Gender, the Brain and Education: Do Boys and Girls Learn Differently?

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ABSTRACT

Recent discoveries of cerebral structural and functional differences between male and female brains indicate that boys and girls are wired differently for learning. These differences have significant implications for schools and pedagogy. Several gender-specific methodologies from the literature are suggested for teaching boys and girls that incorporate the scientific findings. Several of these methodologies were tested in a study, conducted at a British Columbia, private, all-girls high school. Two Science 9 classes received lessons that were designed to target either boys or girls. Results indicate that engagement and enjoyment of lessons do not always correlate to successful learning of content. In an all-girls setting, the literature strategies aimed at teaching girls produced higher achievement than those targeted to teaching boys.

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BACKGROUND AND ORIENTATION TO RESEARCH TOPIC

Gender differentiated instruction has been a feature of teaching methodology since the time of Aristotle (Gigi, 1997). However, by the time I began teacher training in 1999, it had fallen out of vogue. Despite observed gender differences in learning styles, rates and behaviours, the lack of discussion around how best to teach to girls' and boys' strengths left me puzzled as a novice educator. Later, as a teacher in the British Columbian public high school system from 1999-2004, I found that a gender-blind approach to teaching boys and girls was the assumed norm. Indeed, attempts on my part to engage my colleagues in discussions around what works better for boys versus girls, often brought uncomfortable silence or a lecture on how males and females have equal abilities and must be taught in the same way. Yet, despite my colleagues' discomfort with what was perceived as a sexist viewpoint, my own classroom observations told me that certain activities worked better for boys and others for girls in terms of engagement, learning rate and retention. A "one-size-fits-all" pedagogy just didn't make sense.

In 2005 I began teaching at an all-girls private school, where recognition of gender differences and discussions of how best to teach girls were encouraged. I was excited to be a part of a group of educators who were not afraid to state that there were differences between boys' and girls' learning styles and abilities. With the single-sex school network, I finally found colleagues who believed as I did – that gender differentiated instruction, far from being an antiquated and sexist notion, was good pedagogy, grounded in solid research, and backed up with impressive results.

During a professional development seminar in 2006, I was introduced to emerging brain research data and some of the potential implications it had for education. I discovered scientists had the ability to image people's working brains as they processed information and performed learning tasks. Their preliminary findings indicated significant brain gender differences in both cerebral structure and cognitive functioning. Educational researchers are now just beginning to gain a sense of what these findings might mean for how boys and girls learn. As opposed to traditional psychological-cognitive testing, where results offer only indirect insight about the brain and learning, imaging techniques offer tantalizing direct evidence for how brains actually work in "real time". As a high school science teacher and former medicinal chemist, I also found this research field highly intriguing. I wanted to learn more on this topic to see if I could use the research findings to improve my teaching. Thus from the summer through the fall of 2008, I reviewed brain and gender-targeted instruction studies. The literature review that follows provides a synopsis of my findings.

LITERATURE REVIEW

Introduction

Neuroscience research has expanded rapidly over the past decade with the use of more sensitive imaging techniques to study the brain. This research has led to increased understandings of how brains function and how they develop. Despite advances in knowledge, the diffusion of brain study findings into the field of education has been slow, impaired by a lack of interaction between the hard sciences and the social sciences. Thus, within the teaching population, the awareness of brain research and its possible implications for pedagogy remains low. However, this research has the potential to challenge what many educators believe about current best practices. Research showing that boys and girls think and learn in different ways has encouraged some school reformers to rethink the nature of our current education system. They believe the data from neuroscience research offers intriguing possibilities for future innovation (Gurian & Stevens, 2004).

The discovery of both structural and cognitive gender differentiation within the brain could have far reaching consequences for schools. Yet, how significant and valid are the actual differences reported? How do they affect classroom learning and performance? Can educators influence cerebral abilities and to what extent? And crucially, how might instructional models (curricula, teaching methodologies, school environments, etc.) be adapted to take advantage of what the research tells us about how children learn?

This literature review attempts to answer these questions drawing upon the medical/scientific findings and from educational sources (including education databases: Education Resources Information Center (ERIC), Journal Storage (JSTOR); medical/scientific databases: The Database of Abstracts of Reviews of Effects (DARE), American College of

Physicians (ACP -Ovid), and the Web of Science). However, bridging these two fields is not without pitfalls. The potential for abuse and misunderstanding of the data is significant, as is the risk of overconfidently stating research findings from a field that is still in its infancy.

Brain Research Findings

Structural Gender Differentiation

Researchers have studied the brain well before the invention of “modern” medicine. In addition to cadaver research, data from neurosurgeons have also been invaluable for furthering the understanding of cerebral structure and function. However, before the introduction of non-invasive imaging techniques such as electroencephalography (EEG), functional magnetic resonance imaging (fMRI) and positron emission topography (PET), it was difficult to perform large scale studies on live, healthy individuals. Understandably, living people do not generally volunteer to have pieces of their skull removed for the sake of science. Thus brain injured individuals were treated experimentally, and data was slowly accumulated through trial and error. The combined efforts of many decades of research have produced detailed structural models of the brain (for instance, see Figure 1), and these cerebral structures are now widely associated with various cognitive processing tasks.

Brain studies have also yielded considerable information on gender-related structural differences. It is known that cerebral morphological differences begin in the womb, and are relatively permanent after the fetus is 26 weeks old (Achiron, Lipitz & Achiron, 2001). These structural differences do not seem to be affected to a significant extent by hormonal influences as children mature, nor by innate racial differences (Diamond, 2001; Gurian & Stevens, 2004; Mack, McGivern, Hyde & Denenburg., 1996; Rabinowicz, Petetot, Gartside, Sheyn, Sheyn & deCourten-

Myers, 2002; Shors & Miesegaes, 2002). Gender differences in physical structure include overall cerebral volume differences (male brains are generally larger – after correcting for body mass differences), distribution percentage differences in gray and white matter found in different brain structures, and many specific instances of cerebral regional size or thickness variations (Diamond, 2001; Good, Johnsrude, Ashburner, Henson, Friston. & Frackowiak, 2001; Haier, Jung, Yeo, Head & Alkire, 2005).

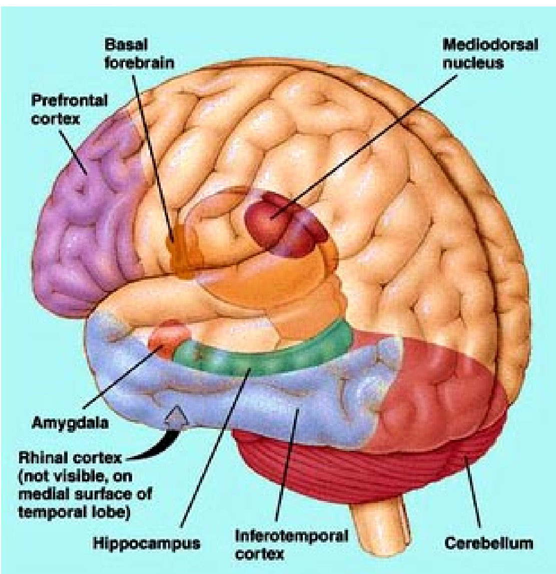


Figure 1. Major brain structures.
Downloaded from: http://bama.ua.edu/~sprentic/672%20aggression-brain.jpg

Functional Gender Differentiation

Brain functional processing is related to, but different from, its structural morphology. A large number of functional brain differences have been documented between the sexes. Physiologically, female brains have been found to metabolize glucose at higher rates and to experience greater blood flow in comparison to males (Gurian & Stevens, 2004; Rabinowicz, Petetot, Gartside, Sheyn, Sheyn & deCourten-Myers, 2002). Navigation, fine and gross motor skills are also managed in different brain structures for men and women (Gron, Wunderlich, Spitzer, Tomczak & Riepe, 2000), as are many other specific tasks. In particular, differences in how male and female brains process language tasks and spatial-mechanical activities garner a lot of research attention.

Decades of psychometric testing, observation and imaging techniques have revealed that, in general, female brains process language activities more easily, earlier and faster than males, while males more readily excel at spatial-mechanical and gross motor skill tasks (Clements, Rimrodt, Abel, Blankner, Mostofsky, Pekar, Denckla & Cutting, 2006; Kansaku & Kitazawa, 2001; Mack, McGivern, Hyde & Denenburg, 1996). Gurian and Stevens (2004), state that these differences explain why girls outperform boys in reading and writing, and why boys tend to gravitate toward physical activities and video games. These well-published brain and education scholars state that certain skills are simply more “hardwired” in the brain. However, it seems that this hardwiring can be changed. Many scholars (for instance Barnea, Rassis, & Zaidel, 2005; Caine & Caine, 1990; Feng, Spence & Pratt, 2007; Garon & Moore, 2004) note that training and practice can change the brain’s ability (ease/speed) to process tasks. Thus, when making generalized statements regarding how brains function, the concept of neuroplasticity (the brain’s ability to be trained) should never be ignored.

Imaging studies have led to the discovery of fascinating symmetry differences between male and female brains. Contrary to popular notions, it is not correct to say that men are more left brained (logical, objective) and women more right brained (intuitive, creative, and emotional). In fact, both sexes use both hemispheres of their brains regularly (Phillips, Lowe, Lurito, Dzemidzic & Mathews., 2001; Gur, Alsop, Glahn, Petty, Swanson, Maldjian, Turetsky, Detre, Gee & Gur, 2000). However, male brains frequently process information and perform tasks with greater asymmetricality, in comparison to the generally more symmetrical processing seen in female brains (Azari, Pettigrew, Pietrini, Murphy, Horwitz & Schapiro, 1995; Phillips et al., 2001; Gur et al., 2000), although some exceptions apply (Clements et al., 2006). This asymmetric activity (particularly with language tasks) is seen in the greater *intra*hemispheric activation magnitudes seen during task processing in men (Gur et al., 2000; Phillips et al., 2001; Shaywitz & Shaywitz, 1995). Furthermore, the larger activation magnitude could explain why males tend to compartmentalize learning, and can focus on a single enjoyable task, such as computer programming, for longer periods of time than females (Havers, 1995). Moreover, a greater regional activation magnitude could also explain why males have a more difficult time than females in recovering from certain types of brain injuries that affect those regions (Phillips et al., 2001).

Conversely, in several studies, females have been shown to exhibit greater overall *inter*hemispheric bilateral symmetry, using both halves of their brains to process tasks – particularly while performing language tasks (Clements et al., 2006; Gur et al., 2000; Phillips et al., 2001; Shaywitz & Shaywitz, 1995). These activation symmetry differences provide evidence that males and females think in different ways and draw from different brain regions to process the same mental or physical tasks. Some cognitive researchers hypothesize that greater brain activation symmetry explains why girls are (arguably) considered better multi-taskers, can link more concepts together, and can transition faster between lessons compared to boys of the same age (Havers, 1995). Figure 2 (from Phillips et al., 2001) illustrates these phenomena using fMRI composites. The corpus callosum hemispheric bridge (see Figures 3 and 4), has commonly been associated with the ease of bilateral brain processing. While there has been considerable debate over whether there is a gender-related thickness difference in this white matter structure, it is generally thought to be slightly thicker in females (as a percentage of overall brain matter), and have a somewhat different shape (Achiron, Lipitz & Achiron, 2001; Gurian & Stevens, 2004; Hwang, Ji, Lee, Kim, Sin, Cheon & Rhyu, 2004; Smith, 2005). In the fMRI diagrams in Figure 2, the rightmost images also show greater corpus callosum activation in the female brain composite during cognitive processing. Scientists have not reached consensus about what this means, but several speculate that greater callosum thickness would allow for better "cross talk between hemispheres in the female brain" (Gurian & Stevens, 2004, p. 22).

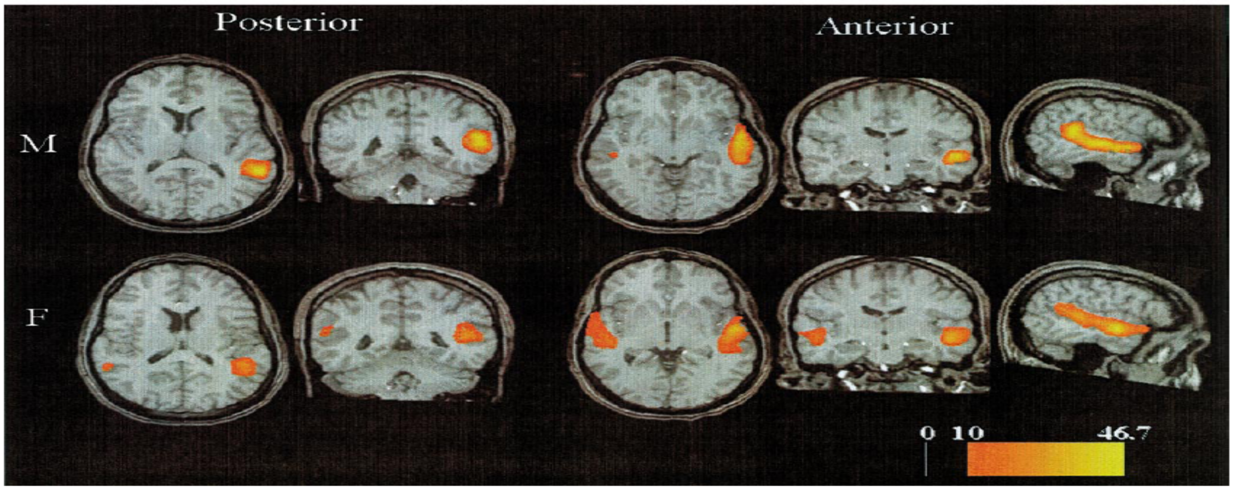
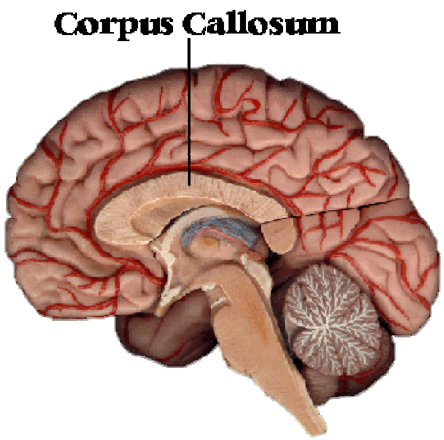


Figure 2. Male and female fMRI brain scans.
Combined subject fMRI activation data for 10 men (top row) and 10 women (bottom row) show both anterior and posterior temporal lobe activation at a threshold of 10210 (see color bar, lower right). Men demonstrated markedly asymmetric activation, whereas women tended to show more symmetric temporal lobe activation. Note: the right side of each image corresponds to the left brain hemisphere, as individuals are positioned face up during scanning.

It has become a commonly held belief that men and women have equal general intelligence. However, Johnson and Bouchard's (2007a, 2007b) analysis of data from the *Minnesota Study of Twins Reared Apart* project helped demonstrate that while men and women appear to have equivalent general intelligence, they rely on different cerebral structures and pathways to accomplish the same tasks. Their research led them to imply there "is no single structural and functional brain system that manifests as general intelligence" (2007a, p. 24). Rather, (they say), general intelligence is like a "toolbox", containing a variety of tools that can be chosen and used with varying skill for a particular task. Gender influences what tools are available and the ease of tool use.



