is provided by the teacher and then the class is engaged in a “Jeopardy” like game using a SRS or “clickers”. Students are presented with questions that challenge pre-existing notions and are then encouraged to discuss their answers with their peers before responding to the question. A histogram of responses, with the correct answer identified, is then presented to the class as feedback. This interaction provides each student with
immediate, personalized feedback as to their understanding and, just as importantly, feedback to the teacher as to how the class is doing as a whole. With clickers ID’s assigned to specific individuals the teacher can also identify those students in need of remedial help. This type of interaction creates two distinct types of participation: the conventional social interaction associated with a classroom and the anonymous informatic participation made possible by the clickers (Roschell, 2003).

In preparation for an in-class lab experiment the students will be directed to conduct an online experiment at: http://www.chm.davidson.edu/ChemistryApplets/PhaseChanges/HeatingCurve.html

Based on this simulation students will predict what they expect to observe when a beaker of ice is gradually heated to the point of boiling. Students will work in small groups and record the temperature of the ice/water as a function of time. Conclusions from the experiment will be added to the students’ eFolios as a concluding entry for the lesson.

Upon completion of the lab exercise students will document their results in an eFolio entry guided by leading questions that ensures students extract important points. Once students have completed this exercise they will be directed to the weblink http://www.chem4kids.com/files/matter_intro.html. This provides an important review and summary of particle theory and phase/chemical changes before the students complete the lesson with an online quiz.

To ensure the students have achieved an appropriate level of knowledge about particle theory and phase / chemical changes the students will take an on-line quiz. The quiz tool randomly selects questions from a test bank so that students can each be given a unique combination of questions, regardless of how many times they are required to take the quiz in order to achieve the required level of proficiency.

Lesson 2 - Solutions and Mixtures

Learning Outcomes

Moving away from chemical properties of matter, this lesson focuses on physical interactions of matter, specifically, the students will be asked to explore liquid-liquid, liquid-solid and solid-solid interactions. This lesson will ask the students to perform some physical experiments and utilize technology to record, explain and present their results. By the end of this lesson the students will be able to:

- explain the difference between the terms solvent, solute and solution.
- differentiate between solutions, mixtures, saturated and unsaturated solutions.
- differentiate between soluble and insoluble substances (salt, sand).
• describe the meaning of the terms solvent, solute and solution.
• explain the difference between solution and mixture using particle theory.

Lab Exercise
For this lesson, lab stations should be established at each of the six tables consisting of a container (beaker) into which two substances can be combined. Split the students into groups and assign each a lab station where they can mix together the following matter combinations:

• sand & flour
• water & sand
• water & sugar
• water & vegetable oil
• water & flour
• vegetable oil and sugar

Each station should be provided with a computer and web camera that can be used to record the mixing process. The video that is recorded should be stored to their eFolio and will be used to present to the class each group's findings. Additionally, the students are required to explore the web to help them describe the process. The web site Chem4Kids has a good description of solutions and mixtures (http://www.chem4kids.com/files/matter_solution.html).

Through leading questions, each group should be asked to identify the solvent, the solution (should either exist) and the type of solution or mixture that results. The technology not only helps them find the answers to their questions, but it helps them present their answers to the class. In turn the video presentation and description process will help the students gain a deeper understanding as they attempt to teach their fellow classmates. At the same time, the students now can draw parallels and conclusions between their presentations and those of their classmates. Open discussion should be encouraged. Lastly, the video presentation has the added benefit of showing concepts that may be difficult to describe. This should speak to the visuospatial qualities of the learners and as such will provide a second opportunity to develop deeper understanding.

Lesson 3 - Fluid Properties
Students will develop an understanding of the fluid properties of matter through guided research activities and experimentation. Specifically, students will learn:

o the concepts of density and viscosity of fluids.
o to differentiate between viscosity and liquid density.
o how to calculate a fluid’s density.
o to use Archimedes’ principle explore mass.
 o to use the particle theory to describe the relationship between mass, volume and the density of solids, liquids and gases.
Part 1 - Exploratory Activity

The topic of fluid properties will start with a quick review of particle theory and properties of matter from Lesson 1 and solutions from Lesson 2 guided by the teacher. After a short presentation and discussion students will break into groups and identify properties of matter. Each group will create a short, meaningful descriptions and/or illustrations of the properties they identified and will add it to a glossary in their eFolio. Students are once again forced to bring forward important anchoring ideas related to the upcoming new material.