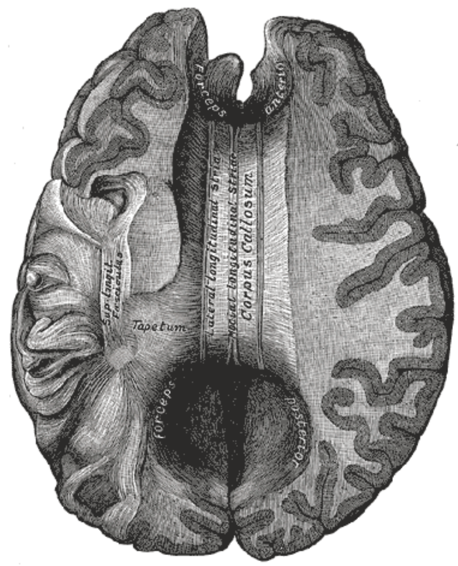


Figure 3. Corpus callosum side view (above left).
Downloaded from http://www.macalester.edu/psychology/whathap/UBNRP/Split_Brain/brmodelc.gif

Figure 4. Corpus callosum top view (above right)
Rendering from Gray's Anatomy

Certain skills and tasks will be generally easier for one gender over another, although training and experience can enhance a tool user's skill. For example, men's larger activation volume in the visual cortex and greater spatial-mechanical aptitude give them a performance advantage over women when playing video games. However, it has been documented that women who play a lot of video games can outperform men who do not often play video games when both groups are presented with a new game (Feng, Spence & Pratt, 2007). Further, Feng, Spence, and Pratt saw that significant gains in visual processing ability in both sexes can occur with a relatively limited amount of training.

While there may be no single structural brain system that manifests as general intelligence, a joint fMR imaging study between the University of California-Irvine and the University of New

Mexico on intelligence and gender has garnered considerable media attention. This study, conducted by Haier, Jung, Yeo, Head & Alkire (2005), claims that the brain is made up of two types of matter – gray and white, and both types of brain matter contribute to intelligence quotient (IQ). Gray matter is comprised of dendritic structures associated with processing power (like computers), while white matter is made from myelinated fibres that act as connections between gray matter structures (like network cables). Surprisingly, the researchers found that male brains contain approximately 6.5 times more gray matter related to intellectual processing than female brains. However, female brains contained nine times more white matter linked with intelligence than males. Both groups of males and females in the study had comparable overall IQs, and had similar results on the mathematics problem solving task that they completed during the brain imaging scans. However, the activated areas of their brains showed up in different regions, with different intensities, and used different amounts of white and gray matter, depending on the subject's gender. This evidence suggests that there are two separate gender-related modes for operating intelligence – neither one with superiority over the other.

These findings by Haier et al. (2005) are intriguing, but have yet to be fully verified. Few studies relating separate full scale intelligence quotient (FSIQ) factors to brain structure have shown consistency with regard to sex (Narr, Woods, Thompson, Szeszko, Robinson, Dimtcheva, Gurbani, Toga, and Bilder, 2007). Narr et al.'s (2007) analysis reveals that "greater intelligence is associated with larger intracranial gray matter and to a lesser extent with white matter" (p. 2163). Positive correlations between certain brain structures and specific intelligences in men (performance) and women (verbal) have been demonstrated, but Narr et al. were unable to generalize brain structure to FSIQ. The authors admit that "sex moderates regional relationships that may index dimorphisms in cognitive abilities, overall processing strategies, or differences in structural organization" (p. 2163), but do not state that sex is the largest discriminating factor.

Maturation Differences and Behaviour

Cerebral maturation-rate differences between boys and girls may explain observed learning behaviours, as well as offer predictions about how children learn best. Gurian & Stevens (2006) state that “as of four days of age, girls tend to spend twice as much time as boys maintaining eye contact with adults” due to faster maturation within their visual cortices (p. 88). Lower oxytocin levels (the primary human bonding chemical found in the brain) in male babies also affect bonding and their desire to study faces. They are more interested in studying physical objects in their surroundings than people (Taylor, 2002). Garon and Moore’s (2004) results on studying 69 three, four and six year olds using a simplified version of the Iowa Gambling Task (a complex decision-making game) revealed that not only did girls learn the game faster, but they also significantly outperformed boys of the same age. This indicates faster development of the areas of their brains involved in logical processing.

Gender differences in cognitive brain development are not limited to logical decision making discriminators. In one of the largest and most carefully conducted studies of its type, Hanlon, Thatcher and Cline’s (2000) EEG results on 508 children aged two months to 16 years showed that the areas that process spatial rotation and targeting are not just superior in male brains, but they also mature four years earlier in comparison to girls. On the other hand, they found that the cerebral areas that process language, verbal-emotive, social cognition, and fine motor skills develop six years earlier for girls. Boys’ advantages in spatial processing come with a cost, however. The areas of the brain which process these skills take up greater cortical volume in males, which gives them around “half the brain space that females use for verbal-emotive functioning” (Gurian & Stevens, 2004, p. 23).

Another study by Barnea, Rassis, and Zaidel (2005) used EEG neurofeedback to study and train the brains of children aged 10-12 years. They found that while both male and female brains responded positively to the neurofeedback (increased neural activation in targeted regions), the regional areas of the cortex that showed improved activity were different for boys and girls. This research is important because it demonstrates the brain's ability to be trained within a relatively-short timeframe (four weeks).

As children age into adolescence, their brains undergo many fundamental changes that affect boys and girls in different ways (Hanlon, Thatcher & Cline, 2000). In late childhood, the brain kicks into a building spree – over-producing dendritic branches (gray matter) and creating more synapses than are required in adulthood. This is a period of intense learning and preparation for the brain. Throughout adolescence, the synaptic pathways that have been well used (predominantly in the cerebral cortex) are smoothed, while lesser used gray matter structures remain rough or are pruned back significantly (Diamond, 2001; Gurian & Stevens, 2004; 2006; Jausovec & Jausovec, 2005; Spinks, 2002; Wilson & Horch, 2002).

Marian Diamond's 2001 study on the effects of learning environments on rat brain structure gives compelling graphic evidence for the consequences of effective education. Diamond showed that when rats are placed in an enriched environment, they grow neural connections and more dendritic branches in the cerebral cortex (See Figure 5). Rats that are placed in impoverished environments, without much neural stimulation, shed dendritic structure. Furthermore, when rats with pruned structures were later enriched, dendritic branches regrew, but never to the same levels as rats who were enriched since birth. When these rat study results are extended to human brains, implications of 'use it or lose it' become of greater importance in and outside of the classroom. In a recent Scientific American paper, Shors (2009) indicates that thousands of new cells are generated in the human brain every day - "particularly in the hippocampus, a structure involved in learning and memory" (p. 47). These new brain cells are developed when the brain thinks they might be useful for processing difficult mental tasks, but are very quickly shed in a matter of weeks if they are not used.

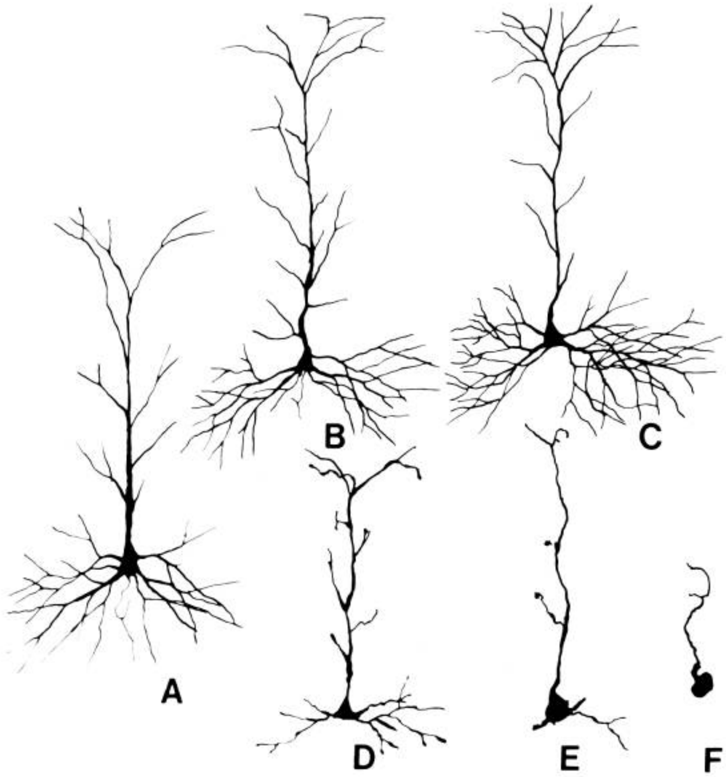


Figure 5. Dendritic brain structure in rats.
Dendritic brain structure composites of normal healthy rats are shown in A. In an enriched environment rat dendritic structure become more branched over time (B and C). In an impoverished environment (isolation) rats shed dendritic branches over time (D, E, and F).

Other changes in brain structure during adolescence have tremendous implications for behaviour. Before imaging studies, it had been thought that the brain was more or less a finished product after puberty. However, research has demonstrated that the prefrontal cortex (often called 'the area of sober second thought' or the brain's CEO), does not reach full maturity until well into adulthood (Gurian & Stevens, 2006; Killgore, Oki & Yurgelun-Todd, 2001; Spinks, 2002). In decision making, the prefrontal cortex is thought to be partly mediated by the amygdala (see Figure 1) – the brain's 'emotional centre' (Goldberg, 2001, p. 143). It is the amygdala that first responds to emotionally-charged and exciting situations involving feelings such as anger, fear, happiness and sadness (Hariri, Bookheimer & Mazziotta, 2000). Dr. Joann Deak (2005) states that as children age, they gain greater control over their emotional responses as their prefrontal cortex develops. When brain maturation is complete, both brain structures are involved in decision making. Thus, emotions and cognition cannot be separated and behaviour is the result of these interactions.

The maturation of the prefrontal cortex proceeds differently for boys and girls. During adolescence, “girls’ prefrontal cortices are generally more active than boys’ and develop at earlier ages” (Gurian & Stevens, 2004, p. 22). This allows them to handle boredom better, have greater attention spans, and display greater emotional intelligence (Davidson, Cave & Sellner, 2000; Jausovec & Jausovec; Killgore, Oki & Yurgelun-Todd, 2001; Sax, 2006). Conversely, adolescent boys’ amygdala volume is much greater than girls’ and continues to grow larger during puberty (Jausovec & Jausovec; Wilson & Horch, 2002). Thus for boys, negative emotional responses are said to be “stuck in the amygdala; there is no change associated with maturation” (Sax, 2006, p. 197). It is reasoned that the lesser ability of the prefrontal cortex to overrule the emotionally excitable amygdala could explain the tendency for boys to take greater physical risks, be more impulsive, and exhibit less emotional intelligence than girls of the same age (Killgore, Oki & Yurgelun-Todd, 2001). Amygdalae volume (and the presence of excess testosterone) may also help explain why stress has a positive effect on learning in males, but inhibits learning in females (Sax, 2006; Shors & Miesegaes, 2002; Wood & Shors, 1998). For boys, stressful situations can be highly stimulating.

Cautions and Limitations of Brain Research Data

While brain research and its applications to education are potentially promising, this is still a young field. Despite many advances in imaging techniques, scientists do not yet fully understand the brain. Nor do researchers always agree with each other's findings. There are many conflicting studies – some reveal cerebral structural and/or functional differences between the genders, and some fail to find significant differences. Further muddying the waters in this field are the quasi-scientific reports that blend good science with mere speculation, expressed as fact. Which studies are correct and reliable? While meta-analyses are often a useful tool to deal with these kinds of conflicts, it is challenging to perform reliable meta-analyses on these results, as evolving techniques and instrumental innovations are constantly rendering old data suspect.

One study, by Sommer, Aleman, Bouma, and Kahn (2004), highlights this disparity in outcomes. Their meta-analyses of similar language-task imaging studies conducted between 1995 and 2004, reveals that of 24 studies, only 11 reported statistically significant brain lateralization differences between the genders. These discrepancies in the findings may not just be due to differences in instrumental techniques. A major technical challenge remains to distinguish between distributional data curves that overlap for both genders.

Figure 6, from Hyde (2005), highlights just this kind of technical difficulty. It is common in humans that intra-gender differences are often greater than the inter-gender ones, and hence effect sizes (standardized mean difference) can be small. Hyde's (2005) meta-analysis of gender differences in the performance and cognitive realms indicates that approximately 60% of the reported differences (such as attribution of success to ability rather than effort, mathematics self-confidence, and reading comprehension) had standardized effect sizes that were small (less than 0.2). As quoted in Hyde's analysis, research from Maccoby and Jacklin (1974) concluded that gender differences in performance were well-established in only four areas: verbal ability, visual-spatial ability, mathematical ability, and aggression. When significant performance and brain differences do exist, it may also be that other influences, such as inherent intelligence, language, handedness and environment, may play greater roles in explaining these differences than gender (Buckner, Raichle & Petersen, 1995; Diamond, 2001; Good, Johnsrude, Ashburner, Henson, Friston & Frackowiak, 2001; Sommer, Aleman, Bouma & Kahn, 2004). Further, it is a fallacy to think that the brains of all men and women are gender typical, differing only by individual intelligence. As with almost all other natural phenomena, brain characteristics will fall on a distribution curve (such as the one in Figure 6). However, the scientific literature appears to be silent on what might be the percentages of men and women with gender-typical brains and what the distribution curves look like. Certainly, this lack of information calls for further research.

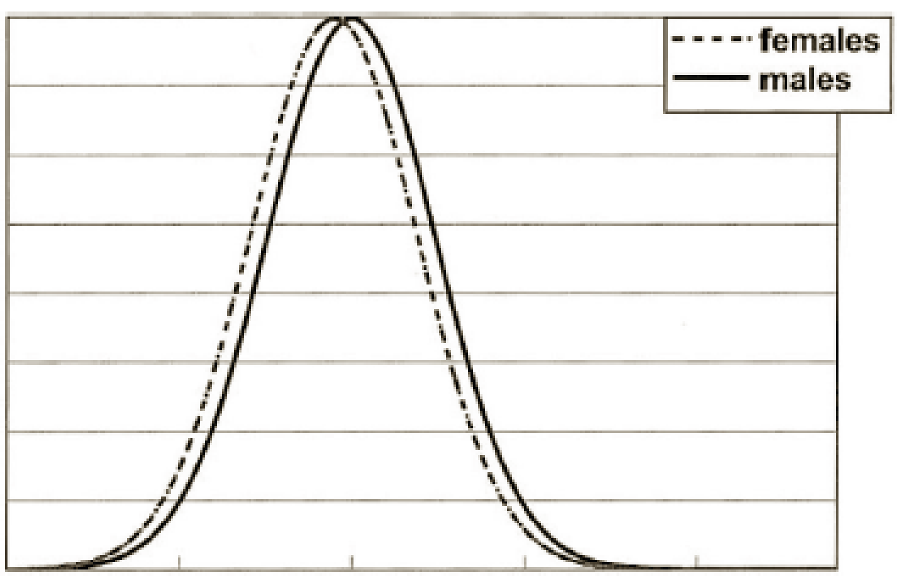


Figure 6. Two normal distributions 0.21 standard deviations apart – a 0.21 effect size.

Finally, rats and other animals are often used in brain studies in place of humans, partly because their environments can be more effectively controlled, and unlike with humans, animals can be later sacrificed to gather data. It is also believed that inter-species brain structures and biological functioning have a great many similarities. However, while some aspects of animal brains share commonalities with human ones, there is not always a perfect correlation. Thus rat brain studies may provide a signpost for what happens in humans, but they do not guarantee the same results. Hence, authors looking to animal brain studies as evidence to support gender hypotheses must be particularly cautious to not over-state their claims.

Despite the debate over the validity of some reported structural differences, it is clear that many differences are definitive and significant. However, it has not been fully proven that differences in brain structure or cognitive processing can be linked directly to pedagogy. While the connections between these might seem obvious, this is an area that remains controversial and must be explored further. Despite the potential risks of misinterpreting research findings, a combination of scientific evidence and educated speculation can lead us to consider alternate methods of teaching children.

Implications and Applications for Schools

It is clear from the research that males and females have brain tissue and cognitive processing differences. For educators, cerebral sexual dimorphism is of pedagogical concern as it is thought to affect how children think, learn, and behave. This is also true in reverse; "the actual 'wiring' of the brain is affected by school and life experiences" (Caine & Caine, 1990, p. 66). While this wiring is different for each gender, it is not correct to say that boys and girls are opposites in their learning styles. There are many learning activities and teaching methods that can be jointly beneficial for both boys and girls – although perhaps for different reasons.

The following sections deal with ideas on how to provide a gender-specific education for boys and girls. These sections are meant to be speculative, looking to collate brain research and current best practice pedagogy – particularly best practice techniques established by single-sex school educators. While much has been published in this area, not all of the literature is peer-reviewed. It remains to be seen if the causal relationships that are hypothesized to exist between the brain and learning can ever be conclusively proven.

The Education of Boys

Many educators and parents agree that boys, in particular, are increasingly more at risk in our current Canadian school climate. For example, results from the Programme for International Student Assessment (PISA, 2000) show that males in all countries (and in all 10 Canadian provinces) lag significantly behind females in most school subjects, with only math and science showing small gender gaps (Statistics Canada, 2008). This does not necessarily mean that achievement needs to be equal between boys and girls, but large performance differences indicate systemic educational shortcomings. In addition to gender gaps in learning, Statistics Canada reports that 15% of male Canadian students drop out of high school, compared to only 9% of females (1999 data). Despite there being a call to address the failings of schools in girls' education less than a generation ago (e.g. Lee & Bryk, 1986), it is boys who currently seem to be the most disadvantaged.

In addressing the apparent shortcomings of boys, the research provides a strong caution about the limits of neuroplasticity (the brains ability to be altered). Science shows us that brains develop thicker neural networks and greater dendritic connections with learning. With practice, girls and boys can develop strengths that do not naturally come easily to their gender. However, "the gender of the human brain is not plastic…. You cannot change the brain of a boy into the brain of a girl" (Gurian & Stevens, 2006, p. 91). Thus, we are left with the need to accommodate gender differences without the hope of a universal education prescription for all brains. The question is: how?

Educational literature is rich with books and articles about how best to address gender differences through teaching methodology. In fact a Google search of “brain AND teaching strategies AND gender differences” yielded 160 000 listings! While some of the methods suggested in the literature may leave educators baffled (such as instructions to use pink in all-girls classrooms and soft blue for all-boys classrooms), many of the brain-based gender strategies will not seem particularly new, and have been in use within co-educational classrooms for some time. Other strategies are significantly different for each gender and suggest the need for a gender-specific education system.

The literature is clear that to address boys’ multivariate needs, one requires a multitude of strategies. For instance, practically all educational theorists encourage teaching through the provision of hands-on and experiential activities. For boys, this is particularly important because their brains (with their innate spatial-mechanical and gross motor skills aptitude) are highly geared toward the physical universe. When boys are engaged in kinaesthetic activities, such as using manipulatives in mathematics or building a model of a fur trading fort in social studies, they will not only be more interested in what they are doing, but they will also be strengthening neural connections within the most active areas of their brains. However, hands-on activities can also be designed to help improve boys’ fine motor skills, which are weaker than girls’. Activities such as beadwork, creating circuit boards in science, and detailed map sketching are engaging and will improve their small muscle hand-eye coordination.

Where possible, key lesson ideas should be conveyed using diagrams, charts, maps, symbols, analogy, and mental imagery to supplement verbal and written instruction (Gurian & Stevens, 2004; Gurian & Stevens, 2006). Gurian and Stevens (2004) caution that the more words teachers use, the more boys lose track of meaning and become “bored” (p. 23). During physical activities teachers can ask boys to describe their experiences verbally and in writing. When physical activities are connected to communication, it becomes easier for boys to express themselves. This way the language areas of their brains that lag behind girls in development are also stimulated. Sax (2006) states that verbal instructions should not be too long or too complex, especially for younger boys. Sax also reports that teachers in all-boys schools have found that verbal instructions should be delivered in a loud voice, since speaking softly puts boys to sleep, and may even demonstrate weakness or inferiority.

A rationale to explain why boys have a difficult time transitioning between topics might be their greater asymmetric brain activity. Gurian and Stevens recommend that teachers stick to one key idea per activity or give enough wait time to allow boys’ brains to switch modes. For high school-aged boys, a semester system may be more successful than linear ones, as it makes for fewer transitions during the day and fewer subjects to focus on during the week. Furthermore, increasing school day start times to begin a little later in the morning has been demonstrated to have positive effects on both boys’ and girls’ attendance rates, academic success, and focus in class (Wahlstrom, 2002).

The links between focus in class and academic success are easy to establish. One of the reasons why boys make up around two thirds of the diagnosed learning disabilities (such as ADD and ADHD) is because their brain physiology leads to lower attention spans, so they frequently find it difficult to sit still and listen (Gurian & Stevens, 2004). While classroom instructional methods are crucial to maintaining engagement and focus, attention to physical space and environment within the classroom is also important. Ergonomic specialists have found that boys learn better and stay more focussed when classrooms are kept cool. According to Sax (2006), a temperature of 69°F is ideal for boys (too warm and they fall asleep), compared to 75°F for female students – a detail that he calls “six degrees of separation”. To maintain focus, boys should also be given more opportunities for movement in the classroom (Gurian & Stevens, 2006). This might be achieved through creating greater space between desks (for arms to swing out) or allowing alternative seating arrangements, including the possibility of sitting and stretching out on the floor during parts of the lesson. Repetitive pen tapping, leg swinging or arm flapping should not be thought of too harshly by the teacher. Such small physical activities are often unconscious and can actually help boys focus on lesson activities by engaging the spatial-mechanical areas of their brains.

Encouraging healthy competition (through sport and academic opportunities) is another good strategy for engaging boys’ energetic spirits. Males enjoy competing and can often be spurred on to greater performance when there are reputations and pecking orders at stake. When girls are seen performing some tasks at a much higher level, many boys see these activities as games they cannot win. Hence, they may not even try (Pastor, 2008). From a physiological point of view, competition allows boys to work out some of their aggressive behaviour needs, caused jointly by testosterone and their growing amygdalae. Further, competition may be used to build camaraderie and create powerful memories. Opponents who worry that competition begets stress are reminded that brain studies indicate boys thrive under stress - at least manageable doses of it (Sax, 2006).

Competition is only one aspect of creating bonding opportunities for boys within the school environment. Forging emotional connections are crucial since relationship building is not as easy for boys as it is for girls, due to boys’ lower cerebral oxytocin levels (Gurian & Stevens, 2006). Research also shows that many adolescent boys simply do not see the relevance school has for their lives, especially when there are high paying jobs available that do not require high school graduation (Draves & Coates, 2003). While improving their learning experience is one part of solving male dropout problems, increasing their emotional connections to school will also help. While the classroom teacher has an impact on student attitudes and commitment to academics, it is important to note that many boys lack positive male role models in their lives. This is especially true for younger children, as most elementary school teachers are female. One strategy to address this lack of male presence in the classroom includes exposing boys regularly and purposefully to male figures (other teachers, volunteers, and guest speakers), who can model healthy values, attitudes, and behaviours. Not only can this provide boys with positive visual images, but having same gender role models is thought to improve both attitudes toward school and academic success (Lahelma, 2000; Mills, Martino, & Lingard, 2004). To create further personal connections boys should also be given opportunities to individualize their work spaces (Gurian & Stevens, 2006). This might include decorating cubbies and desks for elementary-aged children or personalizing lockers for middle and high school-aged boys. Posting projects, art and pictures of boys and their friends throughout the halls can also foster school ownership and pride.

Gender sensitivity might also require different discipline techniques for boys and girls. When girls have behavioural problems, it is typically a successful course of action to begin by asking them to express their feelings and explain their actions. In contrast, Sax (2006) states that asking a 17 year old boy to discuss his feelings will garner about the same results as asking a six year old – the areas of the brain that deal with emotional intelligence and perspective taking are simply not yet developed enough. Gurian and Stevens (2004) share the observations of an assistant principal, who found a way to deal constructively with a young boy, who would act out explosively and then run out of the classroom. Instead of talking with him in her office, the assistant principal took him outside to bounce a ball. While passing the ball between them, she asked the boy to explain what happened. The physical activity gradually calmed him down and allowed him to articulate his frustrations.

The Education of Girls

Many of the strategies designed to improve boys' achievement may also be good pedagogy for teaching girls. Like boys, girls also need opportunities to foster school ownership and form bonds. They too benefit from decorating their cubbies and seeing their art and pictures on the wall. However, it is more important for girls than boys that learning objectives and activities are connected to real life situations and problems. Theoretical concepts, without practical application are of little interest to most girls. It is also of particular importance to girls to bond with their teacher, as many girls will not take intellectual or emotional risks before those relationships are established (Crosnoe, Johnson & Elder, 2004). To help establish trusting and caring relationships, teachers should speak softly with girls (unlike with boys), smile often, and maintain eye contact. Teachers should seek always to be positive and fair with both boys and girls. Special treatment (both positive and negative) will distance children from the teacher and increase feelings of distrust.

Bonding to classmates comes easier for girls than for boys, as their greater oxytocin levels make them more socially motivated (Campbell, 2008; Gurian & Stevens, 2004; Wilson, 2006). Most girls will readily look for ways of being part of a group. Within classroom small group settings, even timid girls, whose voices are not always heard in a larger setting, can discuss their ideas. Working together in this manner will strengthen the connections within female cortical language regions and improve listening skills. Teachers should look to scramble group compositions often so girls become used to leaving their comfort zones and gaining exposure to new ideas. Shifting group dynamics will also create increased opportunities for leadership roles and breaking out of established patterns of behaviour. Moreover, using small groups to break down social barriers within the classroom may help prevent the pervasive girl-girl psychological bullying that affects many females.

Girls need positive female role models in their lives. Meeting successful female professionals, especially women in the sciences, can help to break down perceived barriers, and lead to higher performance (Marx, 2002). In fact, while enrolment in the traditionally male-dominated subjects of Physics and Calculus is generally lower for girls than boys at co-educational schools, it is certainly not because of a lack of intelligence or aptitude for these disciplines. Lack of confidence, low self esteem, and being inordinately critical of their own performance are some of the major hurdles that prevent girls from choosing these subjects (Feingold, 1994). Moreover, self-esteem tends to be lower for females in general, which is thought to be partly a mechanism of the higher levels of serotonin released in female brains (Taylor, 2004). For instance, many educators have stories of boys who get B's and think they're brilliant, while girls, who get B's, think they're dumb. When this lack of confidence creates stress, brain studies show this inhibits learning in girls. Furthermore, girls are more likely than boys to attribute academic difficulty to lack of ability, rather than lack of effort - especially in mathematics (Lloyd, Walsh, & Yailagh, 2005). When girls are trained in the concepts of neuroplasticity (that the brain can grow greater neural density and form more connections with increased effort), then attitudes, effort, and performance have improved (Blackwell, Trzesniewski, & Dweck, 2007; Halpern, Aronson, Reimer, Simpkins, Star & Wentzel, 2007; Utman, 1997). Thus teachers of Science and Mathematics, in particular, need to be more patient with girls, work to boost their self confidence, and focus on the concept of 'success through effort', rather than 'success through ability'.

Physical games and activities should be used to supplement sedentary tasks so girls can improve their gross motor skills, which lag behind males of the same age. These activities do not have to take place only in Physical Education (P.E.) or on the sports field, but can also be a part of academic classes. For instance girls can act out a scene from a story in English class or go outside to estimate the height of trees through trigonometric triangulation in Mathematics class. Such activities will improve the connections within the cortical regions that process spatial-mechanical skills, which tend to be their least developed cerebral areas, in addition to providing meaningful applications of learned skills. Through the use of puzzles (such as Rubik's Cube and tangrams), and other hands-on spatial training activities, girls' logical and abstract brain regions in both hemispheres will also be strengthened (DeLisi & Wolford, 2002; Halpern, 2000). These same neural connections help enhance the abstract/symbolic brain structures that process higher level mathematical relationships so girls are more prepared for the rigours of high school and university level science and mathematics in later years (Sorby, 2001).

Despite the results of pen and paper testing, some may also debate whether girls are truly more successful than boys. How is this success measured best? By test scores, self-esteem levels, or the percentage of girls who enter university? By job salaries or upper-level job titles? Many would agree that *success* is multivariate and not always quantifiable. Regardless of the measuring stick used, few believe that traditional school environments have been tailored to provide all of girls' needs.

Gender Training and Single-Sex Education

With the increased interest in gender-sensitive teaching models, thousands of teachers have received some kind of training on brain-based and gender-differentiated instruction. Gurian and Stevens (2004) explain that state-wide gender training in Alabama "has resulted in improved performance for boys in both academic and behavioural areas" (p. 24). Other school districts that received gender training as part of a study with the University of Missouri-Kansas also saw increased achievement on state-wide tests. Defenders of co-educational classrooms will point out that a number of the activities that are designed to brain-strengthen one gender can also be used for the other. For instance, boys love physical activities and girls need greater exposure to these activities, thus the same activity can accomplish two goals. However, many parents and educators believe that to meet the separate needs of boys and girls there needs to be gender separation in schools.

Single sex education is an old idea that has gained new relevance and support in light of brain studies. Research findings increasingly show that boys and girls in single sex schools outperform their peers in co-ed schools (Hamilton, 1985; Lee & Bryk, 1986; Sax. 2007; Shapka & Keating, 2003). For instance, Sax (2007) reports on a three-year pilot project within a Florida public school that separated students into three groups: co-ed, all girls, and all boys. All the groups were roughly equal in terms of ethnicity, intellectual ability and socio-economic factors. At the end of the project, the percentages of 4th Grade students who met grade proficiency on the *Florida Comprehensive Assessment Test* were found to be: boys in co-ed classes 37%; girls in co-ed classes 59%; girls in single-sex classes 75%; boys in single-sex classes 86%. This study clearly shows significant advantages for children educated in a single-gender classroom. However, details about the methods of instruction and whether they matched brain-based gender strategies were not offered in Sax's analysis.

Beyond improved scholastic achievement, research findings highlight other benefits to attending single-sex schools. Students at these schools describe feeling socially better adjusted and happier with their educational environments. Furthermore, they often take on leadership roles that go against gender stereotypes (Lee & Bryk, 1986; National Coalition of Girls' Schools, 2006). At single-sex schools boys and girls also tend to take more subjects that are traditionally gender-biased – such as physics for girls and foreign languages for boys (Stables, 1990). In addition, studies on classroom conduct have shown that when boys and girls are separated, boys generate fewer behavioural problems (Hutchinson, 2001). In separate environments boys and girls better concentrate on their own education, without the social posturing and opposite sex distractions common in coeducational schools (National Coalition of Girls' Schools, 2006; Stables, 1990). Furthermore, university professors have noted the self-esteem differences between co-ed and single sex graduates at the post-secondary level, especially for girls. Robin Robertson, a former professor, states that "As a college professor I could identify students from girls' schools with a 90 percent accuracy. They were the young women whose hands shot up in the air, who were not afraid to defend their positions, and who assumed that I would be interested in their perspective" (National Coalition of Girls' Schools, 2006, p. 7). The research on single sex schools has been so promising that new laws in the U.S. have made it possible for public schools to offer single sex education, and more schools are increasingly offering gender-separated classes within a co-educational mainstream (Associated Press, 2006; Associated Press, 2008).

Literature Summary

Sex-based cerebral differences are real and permanent. These differences are not just structural in nature, but also functional, and are directly related to perception and ability. While men and women have equivalent general IQs, their intelligence is manifested through activation of different cerebral structures. Female brains tend toward greater bilateral brain symmetry than male brains, while males display greater intra-hemispheric localized activity during task processing. These processing variations contribute to inherent gender-based strengths. For instance, girls tend to naturally excel at activities that require multi-tasking, and boys tend to perform well at tasks that require a more narrow focus. Brain maturation rate differences, such as those involving the language-specialized and spatial-mechanical regions also affect boys' and girls' aptitudes and readiness for learning. Furthermore, amygdala and prefrontal cortex interactions play large roles in mediating behaviour – especially in school-aged children. During adolescence, synaptic pathways are strengthened and others are pruned back according to use. Thus, there are large implications for the role of education in preparing the brains of children for adulthood. Since training has been demonstrated to improve and broaden cognitive skill sets in both males and females, a solid educational foundation is crucial for producing well-rounded individuals.