Part 2 – Density

Once the website glossary has been completed the students will begin working individually using their laptop computers to read about mass, volume and density in supplementary print materials and complete the online exercise located at:
http://www.edinformatics.com/math_science/mass_volume_density.htm

Upon successfully completing the online exercise the students will again form groups and revise and update the properties of matter in the glossary that was created earlier. Each group will then generate one question, along with a corresponding answer, related to their online reading exercise and post this on a common eFolio for this lesson. In addition, the group will formulate at least one question for the teacher that identifies a difficulty they continue to have with the subject.

Once all of the groups have completed the task of updating the glossary and generating their questions the class will come together to discuss the topic using the questions as a springboard for the discussion. To encourage participation of all students the discussion will take place not only verbally but also in a cyber-space chat room where only the teacher can identify the source of the comments (to encourage shy or reluctant students to participate). The teacher can then present problems that probe for conceptual understanding of the lesson allowing students to work collectively to solve these problems. Once proficiency at solving the problems is achieved students then visit a computer-based quiz tool so their individual performance can be assessed and remediation be put in place if necessary. These steps in the students’ cognitive development reflect a constructivist approach to developing an understanding of the subject.

Part 3 - Activity/Lab

In preparation for a practical lab involving measurement and calculation of density the students are directed to the following website to perform this online density experiment: http://www.explorelearning.com/index.cfm?method= cResource.dspView&ResourceID=17. Incorporating the virtual experiment into the curriculum here removes the complexities and distractions associated with physically conducting an experiment allowing appropriate focus on reinforcement of the material to be learned.
**Lab Experiment**

Students, working in small groups, will investigate density and buoyancy effects of various materials. At each table a beaker, with graduated markings for volume, is placed and filled with a different fluid (water, vegetable oil, vinegar, orange juice, soda pop (with carbonation removed) and shampoo). A small digital scale is available at the teacher’s desk so student can measure the weight of plastic, egg-shaped containers and the contents of those containers. The egg-shaped containers are each filled with different materials: iron pellets, wood chips or sawdust, dirt or sand and a mystery material. The students record the weight of each of their “egg-shaped” containers into a spreadsheet template on their laptop computer (see sample below).

From the measured fluid displacement and the weight of each of the “containers”, the density of the fluid in each beaker can be calculated using the arithmetic functions within the spreadsheet.

Upon completion of the experiment, students will post their results to this lesson’s website and compare the results they obtained with those of fellow students.

**Fun Experiment:** Who’s Denser – Boys or Girls? (if time and weather permit).  

<table>
<thead>
<tr>
<th>Container</th>
<th>Weight</th>
<th>Height of Fluid in Beaker with Container</th>
<th>Fluid height without container</th>
<th>Millilitres of Displaced Fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron pellets</td>
<td></td>
<td>Water</td>
<td>Vinegar</td>
<td>Veg. Oil</td>
</tr>
<tr>
<td>Sawdust</td>
<td></td>
<td>Water</td>
<td>Vinegar</td>
<td>Veg. Oil</td>
</tr>
<tr>
<td>Sand</td>
<td></td>
<td>Water</td>
<td>Vinegar</td>
<td>Veg. Oil</td>
</tr>
<tr>
<td>Mystery</td>
<td></td>
<td>Water</td>
<td>Vinegar</td>
<td>Veg. Oil</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Container</th>
<th>Weight</th>
<th>Calculated Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron pellets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sawdust</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mystery</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculated Density = Weight of container ÷ millilitres of displaced fluid (kg/cc)
Part 3 – Viscosity

The teacher will present information and demonstrate the concept of viscosity to the class. A number of different fluids including alcohol, water, oil, shampoo, honey and molasses will each be poured from one container to another and students will be asked to write a sentence describing how each fluid pours from its container. The teacher then introduces the term viscosity to encompass all of the student descriptions.