Due to their unique developmental needs, boys and girls benefit from gender-tailored instructional methods to enhance enjoyment, target cerebral aptitudes, and improve the areas of their brains that are weakest. It is not a ‘one size fits all’ concept. For boys, physical tasks and experiential learning should be used to stimulate interest and teach to their strengths. Kinaesthetic activities can also be used to introduce tasks that develop weaker areas such as language and fine motor skills. Visual methods of delivering instructional concepts (such as using maps, charts, symbols, and models) are preferable. Providing opportunities for boys to become more emotionally vested in school through competition, personalizing instructional spaces and the introduction of positive male role models can help male students see school as relevant and important. Environmental requirements such as room to move around, bell schedule adjustments, fewer distractions, and cooler classroom temperatures are also important considerations in the education of boys.

Group processes are thought to be critical for sustaining interest and creating opportunities for leadership, bonding and idea exchanges when teaching girls. These interactions also strengthen language and communication skills and serve to diminish barriers that can create tension. Sedentary tasks should be supplemented with physical ones to improve gross motor skills. Puzzles and other activities geared to stimulate the spatial-mechanical areas of girls’ brains are also important, as these cognitive processing skills are highly trainable, despite most girls lagging behind boys in this area. Since many girls suffer from lower self-confidence than boys, it is particularly important for teachers to encourage girls to try activities and subjects that are traditionally male-dominated, such as drafting, carpentry, Physics and Calculus. Emphasizing that effort beats natural ability can be crucial for getting girls to stick with difficult material. For both girls and boys, instructional concepts should be made as relevant as possible to their lives and to society.

Drawing from best-practice experiences and the findings of brain researchers, it may be possible to create mainstream schooling environments that can address the learning needs of both sexes. However, the differential needs of girls and boys may be difficult to accommodate in a co-ed environment – especially in the context of overcrowded classrooms. Single-sex education, on the other hand, is a compelling and viable means of providing gender-differentiated instruction – even in a public school milieu. It is clear that more studies need to be conducted to observe the impact of brain-based and gender-differentiated education methods as they are introduced into schools. Although promising, brain research should not be viewed as a panacea for fixing educational problems. Its potential for impacting how children are taught must be explored further.

While much has been written about brain studies and its potential impact on the classroom, most of the researchers who look to apply scientific data to the educational environment tend to be scientists (including psychologists) or educators, but are rarely both. This is unsurprising since there is often a divide between the hard sciences and the social sciences, and few people are fully versed in both areas. Since this is a young field, the definitive research paper on this topic has not yet been written. Much of the existing research relating brain studies to gender-targeted instruction is speculative, containing little hard evidence to support statements of fact surrounding how students learn. Other research is small scale, offering limited information for educators wishing to diligently explore the topic. To explore this concept further, more studies need to be conducted applying gender-targeted instructional strategies to students in real educational settings. To address this need, one such gender-targeted instructional study, the focus of this project, is presented in the sections that follow.

GENDER-TARGETED INSTRUCTION STUDY

Experiment Overview

After finding solid evidence in the literature of cognitive function differences between boys and girls, I decided to investigate the impact gender-targeted instruction strategies has on learning in a single-sex environment. It has been well-documented that the environment of a single-sex class can positively affect student learning and behaviour. However, the use and impact of brain-based, gender-tailored instruction within a single-sex class has not been studied in depth. Would behaviour and achievement for girls in a single-gender class be different if they were taught with strategies geared towards boys instead of those for girls?

To address this question, I first compiled a list of gender differentiated instructional techniques suggested by the literature (see Table 1). Using this list, I wrote paired lesson plans for a Science 9 Chemistry unit that would be given to two different Science 9 classes (see Appendices 1 - 4). Each lesson was written in duplicate, one with activities and techniques that were geared toward girls' learning styles, and the other toward boys' styles. Each lesson, while differing in approach, contained the same curricular content. The use of two classes in this research was crucial. I wanted to investigate the effects on learning of the same material taught from two different perspectives. It would not have made sense to teach the same material twice to the same class.

Table 1. *Gender Differentiating Instructional Strategies Derived From the Literature*

Instructional Strategies for Boys
Mannerisms - Use a loud voice when speaking to class - be directive, concise and brief with instructions - minimize verbal and written instructions - call on boys, rather than waiting for volunteers (slight pressure/stress enhances performance) - question boys while they are doing an activity - avoid lots of transitions and give adequate time to transition between topics - when confronting a boy for a more serious talk, sit or stand beside them rather than in front of them (less intimidating) or use a physical activity, such as passing a ball to mediate discussion - foster ownership of learning by displaying boys' work and personalizing material - provide opportunities for boys to relate to male role models Environment - maintain a slightly cool temperature in the classroom - ensure boys have enough physical space to move freely in classroom (e.g. arm swinging) - provide an environment free from external distractions Activities - provide learning opportunities that are physical in nature - provide activities that don't have too many things to focus on - use games and other ways to build competition into lessons - provide activities to build fine motor skills - provide visual means of learning material (maps, diagrams, charts, models, etc.) when possible - provide activities that promote male bonding between students and with teacher
Instructional Strategies for Girls
Mannerisms - use a soft and gentle voice - use body language that conveys openness and approachability including smiling and good eye contact (crucial for girls to trust and bond with teacher) - allow girls to volunteer answers without pressure (stress/pressure situations lessen performance) - avoid creating high stress situations in class when possible - be consistent and even-tempered - seek privacy when confronting girls for behaviour - provide opportunities for girls to relate to female role models - provide connections between what girls are expected to learn and real life and/or their interests - scramble group compositions so girls become used to working outside their circle of friend and so they have different opportunities for leadership and followership - be particularly supportive and encouraging when teaching science and math (girls can lack confidence in these areas) - teacher's appearance is important for establishing relevance and respect – following current fashions is recommended Environment - maintain a slightly warm temperature in the classroom - try to use materials that make the classroom more homely, such as plants and warm colours Activities - provide lots of opportunities for girls to work in small groups (cooperative learning is particularly important for girls) - make learning fun by providing girls an opportunity to join in non-competitive games and group tasks - provide hands-on activities that reinforce real world applications

The Science 9 Chemistry unit was chosen for a few key reasons. Science 9 does not have a provincial exam, and as a Chemistry specialist teacher, I know the material very well. Science classes also have the potential to offer a great range of activities and skills for lessons (mathematical and logical reasoning, fine motor skill development from lab experiments, gross motor skill activities, group work, writing, presenting, etc.). Finally, the Science 9 teacher at my school (an all-girls private high school in British Columbia) was interested in my research and willing to volunteer her two Science 9 classes to be tested with the lesson plans. She taught the lessons using the lesson plans I developed, while I observed from the back of the room. My school principal was also happy to give permission for this study, as it worked easily within the scope of our school's professional development activities.

The two Science 9 classes (9X and 9Y) were ideal for this experiment for many reasons. They were the same size (17 students in both classes), the classes met on the same days, and both were single-sex (girls). Because our school is a private school, the classes were also very similar in terms of socio-economic factors (middle – upper middle class), ethnicity, language (approximately 30% English as a second language (ESL)), age range (all 14 or 15 years of age), and abilities (no identified severe learning disabilities within the group). Furthermore, overall student achievement in both classes was nearly identical, with 9X at 83% and 9Y at 84% before this study took place.

To reduce inherent biases and behaviour differences between the two classes, both Science 9 classes received two girl-design lessons and two boy-design lessons (see Table 2). This method allowed greater quasi-experimental control, allowing me to more readily see which behaviours were the result of activities, and which came from the inherent personalities of the students. It also allowed me to compare achievement between the two cohorts after the lessons were completed.

Table 2. *Lesson Plan Delivery Schedule for Science 9X and 9Y*

	Boy Lesson	Girl Lesson
Science Lesson 1	9X	9Y
Science Lesson 2	9X	9Y
Science Lesson 3	9Y	9X
Science Lesson 4	9Y	9X

My observations of the classes focussed on individual time-on-task measurements and on student mood and willingness to engage in the lesson activities. I also noted spikes in interest level or engagement at the class level. No individual students were identified during the data collection, nor were any comments written that would allow their identification. My presence in the class was not too remarkable for the students, as I have visited this class before and have observed their lessons as part of my duties as the Head of the Science Department. The students took two quizzes on the material taught during these lessons. The first was a safety quiz, based on Lesson 1. Quiz #2 followed after the lessons were completed and tested material from all four lessons. (see Appendix 5)

Methods Summary

Four sets of paired lesson plans were written for two Science 9 classes (17 girls each class). For each pair, one lesson contained activities and teaching methods that were designed to maximize boys' learning, and the for girls' learning. Both lessons had equivalent curriculum content. The lessons were taught by the student's regular teacher, while class behaviour and responses to the lessons were observed. Two quizzes were written by each class based on the material that was taught.

Ethical Review

An application for an ethical review of the study was made to the University of Victoria Committee. Title and permission was granted in late February, 2009 for this study to take place (protocol number 09-061). Permission to use deception on the classes by not informing students ahead of time about the gender-targeted nature of the study was granted. A copy of the certificate of approval is given in Appendix 7. Participation in the project was voluntary and no parents requested their daughters be excluded from the study. Several wrote letters of support for the study. No students asked to be removed from the study

Lesson Plan Design

The lesson plans used in this study can be found in Appendices 1 - 4. For each lesson, the teacher was coached in how to use the distinguishing mannerisms (such as eye contact and loudness of voice) and in how to control the environment (such as classroom temperature) in the ways listed in Table 1. The teacher and I also discussed the importance of each activity in the lesson and the relevance it had to gender-targeted instruction before each lesson was given to students. Each lesson covered the same concepts and had many common elements, such as review, questioning, direct instruction, guided practice, videos, lab experiments, and same or similar homework assignments. However, there were also several activities that were designed to preferentially differentiate between boy and girl learning styles. These differences are summarized in Tables 3-6.

Table 3. *Lesson Plan 1 Boy/Girl Differentiation*

Learning Outcome	Boy Activity	Girl Activity	Explanation
Respect for the science classroom	Teacher sets fire to lab bench	Older students come in and demonstrate poor lab conduct. Girls discuss what was done.	Both methods are visual, but the boy lesson required students to get up and move to watch. It grabbed attention and conveyed information without a lot of verbal instructions. The girl activity was more social, involved peer modelling, and involved dialogue.
Bad habits during lab experiments	Student safety skits	Group activity analysing a picture of students doing things wrong	Boy method involved gross motor skill movement, teamwork and promoted bonding. The girl activity was more sedentary, but involved close inspection and working together + sharing insights with other groups.
WHMIS symbols	Choose a chemical and research meaning.	Flashcards	Boy method encouraged students to gain a sense of ownership over their classroom and knowledge of what is in chemical cupboard. It got students out of their seats. Girl method encouraged students to test one another and learn together in a non-threatening manner.
Homework	Students can demonstrate learning through illustrating a comic.	Reading and book questions. Students can choose which homework they do.	Boy lesson allowed for more visual representation of learning, rather than requiring paragraph answers. Girl homework played to general girl strengths (requires reading and short answers) while allowing for more individual practice. Students are given some choice over which homework could be done.

Table 4. *Lesson Plan 2 Boy/Girl Differentiation*

Learning Outcome	Boy Activity	Girl Activity	Explanation
What do chemists do?	The idea that science is an exciting career is explored. Images of male scientists are shown.	The idea that science leads to fulfilling useful goals is explored. Images of female scientists are shown.	The boy activity required students to stand up and remain standing when answering the question – giving students another opportunity to move and a visual representation of peer participation. The male and female scientist images were shown for role modelling purposes. Further, a national survey stated that girls want to know their careers will make a difference from a humanitarian perspective.
Kinetic Molecular Theory	Students physically model atom movement in different states	Students learn concepts from video and discuss major points after as a class.	Boy activity required physical engagement and coordination with others - kinaesthetic rather than passive learning. Girl activity used a Brain Pop video, which students find interesting and fun to watch, although it involves passive learning. The discussion afterwards reinforced concepts and asked students to synthesize information in their own words.
Atomic Model – history of the atom	A video is used to teach this concept	Jigsaw and sharing activity.	Boy activity relied on recommended methods of teaching using diagrams, charts, and other visual ways of conveying information. The girl activity involved individual reading, followed by summarization in small groups – shared learning and distributed leadership.
Parts of an atom	A diagram is used instead of extensive notes.	Notes on parts of an atom are used first, followed by a simple diagram.	Boy activity started from a diagram, which is more visual and required less writing. Girl activity took a little longer with notes and a more simple diagram.

Table 5. *Lesson Plan 3 Boy/Girl Differentiation*

Learning Outcome	Boy Activity	Girl Activity	Explanation
Bohr model of atom	Physically acting out the electron orbitals of an atom, followed by notes and guided practice. An online applet is used to add interest.	Direct instruction with board notes and diagrams. An online applet is used to add interest. Energy levels reinforced with a hands on participatory demo involving clothes and money.	Boy activity involved students actively and asked them to work physically with a group of students, negotiating physical space. Girl's activity gave more time for guided practice with teacher. The demo with the black light involved things girls are interested in (clothes, fabrics, money) and connected learning to real world applications – such as solving crimes. Both classes got to look at an online applet showing whizzing electrons for all the elements so students could better visualize what is happening around an atom

Table 6. *Lesson Plan 4 Boy/Girl Differentiation*

Learning Outcome	Boy Activity	Girl Activity	Explanation
Review the development of the Periodic Table (from homework reading)	Students from each different house race each other to solve the element properties pattern leading to the Periodic Table that Mendeleev realized.	Students listen to and watch the illustrated elements song. Teacher then puts on a Periodic Table cape to wear for the rest of class.	Boy activity created opportunity for competition, bonding (through the use of the school's house system with the winner getting house points), and physical movement. The activity reinforced the idea that each Periodic Table group has common characteristics. Girl activity used a fun song and video to reinforce learning. Teacher's Periodic Table fashion statement is funny and attention getting – again playing to girls' interests.
Labelling the Periodic Table	Students colour and personalize their Periodic Tables while listening to common properties of each major family.	Students label Periodic Tables briefly. They then study the properties of the families from their textbooks in anticipation of a Jeopardy quiz game.	The literature states that boys must be given greater opportunity to personalize their spaces and materials in order to connect with school and learning. In the boy lesson, students learned the material while colouring and labelling their personal copies of the Periodic Table. This activity also helped improve memory retention. Girl lesson differentiated the same material through individual reading of the textbook on element group characteristics in preparation for a full class Team Jeopardy quiz – a fun team-building and knowledge testing game.
Generating Hydrogen Gas	Students get a demo as an introduction to doing experiments. While watching the demo they learn about taking observations and what goes into lab reports.	Students learn about observations and lab reports and then get rewarded by a demo.	The boy activity layers learning on an application where the students are physically surrounding the teacher. It applies meaning in context and minimizes notes. The girl activity conveys more detailed information. When the demo is done, they are tested to see how well they had learned the information.

Lesson Observation Data

The sequential Science 9 lessons were observed in March, 2009 over a seven day period. Lessons for Science 9X and 9Y occurred on the same day, taught by the same teacher. The observation data are given in Tables 7 through 22.

Table 7. *Notes on Lesson 1A (9X, Boy-designed)*

- Classroom temperature was kept cool (18°C). Several students commented on wanting to turn temperature up and asked to put coats on.
- Teacher spoke to students loudly, and more formally than normal. Teacher randomly called on students during questioning. No students were allowed to call out answers.
- Students appeared to enjoy being called on, as this is not typical for this class. Teacher's comment after class is that she got more involvement from students who don't normally volunteer.
- A good natured attitude from students was present throughout lesson.
- This class is generally good at sitting and waiting for the next activity and does not need to be reigned in after such a transition.
- Spikes in interest are noted by positive changes in body posture and attention (body more upright, students keenly focussed), obvious enjoyment and laughing.