The students are then directed to the following websites to read about and experiment with viscosity for themselves:

http://nasaexplores.com/show2_articlea.php?id=03-040
http://atlas.geo.cornell.edu/education/student/viscosity.html

This form of discovery learning, Bruner maintains, is an important means of cognitive development (Driscoll, 2005).

Once the online experiment is completed, students will write their own definition of viscosity and add it to the website’s glossary.

As a review exercise and to consolidate the information and concepts developed in the first three lessons, the students will read pre-selected sections and answer prescribed questions from the following website:

http://antoine.frostburg.edu/chem/senese/101/matter/index.shtml#objectives

Lesson 4 - Atoms, Elements and Molecules

After gaining an understanding of matter and its properties, the next activity for the students is to consider the chemical makeup of matter. Building on the previous lessons, students in Lesson 4 will explore matter further through the investigative consideration of atoms, elements and molecules. After completion of this lesson students should be able to:

- Demonstrate an understanding of basic atomic structure
- Describe an element as a pure substance made up of one type of particle or atom with its own distinct properties.
- compare the similarities in properties of families - atomic structure and properties and utilize the periodic table to predict physical and chemical properties
- additionally consider the arrangement of the table of elements - based on atomic structure, groups or families of elements. Look at the horizontal rows and vertical columns (periods).
- demonstrate the an understanding that compounds molecules comprised of 2 or more atoms.
- Explore and construct molecular structures

This particular lesson will draw from primarily from the online resource Chem4Kids (http://www.chem4kids.com). This web resource describes basic
chemical principles that are not too advanced for younger students. The web is a valuable resource for introducing topics without resorting to expensive textbooks.

**Part 1 - Exploration activity (Atoms and Atomic Properties)**

Since atoms are the building blocks of all matter, a basic understanding of atomic structure is necessary. In this exercise students will be asked to think about what atoms are. Further to this they will be asked to describe the three components of all atomic structure, the proton, the neutron and the electron. A good place to start is the Chem4Kids website: [http://www.chem4kids.com/files/atom_intro.html](http://www.chem4kids.com/files/atom_intro.html).

Assign groups of 2 or 3 students to one of the notebook computers in the room. Using leading questions the students are required to make an entry in their eFolio describing the 3 atomic components of an atom. ([http://www.chem4kids.com/files/atom_structure.html](http://www.chem4kids.com/files/atom_structure.html)).

While there is more advanced information on atoms available at Chem4Kids, these first two pages provide a basic understanding necessary to move on to Part 2, however, advanced students may be encouraged to read further. As a means of review and before moving onto elements, the students will draw their own atom using a graphics program and then post the graphic to their eFolio along with a description of the components and significance of atoms.

**Part 2 - Exploration Activity (Elements):**

As with atoms, a background on elements is required before asking the students to examine elemental properties. Once again Chem4Kids provides a resource for the chemistry of elements ([http://www.chem4kids.com/files/elem_intro.html](http://www.chem4kids.com/files/elem_intro.html)). From this activity, students should record what an element is, how it relates to atoms and how the periodic table is configured. After the students have completed the section on elements some time should be spent discussing the main lessons of the website. Of importance is that atoms are larger as you move from left-to-right and down the periodic table and the recognition that families of elements share common properties. This will be explored in the laboratory.

**Part 2 - Laboratory exercise (Video Conference Laboratory Exercise (Alkali Metals))**

The elements of the alkali metal family are highly reactive due to the single electron in the outer valence of each atom. As an example, alkali metals react (violently in the cases Potassium, Rubidium, and Cesium) when exposed to water. This particular periodic family dramatically demonstrates how families of elements share similar chemical properties to other members of the same family.

Unfortunately it is not possible to bring this experience into the classroom via conventional means. While it would be ideal for each student to experience
the chemical properties of this family first hand, it would be ill advised to attempt with students due to dangers of fire and injury.

Through video conferencing it is possible to visit a lab without leaving a classroom and without unnecessary risk to the student. The video conferencing equipment is comprised of a projector or television set and a camera on both sides. This allows the classroom to see the lab and the lab to see your classroom. The camera in the lab should be controllable by the classroom so that students can take a ‘closer look’ at the experiment. This system has the advantage that it allows the students to direct the actions of the ‘scientist’ in the lab. Not only do the students control when the experiment begins, they now have the opportunity to ask more in depth questions of the expert. Here education is not top down, as in a lecture, but gives the student a large participatory element to their learning. Before the ‘scientist’ introduces the next element to water and starting a reaction, the student should be encouraged to predict what they think will happen when the metal is added to water. What the students should recognize is that as we move down the alkali family of elements from the lightest, Lithium, to the heaviest, Cesium, in each case, the reaction with water will last longer, and is more aggressive yielding more light and smoke. The experiment should only take a half hour. Once complete the students log their experiences to their eFolio.

Part 3 – Molecules
With a basic understanding of atoms and elements it’s possible to learn about molecules. In this section the student should gain the understanding that molecules are pure substances made up of different atoms. Molecules themselves can be created from atoms or other molecules via chemical reactions. Similarly, molecules can also be split apart by other chemical reactions. In this exercise students should gain an understanding of the shape and components of different molecules.

For this exercise, it is proposed that the student use both a digital and physical molecular modeling kit. A good example of a molecular model kit is available from indigo instruments (http://www.indigo.com/models/gphmodel/organic-chemistry-model-set-62053.html). For the digital, computer based modeling system we will use the application JMOL v10.00 (Figure 1). JMOL includes a wide variety of molecular structures that are easily displayed from a library. Some example molecules that could be considered are water, methane, and ammonia. You may have other molecules that would be relevant to, and worth exploring, with your students. Using the digital module the student can virtually manipulate the graphic in three dimensions.

Figure 1: JMOL displaying a water molecule.
While digital representations of chemical properties have been shown to improve understanding (Stieff and Wilensky, 2003) it is best to use the physical molecular modeling kit also to reinforce the visuospatial presentations viewed using JMOL. This supports the need for alternative learning styles and helps address issues associated with Gardner’s multiple intelligences theory. Have the students construct the same molecule in a graphics program. This physical representation of the molecule will compliment JMOL as it allows the student to manipulate the structure in a way that the digital image does not.

Have the students consider the atoms in each molecule, and the angles between atoms, using the model of their preference and record their findings in their findings in the eFolio. A conceptual understanding of how atoms fit together
to form molecules is derived from this lesson. Specific structural properties will be important to future chemistry study.

Lesson 5  Acids, Bases and pH
At the end of lesson 5 students will have investigated and be able to:
• demonstrate an understanding of simple chemical reactions
• classify substances as acids, bases or salts based on their characteristics
• demonstrate an understanding of neutralization by investigating acid-base reactions
• describe the pH scale and its purpose
• identify commonly used pH indicators and their useful range of sensitivity

Part 1 - Exploratory Activity
The teacher pairs up the students and has them organize themselves at the laptop stations in the classroom. They are directed to this website to begin their exploration of acids and bases (http://www.miamisci.org/ph/index.html). Students click on ‘Excite’ and try the activity that is presented. Then they are to click on the button at the bottom called ‘Using Your Tongue’. The teacher reads through it with the students and the pairs then move to the round tables in their classroom where equipment has been set up to participate in the tongue tasting test with a partner. Paper sheets of the experiment are at each table for the students to refer to. The safety protocols are to be stressed by the teacher. When the experiment is complete students go back to their computers and click on ‘Tasting Acids or Bases’ and read the information provided. They read the ‘Challenge’ question at the bottom of the page and then, in their eFolios, discuss the question with their partner and provide answers to the challenge question.

Part 2 - Activity/Lab
The students are then ready to test unknown substances with the introduction of litmus paper or purple cabbage juice as a pH indicator. The students are directed to http://www.middleschoolscience.com/cabbage.htm and together with the teacher, read over the activity provided. The students gather the equipment necessary, set up their working station and proceed with the experiment. Paper recording sheets are provided. Following the experiment the students are instructed to do some recording in their eFolios and title this as “Challenge #2”. They are to create a graph in Microsoft office (prior learning) that graphs the pH of the substances that they tested.