Table 8. *Notes on Lesson 1B (Girl-designed, 9Y)*

- Students seemed comfortable with the casual structure of class – calling out answers, asking questions, and interjecting. This casual structure; however, did mean that some students can get away with never volunteering an answer or asking a question.
- Teacher spoke to students softly and informally.
- The classroom temperature was 22°C (warm).
- Students in the back of the room were a bit chatty, but also got work done and were on task at the same time.
- The class was good natured and naturally curious. A good rapport was evident between students and teacher.
- Spikes in interest are noted by positive changes in body posture and attention (body more upright, students keenly focussed), obvious enjoyment and laughing.

Table 9. *Notes on Lesson 2A (Boy-designed, 9 X)*

- The students are extremely well behaved; however, they only seem to enjoy the learning and have fun when they are up out of their seats, watching a video or doing something other than the typical
- Very nice class dynamic – cooperative, good sense of humour between students and teacher
- Classroom temperature was cooled to 19°C. Some students commented on how it was chilly.
- Teacher spoke to students loudly, and a bit more formally than normal. Teacher selected from raised hands to answer questions or called on students. No students were allowed to call out answers.
- Spikes in interest are noted by positive changes in body posture and attention (body more upright, students keenly focussed), obvious enjoyment and laughing.
- This was 9X's 2nd boy lesson.

Table 10. *Notes on Lesson 2B (Girl-designed, 9Y)*

- Teacher mentioned that this is the more difficult of her two classes in terms of behaviour. She felt that this class would do better with the boy lesson – which they will get next class.
- Classroom temperature was warm (23°C).
- Teacher spoke to students softly and informally. Students were allowed to call out answers.
- Spikes in interest are noted by positive changes in body posture and attention (body more upright, students keenly focussed), obvious enjoyment and laughing.
- This was 9Y's 2nd girl lesson.

Table 11. *Notes on Lesson 3A (Boy-designed, 9Y)*

- Overall, students appeared to be more on task for this lesson, especially considering this was the last class of the day. This is perhaps even more significant because this lesson contained more board work and more difficult concepts than the previous lessons.
- Classroom temperature was cooled to 18°C.
- Teacher spoke to students loudly and more formally than usual. Students were called on for many questions, although the teacher also chose from raised hands. No students were allowed to call out.
- Spikes in interest are noted by positive changes in body posture and attention (body more upright, students keenly focussed), obvious enjoyment and laughing.
- 9Y had 2 previous girl-designed lessons. This was their first boy lesson.

Table 12. *Notes on Lesson 3B (Girl-designed, 9X)*

- 9X had 2 previous boy-designed lessons. This was their first girl lesson.
- This lesson had more board work and covered more difficult concepts than previous 2 lessons.
- Overall, students appeared to be a little less on task for this lesson than previous.
- Classroom temperature was warm.
- Teacher spoke to students softly and warmly.
- Students were allowed to call out, but most raised their hands.
- Spikes in interest are noted by positive changes in body posture and attention (body more upright, students keenly focussed), obvious enjoyment and laughing.

Table 13. *Notes on Lesson 4A (Boy-designed, 9Y)*

- Classroom temperature was cooled to 18°C.
- Teacher spoke to students loudly and more formally than normal. Students were called on for many questions, although the teacher also chose from raised hands. No students were allowed to call out.
- Spikes in interest are noted by positive changes in body posture and attention (body more upright, students keenly focussed), obvious enjoyment and laughing.
- This was 9Y's 2nd boy lesson.

Table 14. *Notes on Lesson 4B (Girl-designed, 9X)*

- This was the 2nd girl lesson for 9X
- Classroom temperature was warm.
- Teacher spoke to students softly and warmly.
- Students were allowed to call out, but most raised their hands.
- Spikes in interest are noted by positive changes in body posture and attention (body more upright, students keenly focussed), obvious enjoyment and laughing.
- The students did not struggle with the multiple transitions in this lesson. They seemed to follow well and enjoyed multiple activities.

Table 15. *Lesson #1A Observations (Boy-designed), Science 9X, 17 Students in Attendance*

Time	Activity Description	# students off task	spike in interest? (# students)	Comments
8:15-8:18	Part A: Burning alcohol	0	Yes (all)	Students were fascinated by the fire “cool”
8:18-8:20	Part B: safety video	0	Yes (all)	Students watched video amusedly.
8:20-8:22	Part B: teacher personal anecdote	0	Yes (15 students)	Several students laugh at story
8:22-8:23	Part B: explaining skit expectations	0	Yes (15 students)	This was the first time the teacher started talking loudly and in a more formal way. Students seem a little surprised by the loudness of teacher’s voice.
8:23-8:28	Part B: students rehearse skits	4→0	Yes (13 students)	Most students collaborated and worked hard on skits – some students practiced in hall. A few students took a bit more time to start working.
8:28-8:39	Part B: students perform skits while others watch	0	Yes (all)	All students watched skits with interest. Some students called out answers to what was done wrong when skit was done. Students seemed to enjoy this activity.
8:39-8:47	Part C: going over safety rules	0→3		After a couple of minutes of listening, some students appeared not to be listening to the verbal treatment of material. One student asked “can we light more things on fire?”
8:47-8:50	Part D: Dividing students into groups and explaining activity expectations	0		Teacher used humour to explain the concept, which students enjoyed.
8:50-9:05	Part D: Students work on WHMIS activity in small groups	0 most of the time (2 students off task briefly)		Students chatted amongst themselves when they had finished activity. This activity didn’t seem to grab them. A few students opened up their chemical bottles out of curiosity to observe what was inside.
9:06-9:15	Part E: Homework assigned and students given some time to get started on it.	6→0		Several students had to be urged to get down to work; however, they did work once asked. Teacher calls on each student not working to cause them some embarrassment. Students seem startled by this, but start working.

Table 16. *Lesson #1B Observations (Girl-designed), Science 9Y, 16 Students in Attendance*

Time	Activity Description	# students off task	spike in interest? (# students)	Comments
1:57	Part A: teacher begins with an explanation about the topics to be included in lesson	2→0		Students are a bit chatty in this class, but they start working when nagged by the teacher to do so.
1:57-1:59	Part A: some grade 12 students burst in	0	Yes (all)	All students stopped chatting immediately
1:59-2:01	Part A: Debriefing of what the older students did badly	0	Yes (15)	Students eagerly offered lots of opinions. A good discussion. One student asked if they were going to get fire like the other class. The teacher explained that sometimes the lessons will be different and they got a grade 12 performance instead.
2:01-2:02	Part B: safety video played`	0	Yes (all)	Students laughed at the “dumb teacher” in the video
2:02-2:03	Part B: explanation of activity	0		One student called out “shotty not recorder”. The role of recorder seemed to be a least favourite.
2:03-2:08	Part B: discussion in small groups	0		Students were able to discuss and correct one another with little guidance. They listened to each other well.
2:08-2:11	Part B: discussion of what groups found	0	Yes (14)	Students casually called out answers. They seemed comfortable with the casual structure of class; however, some students don’t volunteer answers.
2:11-2:21	Part C: going over safety rules	0→2		Lots of interjections and shared disaster stories were offered to make this more interesting. Some of the girls deliberately read out the opposite of the safety rule such as “always drink the chemicals” – but this is done to be funny, and not to be defiant. 2 girls chatted in the back row and missed most of the discussion.
2:21-2:23	Part D: teacher introduces the WHMIS concept	3→0		Still some sporadic chatting in the back row when teacher led the discussion. Students came up with creative alternative acronyms for WHMIS
2:23-2:25	Part D: getting into groups	0	Yes (all)	Students asked teacher to choose the groups to be different from the first set of groups – reason: they like variety and don’t want to be the ones to exclude others.
2:25-2:38	Part D: flashcards	0	Yes (all)	Students quietly organized who is going to make what cards. They seemed adept at rotating leadership. Students made the flashcards and began testing each other. They turned it into a game and enjoyed the activity.
2:38-2:43	Part E: House Fire individual reading	1		Some students shared textbooks. Everyone seemed to read independently. Some students took longer than others. When students finished, some started chatting while waiting for new instructions. One student tried to sleep
2:43-2:45	Part E: students share in pairs	1	Yes (14)	Students enjoy talking to one another and share stories of house fires they’ve heard about. One student had to be coaxed to get into a group.
2:45-2:49	Part E: sharing with class	0	Yes (all)	Students liked hearing about the stories. The idea of their house burning down got their interest.
2:49-3:00	Part F: homework assigned (with choice options) and students given time to get started	0		Students expressed interest and surprise at being given an option about what homework to do. Many commented that they liked this.

Table 17. *Lesson #2A Observations (Boy-designed), Science 9X, 17 Students in Attendance*

Time	Activity Description	# students off task	spike in interest? (# students)	Comments
10:42-10:45	HW submission and updates	0		Students got down to task quickly and efficiently
10:45-10:57	Part A: Students write safety quiz	0		All students quietly wrote quiz. While quiz was being written, the teacher hung up the student comics (from homework) around the room. Several students noticed their comic and seemed happy they were on display.
10:57-11:00	Part B: What is Chemistry about?	0	Yes (15)	Students thought standing up to answer the question was fun. There seemed to be a lot of interest in coming up with suggestions. They also liked being called on.
11:00-11:02	A PowerPoint of male scientist images is played in the background on repeat while teacher discusses uses of chemistry	3		Students were not interested in the pictures –no questions asked about what the scientists had done. No students commented that the pictures were all male. This is an interesting contrast to the other class, who definitely noticed that the scientist pictures were all women. 2 students chatted, while 1 student seemed to be tired and semi-dozed.
11:02-11:06	Part B #3 board notes	0		Students were quiet and took notes well.
11:06-11:10	Part C #1 Reading	0		Students read on task the entire time.
11:10-11:14	Part C #2 students model the KMT by acting out vibrational movement	0	Yes (all)	The students loved this activity. They were able to model the vibration without much direction from teacher. Everyone in class got into it and were quite happy to act out the gas part. Lots of giggling and comments such as “that was fun!”
11:14-11:20	Part C #3 notes on KMT	0		Students transitioned well back to taking notes quietly.
11:20-11:21	Part D #1 questions about what an atom is	0		Teacher calls on individual students. Everyone offers an opinion when called on.
11:21-11:26	Part D #2 Brain Pop video	0	Yes (all)	Students love the Brain Pop videos Teacher passes out the summary handouts during the video.
11:26-11:27	Part D #3 handout	0		Students glance at handout, but without an activity or questions about its content, they put it away in binders.
11:26-11:28	Part D #4 alchemists	0		Students had a lot of pre-knowledge on who the alchemists were and what they did.
11:28-11:30	Part E #1 questioning about subatomic particles	0		Students listen to other students well. Teacher calls on specific students, which seems to keep students more alert.
11:30-11:35	Part E #2 notes on subatomic particles	2 → 0		2 students were a bit slow to get notebooks out and start copying down notes. Teacher calls out to students from front of room to get moving. Peers turn around and look at students, prompting them to start working.
11:35-11:38	Part E #2 h	0	Yes (all)	Students fascinated by the concept that all matter is 99.9% empty space.
11:38-11:44	Part E #3 Eureka video on atoms	0	Yes (all)	Students enjoyed this quirky video and were mimicking “eureka!”. Teacher writes up homework on board during the video.
11:44-11:45	Part F Homework assigned	0		Students copy homework into agendas

Table 18. *Lesson #2B Observations (Girl-designed), Science 9Y, 17 Students in Attendance*

Time	Activity Description	# students off task	spike in interest? (# students)	Comments
9:21-9:33	Part A: Students write safety quiz	0		Class quickly and quietly starts the quiz.
9:33-9:36	Homework and updates	7		A number of students didn't appear to be listening to the updates. Some students disappointed that projects assigned previous week were going to be presented that day.
9:36-9:40	Part B #1-2	4 → 0		Students in back row took a little while to get on task, but eventually started listening and participating. Students became more engaged as they started discussing the applications of chemistry in regular life.
9:40-9:42	Part B #3 Students discuss with a partner what they would do with the powers of a chemist.	5 → 0		Some students chatted among themselves about other things, rather than the topic at hand. 1 student didn't try to pick a partner. Teacher quietly reminds them to get on task. Students cooperatively get down to work immediately.
9:42-9:45	Part B #4 Images of young or famous female scientists shown.	0	Yes (all)	Even though teacher played these images in the background as a repeating PowerPoint, students immediately picked up on them. Comments such as "they're all women!" and "she's hot! Oh she's not." Were heard. Students wanted to know more about what these women had done. Teacher used their interest to discuss how the roles and expectations for women in the sciences have changed in the last 50 years.
9:45-9:49	Part C Notes	0		Even the normally more chatty girls stopped to write notes.
9:49-9:54	Part D KMT – Brain Pop video	0	Yes (all)	Students loved the Brain Pop video
9:54-9:56	Part D #2 reviewed video and KMT through questioning. One student volunteer takes notes for the class on board.	0		Students raised hands to answer questions. They seemed to have fully understood the video concepts.
9:56	Part D #3 KMT reading assigned	3		Most students note the reading in agendas
9:56-9:57	Part E #1 What is an atom	0		Some students offer suggestions.
9:57-10:09	Part E #2 Jigsaw on history of the atom	0 → 3	Yes at first	Students engage more as they are separated into groups by being numbered off. As the activity proceeds, some students in 1 group have to be reminded to keep on task. Most students did very well with the jigsaw task in their small groups.
10:09-10:11	Part F #1 Questioning on what students know about subatomic particles	1		One student seems tired and has head on desk. Teacher explains after that this student often does this, but she is normally listening in this position.
10:11-10:16	Part F #2 Eureka video	0	Yes (all)	All students rapt with attention at this quirky video. They laughed happily at the pratfalls.
10:16-10:20	Part F #3 board notes on subatomic particles	0		Students do well with the structured written notes. No talking during notes is observed.
10:21	Part G Homework assigned	0		Students write homework down and wait for bell to ring.

Table 19. *Lesson #3A Observations (Boy-designed), Science 9Y, 16 Students in Attendance*

Time	Activity Description	# students off task	spike in interest? (# students)	Comments
1:56-2:02	Part A #1 Updates, HW checks and safety quizzes returned	0		
2:02-2:04	Part A #2 review and questions about historical development of the atom	1		Class a little “fuzzy” overall on the key people, ex Rutherford.
2:04-2:07	Part B #1 Notes on the atom	0		Students take notes well.
2:07	Teacher tells some atom jokes	0	Yes (all)	A good class laugh
2:07-2:25	Notes continued	0		Students begin to understand the atom concept
2:25-2:30	Part B #2 Student Bohr model	0	Yes (all)	Teacher took the students outside for this activity. They loved it and were able to do the activity without much guidance. Everyone wanted to join in the electron dance.
2:30-2:44	Part B #3 Board notes on Bohr Models	0 → 2		Some students start to lose focus – perhaps as this is a more difficult concept? Most students seem to understand.
2:44-2:49	Part B #3(*l*) David’s Whizzy’s PT website shown	0	Yes (all)	Students thought this very visual applet was “cool”. Led to lots of questions from students. They also wanted to try lots of different elements.
2:49-3:00	Part C Homework/seatwork assigned	0		Students worked quietly on homework until the end of class.