Part 3
The students are challenged to hypothesize about what will happen to the pH number if you mix an acid and a base together. They are to record this in their e-folios entitled “Challenge #3”.

Also in this part of the lesson in their e-folios the students are to comment on the possible effects of pH and how it is used in their everyday lives. Following
the recordings, in a class discussion, discuss the possibility of pH accidents into the surrounding water systems.

**Extension**

Have students click on: [http://www.brainpop.com/science/seeall/](http://www.brainpop.com/science/seeall/) and click on the pH scale button. (*The school would have needed to subscribe to this site prior to this lesson in order to obtain access.*) Have students view the animated movie about the pH scale and print off the worksheet by clicking on it and adding ‘print’. Students should work in their pairs to complete the worksheet.

For fun, have students try this alien juice bar game to further strengthen the concept of acids, bases, and neutral. [http://scienceview.berkeley.edu/showcase/flash/juicebar.html](http://scienceview.berkeley.edu/showcase/flash/juicebar.html) or [http://www.globe.gov/tctg/section_162.pdf?sectionId=162](http://www.globe.gov/tctg/section_162.pdf?sectionId=162)

**Problem-based Learning - Effluent Treatment Problem**

The students are grouped to provide a reasonable balance of overall individual ability within each group. The objective of assigning groups is to ensure each group contains at least one peer mentor that can establish Vygotski’s ‘zone of proximal development’ for the other group members. The groups are then tasked with the following problem.

**The Problem Statement**

In a recent study, researchers from UBC discovered a decline in the numbers and the health of aquatic life in Crystal Lake. The problem has been isolated and has been identified as unusually high acidic levels of the lake water. The increased acidity has been attributed to the 4000 litres per day of effluent being discharged from the Great Plains Mining & Processing plant located on the shores of Crystal Lake.

The Great Plains Mining & Processing plant, being a good corporate citizen, has hired your team to investigate the problem concerning the effluent from their operations and to find a solution. The report to the Great Plains Mining & Processing Corporation must include details of your findings together with:

- the proposed solution
- the amount of neutralizing agent required
- the concentration of the neutralizing agent needed
- the daily volume of agent required
- the cost of the neutralizing agent.

Students will be given samples of effluent to test. Once the acidity level has been established the students will then research to find an appropriate neutralizing agent and will use the IrYdium Project Virtual Chemistry Lab to test
their proposed solution. Findings are recorded and calculated to determine if they meet the above requirements.

Incorporating a problem-based learning exercise into the curriculum forces students to confront a realistic, ill-defined situation where they must recall and integrate knowledge previously learned. “By helping students understand the nature of the real-world problems that are inherently interesting and important, a major goal of anchored instruction is to help students understand why it is important to learn various subskills and when they are useful.” (CTGV, 1992, p.73)

**Tasks for Problem Solving**

**Developing Context**

Including personal eFolios, students are provided with various resources to help them understand relevance and context of the problem. Although the students are aware of the processing plant they may not appreciate the environmental issues that the plant presents. Students are directed to the following environmental sites to assist in developing a clearer picture of the problem:

- [http://response.restoration.noaa.gov/gallery_gallery.php?RECORD_KEY%28gallery_index%29=joinphotogal_id,gallery_id,photo_id&joinphotogal_id(gallery_index)=212&gallery_id(gallery_index)=15&photo_id(gallery_index)=145](http://response.restoration.noaa.gov/gallery_gallery.php?RECORD_KEY%28gallery_index%29=joinphotogal_id,gallery_id,photo_id&joinphotogal_id(gallery_index)=212&gallery_id(gallery_index)=15&photo_id(gallery_index)=145)
- [http://response.restoration.noaa.gov/legacy/watersheds/anacostia/start.html](http://response.restoration.noaa.gov/legacy/watersheds/anacostia/start.html)
- [http://www.uncw.edu/riverview/](http://www.uncw.edu/riverview/)

**Researching Information**

Due to the schools proximity to Crystal Lake, a field trip to view the location where the plant’s effluent flows into the lake is possible. Students make observations of the surrounding area as compared to locations elsewhere around the lake. They continue the field trip with a tour of the processing plant where they gain an understanding of the plant’s operation and the chemicals used in the mineral processing. While on the field trip the students use a PDA (personal digital assistant) to record their observations and important information from the tour. One important piece of information gained from the plant tour is the discovery of the chemical responsible for making the mill’s effluent acidic, sulfuric acid (H₂SO₄). The tour guide explains that while the plant recovers most of this acidic chemical, a very small amount makes its way into the mills effluent. The most relevant lessons to this problem are 2, 3, 4 and 5 above.

**Determining Concentration**

Upon return to the classroom the students are given samples of the mill’s effluent and use an industrial pH measurement device borrowed from the mill to determine the pH of the effluent. Once the students have determined the pH of
the effluent they are guided to the Virtual Chemistry lab (The IrYdium Project - [http://iry.chem.cmu.edu/vlab/vlab.php](http://iry.chem.cmu.edu/vlab/vlab.php)) where they create solutions and experiment with various concentrations of sulfuric acid. Their goal is to create a solution that exhibits the same pH as the mill’s effluent. This activity builds upon the knowledge gained in lessons 2, 3 and 5. Additional references for the students to help them with this work can be found at the following websites: [http://www.iun.edu/~cpanhd/C101webnotes/aqueoussolns/molarity.html](http://www.iun.edu/~cpanhd/C101webnotes/aqueoussolns/molarity.html) [http://dl.clackamas.edu/ch105-04/molarity.htm](http://dl.clackamas.edu/ch105-04/molarity.htm) [http://dl.clackamas.edu/ch105-04/dilution.htm](http://dl.clackamas.edu/ch105-04/dilution.htm)

Upon completion of this experimentation students will know how to calculate the molarity of a solution and, in particular, will be able to produce a virtual solution of sulfuric acid having a pH similar to the mill’s effluent.

**Finding a Neutralizing Agent**

Because there are many possible neutralizing agents the students are provided with guidance as they consider possible agents that could neutralize the mill’s effluent. (Agents discussed here are restricted to those available in the Virtual Chemistry Lab – IrYdium Project) The guidance takes the form of a teacher-led discussion with each group individually where the teacher prompts students to consider various impacts of proposed neutralizing agents. Students record possible chemical solutions and then conduct a web search to identify advantages and disadvantages associated with each solution. When a neutralizing agent has been identified the students again return to the Virtual Chemistry Lab to determine the amount and the concentration of the neutralizing agent required to achieve a pH of 7±0.5.

**Required Amount of Neutralizing Agent**

Once the students have determined the neutralizing agent and concentration required they can then be guided to find the amount of the agent that is required per day to treat 4000 litres/day of effluent from the mill. Students are required to use their mathematics and problem solving skills to determine the total amount of the neutralizing solution that is required. From the total amount volume of solution, and the concentration, they then determine the amount of solid chemical needed per day to prepare the neutralizing solution.

**Cost of Effluent Treatment**

A web site compiled by the teacher, with assistance from the chemical engineering people at the mill, serves as a source of information for the bulk costs of various neutralizing agents. Based on the above calculations the students can determine the cost per day to the mill of neutralizing the effluent using their solution.

**Comparing Results**
As a basis for discussion and comparison a teacher-hosted web site should bring together proposed solutions of each group together with their reasoning for choosing a particular neutralizing agent (pros and cons) and the cost of using the particular neutralizing agent. A summary of the problem-based exercise involves the students reviewing one another’s work and creating a personal web page that identifies, in their opinion, the best solution together with their reasoning for making their selection.

**Conclusion**

The learning experience in chemistry presented is based on social constructivist theories that allow learners to build upon previous knowledge. The activities incorporated in this curriculum were specifically designed to address the multiple intelligence (spatial, logic/mathematic, linguistic, kinesthetic and intra/interpersonal) needs of learners. Attempting to improve visualization and understanding, the learning material makes use of computers, software and the internet to provide students with effective learning tools that aid their understanding of difficult, abstract concepts. Finally, real-life simulation methods are employed in a final constructivist-based problem-based learning exercise that has been created to provide students with a meaningful way to integrate and apply knowledge from the lessons.

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