Table 20. *Lesson #3B Observations (Girl-designed), Science 9X, 16 Students in Attendance*

Time	Activity Description	# students off task	spike in interest? (# students)	Comments
9:20-9:23	Part A #1 Updates, HW checks and safety quizzes returned	0		Students arrive promptly to class and get down to business without distractions
9:23-9:25	Part A #2 Questioning/Review	0		A few students called answers out. Most students didn't appear to remember who was responsible for which atomic development.
9:25-9:26	Teacher tells personal story related to what students are learning.	0	Yes (all)	Students loved the anecdotal story (connections to real life)
9:26-9:31	Part B #1 Notes on the neutral atom	0		Students in this class are good listeners and take notes well.
9:31-9:33	Part B #1 e joke told	0	Yes (all)	Students laugh. One student tells a related atom joke.
9:33-9:43	Part B #1 continued	2→0		2 students a little slow to get back to note taking.
9:43-9:50	Part B #2 seatwork questions assigned	4 →0		Some students a little slow to get textbook open and start working. Teacher reminds students quietly to get on task.
9:50-9:59	Part B #3 Bohr model notes	0		Teacher uses a PowerPoint she's written to guide this section.
9:59-10:03	Part B #3f David's Whizzy PT applet	0	Yes (all)	Students appear fascinated by the applet
10:03-10:10	Part B #4 Black light demo	0	Yes (all)	Students thought this demo was really interesting. Led to lots of conversations and discussions about applications.
10:10-10:20	Part B #5 Bohr model guided practice	1→0		Most students seem to understand concept.
10:20-10:25	Part C HW assigned and students given time to start on it	0		Students were generally well focussed.

Table 21. *Lesson #4A (Boys), Science 9Y, 16 Students in Attendance*

Time	Activity Description	# students off task	spike in interest? (# students)	Comments
9:20-9:21	Part A Updates, HW check	2→0		1 student late to class. Another student didn't seem to be listening at first.
9:21-9:27	Part B Seatwork review questions	0		Students got down to work quickly and quietly. This may be a good way to start lessons in the future for this cohort.
9:27-9:28	Part C #1 a,b Questioning	0		Some students asked clarifying questions
9:28-9:34	Part C #1c Discovering the PT competition	0	Yes (all)	Students got into the competition, and crowded around their house representatives. Teacher colour coded the paper to their house colours. One student tried to cheat by looking at the PT. No one was able to solve the mystery in the time given.
9:34-9:39	Part C #1 d,e Questioning and board notes	0		Some students remembered Mendeleev from the reading.
9:39-10:00	Part C #2	0		Students colour and label their PT's while listening to element family characteristics. Brief notes on characteristics are taken right on PT's
10:00-10:22	Part C #3 Generating hydrogen gas (demo)	0	Yes (all)	Teacher does the demo first, which grabs attention. Students answer questions as teacher goes through the process of what observations would be appropriate for the reaction.
10:22	Part D Homework assigned.	0		Students write homework down before bell rings.

Table 22. *Lesson #4B (Girls), Science 9X, 17 Students in Attendance*

Time	Activity Description	# students off task	spike in interest? (# students)	Comments
10:43-10:44	Part A Updates, HW check	2→0		1 student late to class. Another student didn't seem to be listening at first.
10:44-10:52	Part B Review questions from text	0		Students who finished early were asked to write their answers on the board.
10:52-10:55	Part B teacher reviews answers and concept	0		Some students help each other understand. ESL students explain terms in their own language.
10:55-10:56	Part C #1 a, b Element song played	0	Yes (all)	Students loved the song and were trying to hum along
10:56	Part C #1 c Teacher puts on the PT cape and struts around the class pretending to be Mendeleev	0	Yes (all)	Students call her "chemgirl". Lots of giggling and banter.
10:56-10:58	Part C #1 e Review of Mendeleev's contributions	0		
10:58-10:59	Part C #1 f book PT highlighted	0		Some students flip to book page and look at the PT there with illustrations
10:59-11:02	Part C #1 g board notes	0		Students are quiet and take notes
11:02-11:07	Part C #2 a students watch Brain Pop video	0	Yes (all)	Student excitedly recognize Brain Pop
11:07-11:12	Part C #2 b-e students briefly label their PT's and listen to teacher	0		Quiet, focussed students
11:12-11:17	Part C #2 f students cram for the Jeopardy quiz game	2→0		Students read quietly. 2 chatting students are prompted to start reading. This cramming seems too quick to absorb the info needed.
11:17-11:30	Part C #3 jeopardy game	2-3	Yes (~10)	Students play game. Some are more enthusiastic than others. They have no real reason to root for the team they are on, which is based on where they are sitting. This game was cut short to move on to the demo.
11:30-11:36	Part D a,b observations in the chem. lab - instructions	0→2		Teacher and students discuss how to perform labs. Without the demo to start (as in boy lesson) 2 students lose interest and chat.
11:36-11:43	Part D c demo	0	Yes (all)	When the demo is done, all students are instantly riveted – not knowing if the explosion will be big or little. Several students volunteer quality observations about the reaction, indicating good understanding of the concepts that the teacher has just discussed.
11:43-11:45	Part E homework assigned	0		Students discuss the demo as they write down homework. They were told by teacher that Chem 11 has a huge explosion and are excitedly commenting that they can't wait to take this course.

Observations Summary and Analysis

In general, the students in both Science 9 classes behaved well and participated cooperatively in all activities. Some activities were more engaging than others. Students appeared to enjoy videos, physical and/or hands-on activities, and personal/humorous stories the most. Taking notes and individual seatwork were enjoyed the least, though these activities led to some of the best on-task behaviour. Group work seemed to be enjoyed somewhere in the middle. However, depending on the circumstances and structure of the group work, this kind of activity had greater risks for allowing students to meander off task.

The raw observation data (Tables 7 - 22) do not upon first inspection yield strong patterns of gender-biased responses from the students. Nor did the literature strategies for teaching boys and girls (Table 1) always accurately predict student responses to activities and stimuli. Student off-task behaviour data in Tables 15 - 22 (odd numbered) gives the impression that the boy-designed lessons were possibly slightly better for achieving and maintaining student focus during the lessons. However, the data also indicate that both lesson styles created roughly equal numbers of spikes in interest for both classes.

One of the variables manipulated in this study was the impact of stress on learning. Some literature indicates that stress inhibits learning in females (Diamond, 2001; Shors & Miesegaes, 2002). However, students seemed to respond very positively to being called on and didn’t seem to mind being put on the spot for an answer. In fact, this type of teacher behaviour seemed to cause more students to pay greater attention during questioning. This was a new technique tried by the teacher, and one student commented to her surrounding peers that they couldn’t get away with not thinking about the questions now, as they didn’t know who the teacher would call on. As a teaching technique, it seems this style of questioning might be a good one for teachers of girls to adopt – at least occasionally. Along these lines, the reaction to the Jeopardy activity in Lesson 4 was mixed. Some students enjoyed testing their knowledge in this public, potentially stressful manner. Other students were not as interested in the activity. However, these responses may be more related to individual or group personality than gender.

Some aspects of student behaviour in this study agree with observations in the literature regarding preferred gender teaching strategies summarized in Table 1. As studies suggest, the girls certainly preferred the warm classroom over the cooler alternative, and had no problem staying alert. When the teacher told personal anecdotes the girls were always attentive. Girls in both classes did well, in terms of behaviour, with multiple transitions between activities. They also seemed to understand and follow the lessons well, despite large numbers of activity transitions in each lesson. Indeed, it seemed that the greater the number of activities and transitions, the more successful the lesson was at maintaining student interest.

The importance of showing girls positive images of women doing important work was demonstrated in Lesson 2. When the students were shown a PowerPoint with pictures of female scientists, they became immediately interested and began commenting and asking about the pictures. This reaction was in spite of the fact that the pictures were played in the background and the teacher did not call attention to them. However, when students were shown images of male scientists in the boy-designed lesson, they appeared to not even notice. No comments were made at all. When the pictures were pointed out by the teacher ("In the PowerPoint, I've put up some pictures of famous scientists who have contributed to this field"), students looked at the images, but still did not ask any questions or make comments. They were uninterested. It is also interesting that no student commented that the pictures were only of males, whereas they certainly noticed in the other class that the images were all female. As approximately 30% of the students in this class are from parts of Asia and Mexico, does this indicate how ingrained the male scientist is as a stereotype across cultures? Could it be reflective of cultures where women are not typically seen in professional roles?

Working with both 9X and 9Y revealed that class character can often be a function of the personalities and leadership (positive or negative) of a minority of individuals, who can greatly influence peer responses to an activity. The 9X students seemed in general more enthusiastic, easily led, and less chatty (more on task) than 9Y students. The popular peer leaders in the 9X class asked questions, were attentive, and demonstrated positive attitudes toward learning. Thus, their peers followed suit with similar behaviours. This class appeared to be better suited, in comparison to students in the 9Y class, to the kinds of group work typified by girl-designed activities. They were also more responsive to the low pressure, casual teaching style, and soft-voiced tactics employed by the teacher.

In the 9Y class, the peer leaders appeared to be a bit more easily distracted, prone to call out, and leaned toward attention seeking behaviour. This, however, does not mean that these students were poorly behaved or less intelligent. As students in 9Y were given girl-designed lessons at first, it was predicted that their nature seemed better suited to the boy-designed lesson plans, which would keep them more physically active, and allow for fewer opportunities to “act out” or be off task. This prediction was also independently suggested by their teacher. When the 9Y class received their boy-targeted lessons (Lessons 3 and 4), these predictions about behaviour appeared to be true. The students were more focussed and seemed to enjoy themselves more during the activities. There were also fewer outbursts than before.

After the observation period was over, the gender-targeted nature of this study was revealed to the Science 9 students. The girls were curious about which lessons were boy ones. The 9Y students specifically wanted to know if the Bohr student model activity conducted outside in the field (Lesson 3A #2) was a boy activity because it was their favourite. When told that it was, several girls asked for more activities like this, as “it was really fun”. One insightful student in 9Y asked if the gender study was the reason why they were shown the pictures of “those women scientists”. The students in 9X decided that their favourite activity was the black light demo (Lesson 3B, Part B#4), which was a girl-designed activity.

Quiz Results and Analysis

Two quizzes were given to the students after lessons 1 and 4 were taught to provide numerical benchmarks for learning. Quiz #1 was a safety quiz based solely on the safety and WHMIS material of the first lesson for the students. The results are given in Table 23. From the data, it can be seen that students in 9Y slightly outperformed those in 9X; however, the difference between the two class results is fairly negligible.

Table 23. *Quiz #1 (Appendix 5A) Overall Student Results*

	9X (boy lesson)	9Y (girl lesson)
Safety Quiz Class Average	83.8%	87.5%

Quiz #2 tested the learning from all four lessons in this series used multiple choice and matching questions. A source of error for this data is that in the 9X class one student missed a class, but wrote Quiz #2 anyhow. In the 9Y class, one student missed three classes out of the four, and consequently did not write the quiz. The class results per question are summarized in Table 24.

The data in Table 24 offers interesting information. Questions 1-4, 13 and 15 tested concepts that were taught in gender differentiated ways over the first two lessons. While some results between the two classes were equivalent (or nearly so), it can be seen that students in the

9Y class (given girl lessons) clearly outperformed the 9X group for these concepts. Differences of over 20% can be seen for questions 1 and 15. Examining how the concepts were taught may shed light on why the differences were so large.

Table 24. *Per Question Quiz #2 Results For 9X and 9Y (17 students in 9X and 16 students in 9Y wrote)*

Question	Learning Outcome	Lesson # (Targeted Gender)	9X Average on Question (number of students with correct answer)	9Y Average on Question (number of students with correct answer)
1	WHMIS symbols	1 (Boys) →	58.8% (10/17)	
		1 (Girls) →		81.3% (13/16)
2	KMT	2 (Boys) →	88.2% (15/17)	
		2 (Girls) →		87.5% (14/16)
3	KMT	2 (Boys) →	88.2% (15/17)	
		2 (Girls) →		87.5% (14/16)
4	History of Atomic	2 (Boys) →	64.7% (11/17)	
	Model	2 (Girls) →		68.8% (11/16)
5	Mendeleev and	3 HW (Boys) →		50% (8/16)
	Periodic Table	3 HW (Girls) →	58.8% (10/17)	
6	Organization of	3 (Boys) →		81.3% (13/16)
	Subatomic Particles	3 (Girls) →	82.4% (14/17)	
7	Organization of the	4 (Boys) →		43.8% (7/16)
	Periodic Table	4 (Girls) →	41.2% (7/17)	
8	Properties of Main	4 (Boys) →		75.0 % (12/16)
	Group Elements	4 (Girls) →	64.7% (11/17)	
9*	The Neutral Atom	3 (Boys) →		87.5% (14/16)
		3 (Girls) →	88.2% (15/17)	
10	Bohr Model	3 (Boys) →		81.3% (13/16)
		3 (Girls) →	88.2% (15/17)	
11*	Atomic Number	3 (Boys) →		100% (16/16)
		3 (Girls) →	94.1% (16/17)	
12	Properties of Main	4 (Boys) →		100% (16/16)
	Group Elements	4 (Girls) →	94.1% (16/17)	
13	WHMIS acronym	1 (Boys) →	100% (17/17)	
		1 (Girls) →		100% (16/16)
14*	Subatomic Particles	2 (Boys) →	100% (17/17)	
		2 (Girls) →		93.8% (15/16)
15	History of Atomic	2 (Boys) →	64.7% (11/17)	
	Model	2 (Girls) →		87.5% (14/16)

Note: * indicates material taught the same way (the teaching activity was not gender differentiated)

In the first quiz, both classes achieved relatively similarly scores on the WHMIS and safety concepts (see Table 23). However, one week later, the same content was tested in Quiz #2 (questions 1 and 13) and the 9Y class's scores clearly demonstrated that the students remembered the WHMIS symbols better than 9X students. It is possible that the key distinguishing factor for 9Y's longer memory retention was the use of flashcards (a social peer teaching activity), as opposed to the 9X hands-on activity where the students received their own bottles of chemicals. Similarly, question 15's concepts were learned by the 9Y class through a jigsaw peer-teaching activity, whereas the equivalent information was conveyed to the 9X class using a fun video and summary handouts plus a teacher-led review. Therefore, this study indicates that peer teaching activities are particularly effective for enhancing girls' learning.

Questions 5-8, 10, and 12 tested concepts that were taught in lessons 3 and 4, where the 9Y students received boy lessons, and 9X were taught girl lessons. These questions showed less of a performance differential compared to questions covering the first two lessons. This lack of difference may be a factor of how recently the students learned the material (short term memory). In question 5, the 9X class outperformed 9Y by 9%, however, the 9Y class outperformed the 9X class by 10% and 6% in questions 8 and 12 respectively. Question 5 on Mendeleev was by no means a mastered concept for either class. However, it is surprising that 9X (girls' lesson) had greater achievement on this concept. The 9Y class had a direct hands-on competition game about Mendeleev and how he came up with the Periodic Table. It actively involved all students in the class, and was clearly engaging. The 9X class had a video that briefly mentioned his name, which was subsequently reinforced by the Periodic Table outfit worn by the teacher in Mendeleev's honour.

Table 25 shows the Quiz #2 summary data. The overall class mean scores on the quiz are given (along with standard deviations). Class averages were also filtered to show performance on questions linked to boy and girl targeted lessons. The questions that were not taught in gender differentiated ways were removed from these calculations.

Table 25. *Quiz #2 (Appendix 5B) Overall Student Results*

	Overall Class Average on Quiz + Standard Deviation (SD)	Class Average and Standard Deviation on Questions Taught Using Boy Methods	Class Average and Standard Deviation on Questions Taught Using Girl Methods
9X (17 students wrote)	Average: 78.4% SD: 18.7%	(Lessons 1 & 2: questions 1-4, 13, 15) 77.5% average 22.8% SD	(Lessons 3 & 4: questions 5-8, 10, 12) 72.5% average 26.8% SD
9Y (16 students wrote)	Average : 81.7% SD : 16.4%	(Lessons 3 & 4: questions 5-8, 10, 12) 71.9% average 21.0% SD	(Lessons 1 & 2: questions 1-4, 13, 15) 85.4% average 19.4% SD

Note: questions connected to learning outcomes that were taught in the same way (non gender-differentiated) were omitted from this analysis.

From this analysis, it can be seen that students in 9Y did slightly better on the quiz (81.7% average) than students in 9X (78.4%). Looking at the results testing the material covered in the first two lessons, it can also be inferred that the 9Y class understood the concepts from these lessons significantly better than 9X. Alternatively, the students in 9X performed slightly better overall than the students in 9Y on the material from Lessons 3 and 4. That is to say in both cases, the students who received the girl targeted lessons performed better on the corresponding questions than those who were taught using the boy-targeted approaches. This numerical evidence is particularly compelling since both classes have consistently tested within 1 percent of one another. Further, these results are surprising, as the 9Y class clearly enjoyed the boy-designed lessons the most. While teacher training and current pedagogy promote good lessons as those containing entertaining, fun and hands-on curricular experiences, it seems these do not necessarily achieve the best results for learning. Engaging and entertaining lessons can certainly be motivational, but clearly such activities must be supported by ones that encourage reflection, individual practice, and deep learning.

While this study is mainly qualitative, the quantitative aspects of the quiz data also lend themselves to a nonparametric statistical analysis of the results. A chi-squared test for independence was chosen for this analysis, and the results are presented in Appendix 6.

Summary

Research shows that cognitive brain differences between the sexes can result in learning differences between boys and girls. Many authors have used brain research to speculate on the instructional strategies and types of learning activities best suited to teach boys and girls. As brain studies demonstrating gender differences in learning activities are so recent, many of the teaching strategies that may exploit gender differences have not been tested in the classroom, let alone in the single-sex classroom. This study was meant to provide some evidence to support or reject these strategies in the context of an all-girls science class. While this study is limited in terms of time and scope, it did provide some interesting insights into how girls preferred to learn and the possibility that gender focused instruction can improve achievement.

While it is possible to isolate and image specific brain processing in individuals, it is most likely impossible to create teaching activities that are exclusively targeted to girls or to boys. Certainly, our brains have been shown to be quite adaptive to learning in a variety of situations, and some students can learn, even when instruction is poor. Thus, activities in this experiment were chosen because they contained strong elements of the gender-related variables I wished to explore. One source of error in this type of empirical study is that some activities may fit equally well into both boy or girl-designed lessons, depending on a person's point of view or the variable under exploration.

The experimental evidence, based on the quiz data, suggests that the girl-designed lessons were slightly more successful in terms of achieving the desired learning outcomes. This is not too big a surprise, as these lessons were designed to cater to an all-girl audience, and this is what they got. What is surprising was how engaged the girls were during the boy-designed lessons. Indeed, there were several activities in the boy-targeted lessons that students found particularly enjoyable. However, many of the true outcomes of gender-based instruction may not be easily quantifiable on a test. For instance, girls who were shown pictures of female scientists became immediately engaged, and interested in what these scientists had done. It was obvious that deep associations were being made in these students' minds relating to the subject matter and to their own future potential. These motivational aspects of gender-targeted instruction, which are more phenomenological in nature, could have the greatest impact on students' lives and learning, while not showing up at all with standardized testing. Tables 28 and 29 provide a summary of the specific conclusions and recommendations resulting from this study.

A minor theme in this study turned out to be one of the entertainment value derived from the instruction versus true learning. Today's high school students have been increasingly fed a diet of cell phones, television, Internet websites, video games, i-pods, and social networking. They are used to receiving information from a variety of sources - often simultaneously. Many students will study while texting, listening to mp3's, watching television, and surfing the net – behaviour that less than a generation ago may have been labelled as symptomatic of attention deficit disorder (ADD).

Table 28. *Most Effective Activities For Girls In Estimated Descending Order of Impact*

Activities Best for Learning (based on engagement and achievement)
1. Peer teaching opportunities (e.g. flashcards and jigsaw)
2. Direct instruction (e.g. board notes and guided practice)
3. Physical activities involving gross motor skills (e.g. acting out concepts)
4. Demonstrations
5. Hands-on activities involving fine motor skills (e.g. lab experiments)
6. Individual practice and homework
7. Videos (e.g. Brain Pop) and other visual media (e.g. interesting websites)
8. Group work (e.g. discussion groups)
9. Stories, anecdotes, and analogy

Table 29. *Most Effective Teacher Behaviours to Support Student Attention and Learning*

Teachers should:
• have good eye contact with students
• smile, be friendly, open and personable
• alternate calling on students randomly with choosing from raised hands when questioning
• tell personal anecdotes or stories related to curriculum
• address poor behaviours and other matters with students quietly so as not to call attention or embarrassment
• reinforce positive images of women doing important related work
• pay attention to how they are dressed – girls really notice and care about what teachers wear
• display student work when possible
• where possible build choice into homework assignments
• keep the classroom temperature warm
• provide connections to real world phenomena to explain the importance of what students are learning
• scramble group compositions during group activities to prevent the same students from always working with one another
• use diagrams and visual means of representing information where appropriate

Because students have adapted to multi-tasking, this cannot help but reshape their neural networks and impact the ways they learn. Students may be more engaged and entertained when there are frequent changes of activity – especially activities which are not perceived as being work. Conversely, students are becoming bored more quickly than in the past when asked to sit and listen or take notes. However, as shown in the quiz results from this study, entertainment and enjoyment do not always yield the most thorough learning – at least in terms of performance on tests. The amount of time, work, and dedicated focus students place on their studies may possibly be the most crucial elements for learning.

A few theoretical hypotheses about how girls learn are not supported by the findings of this study. One is that teachers should speak softly to girls. During the lessons the teacher moderated the volume of her voice, using softer/quieter tones for the girl lessons and louder ones for the boy lessons. Students did not appear to notice the difference. Nor was the impact of smiling or eye contact easy to distinguish. The moderation of these variables may have been less effective in this particular study as the students knew the teacher well. Perhaps if the teacher was unknown to the students, voice level, eye contact and smiling would have a greater impact on student behaviours.

Finally, the stress variable and its impact on learning were explored in the boy-designed lessons by putting students on the spot to answer questions. The students were also required to stand when they gave their answers. However, when this was done, several students were observed to become more actively involved in questioning than normal. Many students found the standing fun or at least funny, which would tend to negate the stressful nature of the activity. If this requirement of standing to give answers was continued until its novelty was lost, the student enjoyment and response to the activity would most likely change; however, there was not enough time in this study to observe this eventuality. Likewise with the Jeopardy activity, some students really enjoyed being put on the spot, while others were not as engaged. It is not known how much or what form of stress would be required to noticeably decrease learning for girls, while improving it for boys.

Limitations and Future Research

This study was limited in several ways. Time, scope and access to students were all barriers to achieving the ideal experimental design. For instance, to test long term retention it would have been interesting to give the same Quiz #2 to students several weeks later and see if their performance matched their first attempt. I would also have liked to report on the two classes' performances on their chemistry unit test. However, as this test will not be given until after my report deadline this information is not available. Looking at several grade levels of girls in my school would also have been beneficial to factor out specific cognitive development and behavioural issues. Girls in Grade 9 are very different from ones in Grade 6 or 12 (for example), since there are important developmental differences that change behaviour and brain responses to learning as girls age and mature.

While I wished to test whether boys and girls learn differently, my experiment was only able to give evidence for girls' learning responses in one particular setting. An extension of this research would be to deliver the same dual lesson approach in an all-boys setting, as well as in a co-educational one. It is suspected that a much larger discrepancy in behaviour and performance between classes would have been seen if this study was conducted using co-ed or single-sex boys' classes. This would also provide a sufficiently large number of participants to be able to analyze the results with more parametric statistical tests to determine whether the results are statistically significant.

As this was mainly a qualitative study, there is additional exploratory quantitative work that might be done for gender-based instruction. For instance, it should be noted that the quizzes given to students in this study were simple models of the kinds of questions that would be asked on typical end of unit tests. As such, the questions focussed on Ministry of Education Science 9 learning outcomes, and really only tested a few categories of learning. In contrast, the well-known cognitive theorist R. Gagne (1985), identifies five major categories of learning: verbal information, intellectual skills, cognitive strategies, motor skills and attitudes. As different internal and external conditions are necessary for each type of learning, these have the potential to be categories for future quantitative gender studies. Such studies would help differentiate the effectiveness of gender-based instruction on different types of learning outcomes. For instance, gender-based instruction may turn out to have less of an impact in the area of verbal information, but more on attitudes and cognitive strategies. A well-designed study with a sufficiently large population size could contribute to our understanding of these learning mechanisms in much greater detail.

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Appendices

Appendix 1

Appendix 1A. Chemistry 9 Lesson 1 (Boys): Chemical Safety

Processes of Science

It is expected that students will:

A1 demonstrate safe procedures

Reminder: for all "Boy" lessons talk simply, in a loud, and authoritative tone. Avoid too much eye contact unless you want to challenge an individual student. Ensure the classroom temperature is slightly cool. Don't wait for volunteers. Tell students that you will pick someone at random. Don't let students opt out of answering easily. Give them a bit of a hard time (boys strive under small amounts of stress and like competition). Have very high expectations. Behaviour issues should be dealt with immediately and sternly – in front of student peers to show that you expect no misbehaviour. When asking questions and transitioning between topics, give a little bit longer for boys to answer. When possible, verbal and written instructions should be minimized in favour of diagrams and other visual presentations.

Resources and Materials:

Textbook: BC Science 9 (McGraw Hill Ryerson, 2007)
BC Science 9 Workbook
Alcohol and match
Internet projection capability
8 bottles of chemicals with different WHMIS symbols on them – place on back counter

Overview and Objectives
This approximately 60 minute lesson is geared to teach students about lab and chemical safety.

By the end of this lesson students will know

a. Safe procedures during experiments and when using the lab environment
b. WHMIS symbols and their meanings
c. What to do in case of an accident

Assessment

Formative assessment will be made through observation, and homework. Summative assessment of these objectives will be made with a safety quiz.

Lesson Plan

A. Danger in the Science Lab (5-10 min)

a. Pour a small amount of ethanol or better, a heavier alcohol (30 ml?) in a straight line along one of the desks right before students come into the room.
b. See if anyone notices the liquid and touches it or smells it.
c. Touch the liquid yourself. Show students that your hand is ok so it isn't acid. Is this how we test unknown liquids? How can we identify unknown liquids? What could they do?
d. Turn off the lights and light the alcohol on fire.
e. Ask the class if anyone knows how to put out such a fire?

f. Discuss how there are often unknown liquids or dangers in a science lab – particularly in chemistry. There are set procedures for staying safe.

B. Bad Habits in Science Lab (25-30 minutes)

a. As an intro, play the video at : http://www.bcscience.com/bc9/pgs/videos_007_safety_bad.html
b. Divide students into groups appropriate for the safety skits (Appendix 1C) which they will have to perform for the class (they will have max of 5 min to read and plan who is going to do what role, and 2 min for each skit)
c. As students perform their skits, other students should pay attention to all the bad things that are taking place.
d. After each skit, students are called upon (teacher selected) to explain what was bad and what should have been done differently. Don't let someone get away with passing and don't allow other students to help. Debriefing should take approx. 15 minutes.

C. Safety Rules (10 minutes)

a. Bring out the safety rules for conducting a lab experiment (Appendix 1D)
b. Clarify meaning if needed.
c. Discuss location of safety material (e.g. eye wash station, fire extinguisher, fire blanket, etc.) if needed. Physically show students.
d. Show students some of the WHMIS symbols on the computer (google WHMIS images). Ask students if they've ever seen these before and on what?
e. Introduce the concept of WHMIS and what it stands for and why it was created.
    - workers health management information system
    - to protect people from doing dumb stuff
    - to help people know what to do if there's been a chemical accident

D. WHMIS (10-15 min)

a. Divide students into groups of 2 or 3.
b. Each group should elect one person to go to chemical cabinet at the back of the room and take 1 bottle that has WHMIS symbols on it.
c. Students should write out the name of the chemical and draw the WHMIS hazard symbols on it.
d. Students should then use the guide on p. 12 of the textbook to determine the meaning of the chemical hazard(s) that are on the bottle.
e. Students should compare their symbol with at least 2 other groups. Which group had a container with the most symbols? (competition).
f. If time, students should test themselves on WHMIS symbols using the Reading Check on p. 13

E. Homework

a. Announce quiz on safety rules and WHMIS symbols next day (read handout and p. 12)
b. Design a short comic out of a scene where students are doing something wrong in the science lab. Label the comic in a way that makes it clear that this is what NOT to do.

Appendix 1B: Chemistry 9 Lesson 1 (Girls) – Chemical Safety

Reminder: for all girls lessons, speak in a softer tone. Use eye contact and smile a lot. Make sure classroom is on the warm side. Ask for volunteers to answer questions, but call on students if there aren't enough volunteers. Allow them to get help from a partner or ask for another volunteer. If girls don't feel comfortable answering a question, don't make a big deal about it. Conversations about behaviour issues should be private with the individual.

Processes of Science

It is expected that students will:

A1 demonstrate safe procedures

Resources and Materials:

Textbook: BC Science 9 (McGraw Hill Ryerson, 2007)
BC Science 9 Workbook
Senior student volunteers
Index cards (set of 14 for each group)

Overview and Objectives
This approximately 60 minute lesson is geared to teach students about lab and chemical safety.

By the end of this lesson students will know

a. Safe procedures during experiments and when using the lab environment
b. WHMIS symbols and their meanings
c. What to do in case of an accident

Assessment

Formative assessment will be made through observation, and homework. Summative assessment of these objectives will be made with a safety quiz.

A. Danger in the Science Lab (5-10 minutes)

a. Get some senior students to enter classroom with loud music, giggling, texting, fooling around, etc.
b. Have a previously set up battery electricity experiment on a student desk (not actually live).
c. One student starts to play with the experiment. Pretends to lick their fingers and touches the electrodes. The student then collapses. Another student reaches for her friend and then is also knocked unconscious. The third student runs out of the classroom.
d. Excuse the senior students from the room (thank them for volunteering)
e. Ask the grade 9 students to discuss what the seniors did wrong.

B. What Not To Do (5-10 minutes)

a. As an intro: Play the video: http://www.bcscience.com/bc9/pgs/videos_007_safety_bad.html
b. Then ask students to get into a group of 3 or 4 students. One person in the group should be the recorder.
c. Students should look at the diagram (p. 4 BC Science 9 workbook)

d. Students should verbally discuss all the problems in the diagram. The recorder should make a brief list of the problems seen.
e. Take a survey to find out which group found the most faults.
f. Ask for a few comments from each group about what they found.

C. Safety Rules (10-15 minutes)

a. Hand out the safety rules list (Appendix 1D) and discuss the rules – ask for volunteers to read out each line and another volunteer to explain the rules that aren't necessarily obvious.
b. Discuss location of safety material (e.g. eye wash station, fire extinguisher, fire blanket, etc.) if needed.

D. WHMIS (20 minutes)

a. Introduce the concept and purpose of WHMIS symbols
    - Ask students what they think this stands for,
    - Tell them it is workers health management information system
    - Why do we have it?
      → to protect people from doing dumb stuff
      → to help people know what to do if there's been a chemical accident
b. Students should get into a different group or 3 or 4 (make sure at least at least 1 person is different from previous group – builds empathy and different opportunities for leadership when group compositions change).
c. Take 14 index cards (provided). Create a set of flashcards by drawing all of the symbols of the hazard symbols found on p. 12. Put the names or meanings of the symbols on the other side. Split up the work, then test each other using your flashcards. Keep going until everyone has all the symbols correct.

E. House Fire (10 minutes)

Think-pair-share (tps):
a. students should read p. 14 quietly to themselves and think about questions 1-3 (5 minutes)
b. students should then pair up with another student and share answers
c. Class discussion? Has anyone ever been in a house fire? Share some of the answers students came up with.

F. Homework

a. Read pp. 8-11
b. Choice: Either
    do p. 15 #1, 3, 6, + handout (p. 4 from student workbook) or
    do handouts p. 5 and 7 from student workbook

c. Lab safety rules and WHMIS quiz next class.

Appendix 1C: Safety Skit Scenarios

Skit #1: Fooling around in the science lab (for 4 or 5 students)

Fooling around in the lab (also called horseplay) is a bad idea. People get hurt, chemicals get knocked over and sensitive glassware can be destroyed. Your groups goal is to act out what not to do when starting a lab experiment. This skit should take no more than 2 minutes and should be improvised.

Roles: One person play being the teacher. The rest of you are students

Teacher: Tell the students that they are going to perform a lab with acid and they are going to have to be really careful when working with this substance.

Students:

Ignore the teacher when she is talking – instead talk about your weekend plans
Then get up, grab lab glasses, and start the lab. Except instead of getting your lab materials together, pretend to take notice of another demo or experiment set up in the room. Start touching it. One person should push the other, and then you should pretend to knock over the experiment and break everything.

Teacher: put fake notes on the board and completely ignore what the students are doing.

Skit #2: Electricity (for 3-4 students)

This skit is meant to show the wrong way to plug in a electrical cord and what the dangers are when working with electricity in an unsafe way. You will have 5 min to plan this skit, which should be 2 min long. You will need a hot plate or other electrical cord device as a prop for this skit.

The scene:

Student 1 says that they are going to get a hotplate for the experiment. When the student finds the hotplate, the student should notice and state that the cord looks frayed and old. A second student should grab the hotplate from the first saying “who cares, let’s just start the lab”. The first student should get mad and leave the room.

The second student should plug in the hotplate, holding the frayed wire and get electrocuted. The student should hang onto the plug and collapse over the table. A third student should reach for their unconscious friend and also become electrocuted. This student should collapse next to their friend, still touching some part of their body. If another student is involved in the skit, they should also touch the pile of bodies to shake their friends and become electrocuted too.

Skit #3: Not wearing appropriate clothing (for 2-3 students with longer hair)

This skit is meant to show others how important it is to wear appropriate clothing and eyewear during an experiment. You may want to use some beakers or other glassware as props. You will also need some books and loose paper.

You and your lab partner should pretend to be working on an experiment. Your hair should be in front of your face and you shouldn't have goggles on. You should have a messy work area (take a few pieces of scrap paper or your books to do this). Pretend to be doing an experiment surrounded by your paper and books. Let your hair get in the way so you can't see what you're doing. One person should pretend to get acid splashed into your eyes. Exclaim "oww my eyes" – or something like that. The other lab partner(s) should do nothing to help – maybe tell them to find some water. This skit should take no longer than 2 minutes to perform and should be improvised.

Skit 4: Fire in the Science Lab (2-3 students)

This skit is meant to show what not to do when you create a fire. You will need a Bunsen burner as a prop and some loose paper. You will have 5 minutes to plan and your skit should be around 2 min. long.

Stand at a desk with and partner or 2 and pretend you are working with a Bunsen burner (it produces fire). Have some loose paper surrounding your work area. Make comments such as "look at the pretty fire". You should all leave the Bunsen burner running and go get something on the other side of the lab. When you come back you start to freak out because the Bunsen burner has lit your table on fire. Choose some really dumb things to do about this situation (such as run around, panic, fan the flames, etc.) One of your lab partners should then pretend to get burned.

Skit 5: Chemical Spills (3-4 students)

This skit is meant to show what not to do when you spill chemicals or see a spill. You will have only 5 minutes to plan who does what and 2 min to perform your skit.

You and your lab partners should pretend to be doing an experiment. Student 1 should something like – "I wonder what that puddle of liquid over there is?" Students 2 and 3 just shrug it off – "who cares, let's finish, the bell is about to go".

One of you should pretend to spill your chemicals on the counter and all over your lab partner. Another student "oh don't worry, it's mostly water, you're not going to die"

Continue working and then pretend to hear the bell ring. You all decide to leave the spill lying all over the counter. One student says "let's just leave the spill – someone will clean it up". Then everyone leaves the room except for the student that has been covered with chemicals.

Appendix 1D: Lab Safety Rules

1. Protect your own safety and that of others. Listen carefully to the teacher's instructions and beware the dangers, if any, of the experiment you are about to perform.
2. Always wear lab goggles or glasses when working with chemicals. Personal glasses do not provide as much protection, but your teacher may allow you to wear these instead of lab goggles, depending on the experiment.
3. Before you do any experiment, be familiar with where to find the safety equipment, such as the safety shower, fire blanket, eye wash stations, fire extinguishers and sand buckets.
2. Rushing and running in the lab will not be permitted.
3. Friends from other classes are not allowed to visit you during a lab experiment.
4. You are not to leave the lab without permission from the teacher during an experiment.
5. Never carry hot equipment or dangerous chemicals through a crowd of people. Get them to step aside. If you think an object is hot, gently place your hand near the object and see if it radiates heat.
6. Never hide an accident. Report any injury or spill to your teacher immediately, no matter how minor you think it is.
7. No laboratory work should be carried on without your teacher's permission or supervision.
8. Never assume a spill is just water. Spills are the responsibility of everyone in the lab. Make your classmates clean up their mess or you will have to do it for them.
9. Leave all personal items that aren't necessary for the lab in the designated areas to avoid contamination or cluttering up the lab area.
10. When making a dilute acid solution, add acid to the water, not the other way around.
11. <u>Never</u> put chemicals **back** into the main chemical jar. Take just enough for your experiment. Dispose of excess chemicals according to your teacher's instructions.
12. Ask permission if chemicals are to be poured down the sink. Keep the water running to flush the drains thoroughly.
13. Never taste chemicals or drink from laboratory glassware. When handling chemicals keep your hands away from your face, especially your mouth and eyes. Wash your hands after handling chemicals. If you need to smell a chemical, gently waft the odours toward your nose.
14. If any area of your body or clothing has been touched by acid or other harmful chemical, flush it with lots of water. If any gets in your eye, use the eye wash station continuously for 10 minutes. Get a friend to inform your teacher.
15. Major chemical spills on your body: use the chemical shower outside the classroom.
16. If you must identify a chemical by smelling it, never breathe deeply over it. Instead, carefully waft the vapor with your hands in the direction of your nose.
17. Learn to use the Bunsen burner correctly before you light it. Never lean over it while lighting it or while it is burning. Never leave a lighted burner unattended. Remember the blue flame can almc invisible, so never reach over a burner. Sleeves and hair must be kept well back.

18. When you are unplugging an electrical cord, pull the plug (hard bit at end), not the cord. Report frayed cords to your teacher. Bare electrical wires can be extremely dangerous.
19. Report sharp edges on mirrors, metal plates, and glassware to your teacher. Do not work with glass that has jagged edges.
20. Place broken glassware in the "sharps" or broken glass bin. Never leave broken glass on benches or in sinks and never place broken glassware in the waste paper basket.
21. Before taking a chemical, read the label to make sure you are using the correct one.
22. Let your teacher know if you wear contact lenses before every chemical experiment.
23. At all times exercise caution when in the science laboratory. When in doubt: ASK FOR HELP!

Appendix 2

Appendix 2A: Chemistry 9 Lesson 2 (Boys): Investigating Matter

Reminder: for all "Boy" lessons talk simply, in a loud, and authoritative tone. Avoid too much eye contact unless you want to challenge an individual student. Ensure the classroom temperature is slightly cool. Don't wait for volunteers. Tell students that you will pick someone at random. Don't let students opt out of answering easily. Give them a bit of a hard time (boys strive under small amounts of stress and like competition). Have very high expectations. Behaviour issues should be dealt with immediately and sternly – in front of student peers to show that you expect no misbehaviour. When asking questions and transitioning between topics, give a little bit longer for boys to answer. When possible, verbal and written instructions should be minimized in favour of diagrams and other visual presentations.

Physical Science: Atoms, Elements, and Compounds

It is expected that students will:

C1	use modern atomic theory to describe the structure and components of atoms and molecules
C2	use the periodic table to compare the characteristics and atomic structure of elements
C3	write and interpret chemical symbols of elements and formulae of ionic compounds
C4	describe changes in the properties of matter

Resources, Materials, and Prep:

Textbook: BC Science 9 (McGraw Hill Ryerson, 2007)
BC Science 9 Workbook
Internet projection capability
Pictures of Male scientists preloaded on computer
Log in to Brain Pop account (www.brainpop.com login: qmsfaculty password: brainpop)

Overview and Objectives

This 60 minute lesson will introduce students to the concept of matter and its states. A brief overview of the historical development of atomic theory will be explored and students will learn about the basic subatomic particles.

By the end of this lesson students will know

d. What matter is
e. The key points of the Kinetic Molecular Theory
f. The major historical developments in the history of the atom from the early Greeks through to Rutherford's Gold Foil experiment.

Assessment

Formative assessment will be made through observation, homework, and a quiz. Summative assessment of these objectives will be made with a unit test.

Lesson Plan

A. Safety and WHMIS quiz (10-15 min)
B. What is Chemistry all about? (5-10 min)
1. survey what students think chemistry is all about
2. Open question: What do chemists do?
    - When a student offers a suggestion, have them stand up and remain standing.
    - Offer suggestions if they don’t think of enough things to get them thinking to add to the list (e.g. look for soil contamination, food chemists, pharmaceuticals, work with lasers, mining uranium and gold, coming up with alternate products for petroleum, making plastics, etc.)
    - Reinforce ideas such as chemists are really useful to industry and get paid pretty well. Their jobs can be exciting.
    - Project pictures of male scientists doing field work etc. in the background during this discussion. Don’t make a big deal about the pictures being male – see if students notice and respond that there aren’t female pictures
    - Mention that in fact everything they have touched, worn, and eaten has most likely been the product of some sort of chemical process or inspection.

3. Board definitions: Matter is everything you can touch or see (anything with mass and volume).
    - Chemistry is the study of matter, its properties and its reactions.
    - Matter is made up of atoms and compounds/molecules (explain these terms)

C. Kinetic Molecular Theory (10 min)

1. Students should read about the KMT on pp. 19 and 20 of the text then look at the diagrams (3 minutes).
2. Demonstration: How are state and temperature and energy related?
    - Pick 4 volunteers to get up and model how atoms in a solid behave according to the KMT (make sure they are vibrating in place, but packed closely). Ask students to describe how their actions fit what solids do (using physical activity to reinforce vocabulary).
    - Ask students what happens when solids warm up? What is the temperature where solids turned into liquids called? (melting point)
    - Pick another 4 volunteers to model how atoms/molecules of a liquid behave (make sure they are vibrating and the students are moving slightly, but close to one another).
    - Same types of questions as above.
    - Get the whole class to model how gas molecules behave (let them go a little crazy. Prompt them to use the vertical space of the classroom too).

3. Board Notes
    - summarize the key points of the KMT in their notes
    - state how temperature is a measure of the average kinetic energy of a substance. When the temperature increases, particles have more freedom to move.

D. Atomic Theory (8-10 minutes)

1. We've talked a bit about how atoms behave depending on temperature, but what exactly is an atom? What is an element? Take ideas and discuss.
2. Play the Brain Pop video: Atomic Model.
3. Hand out photocopies of p. 14/15 of the workbook as a video summary.
4. Discuss who the alchemists were and why they couldn't be successful (they didn't realize that atoms couldn't be further divided, concepts of nuclear reactions, etc.). Ignore Bohr for now.

E. Parts of an Atom (15 min)

1. Questions: see what students already know
    a. What are the pieces of an atom?
    b. Where do the subatomic particles go?
    c. What is big and small – relatively?
    d. How big are atoms – can we see them with a microscope?

2. Subatomic particles (board notes)

    a. Start with a diagram of where things go in an atom.
    b. Define the subatomic particles (electrons, protons and neutrons) next to the diagram.
    c. Point to p. 32 table 1.2 as a good summary.
    d. Draw a big round circle on the board and put a dot in the middle representing the nucleus and another dot on the circumference that represents the electron. Tell students that a single electron can be anywhere inside the sphere at a given time, but if you stopped time, it would only be an insignificant speck. Therefore the atom is 99.99% empty space. Everything around us that looks solid actually isn't.
    e. The nucleus is dense, tiny and highly positive. Electrons are attracted to the nucleus like planets are to the sun.

3. Play the Eureka video on electrons: http://www.youtube.com/watch?v=ZB7B_796mVs&feature=PlayList&p=05838CEE514F300D&playnext=1&index=1 (quite good, 5 min long)

F. Homework

1. Read about liquid crystals p. 26 and answer questions 1-3
2. Photocopy p. 17 from workbook and assign all questions

Appendix 2B: Chemistry 9 Lesson 2 (Girls): Investigating Matter

Reminder: for all girls lessons, speak in a softer tone. Use eye contact and smile a lot. Make sure classroom is on the warm side. Ask for volunteers to answer questions, but call on students if there aren't enough volunteers. Allow them to get help from a partner or ask for another volunteer. If girls don't feel comfortable answering a question, don't make a big deal about it. Conversations about behaviour issues should be private with the individual.

Physical Science: Atoms, Elements, and Compounds

It is expected that students will:

C1 use modern atomic theory to describe the structure and components of atoms and molecules
C2 use the periodic table to compare the characteristics and atomic structure of elements
C3 write and interpret chemical symbols of elements and formulae of ionic compounds
C4 describe changes in the properties of matter

Resources, Materials, and Prep:

Textbook: BC Science 9 (McGraw Hill Ryerson, 2007)
BC Science 9 Workbook
Internet projection capability
Pictures of attractive female scientists (chemists) preloaded on computer
Log in to Brain Pop account (www.brainpop.com login: qmsfaculty password: brainpop)

Overview and Objectives

This 60 minute lesson will introduce students to the concept of matter and its states. A brief overview of the historical development of atomic theory will be explored and students will learn about the basic subatomic particles.

By the end of this lesson students will know

a. What matter is
b. The key points of the Kinetic Molecular Theory
c. The major historical developments in the history of the atom from the early Greeks through to Rutherford's Gold Foil experiment.

Lesson Plan

A. Safety and WHMIS quiz (10-15 min)

B. What is Chemistry all about? (5-10 min)

1. Discuss the kinds of things that chemists do. Offer suggestions such as food chemists, pharmaceuticals, work with lasers, mining uranium and gold, coming up with alternate products for petroleum, making plastics, etc. In particular, focus on the humanitarian work that chemists can do – such as improving ways to inexpensively clear up water and get rid

of soil contamination for villages in developing nations. Save fishes from toxic heavy metal poisoning. Creating new ways of making antibiotics so it is cheaper for the poor, etc.

2. Project some internet pictures of chemists from around the world – including pictures of young female chemists and famous female scientists - images of successful chemist role models that girls can identify with are important
3. Tell them that with chemistry they are at the beginnings of a journey that could allow them to change the world someday. Mention that in fact everything students have touched, worn, and eaten today has most likely been the product of some sort of chemical process or inspected by chemists
4. Ask students to think about these things. Have them pick a partner and discuss what they would do if they had the ability to make anything like a chemist. What kinds of things would they do? Where would their interests lie?

C. Matter (5 min)

1. Board definitions: Matter is everything you can touch or see (anything with mass and volume).
2. Chemistry is the study of matter, its properties and its reactions.
3. Matter is made up of atoms (made from elements) and compounds/molecules (made from chemically combining different elements)

D. Kinetic Molecular Theory (10 min)

1. Brain Pop video: States of Matter
2. Review the key points of the KMT through questioning – have a student take short notes for class on the board.
   - Ask students to state something they learned from the Brain Pop video – take a few answers
   - what state has the particles moving the fastest?
   - How do molecules move from one state to the next?
   - What is it called when molecules move from solid to liquid? Liquid to gas? Draw a diagram on the board and label the processes.

3. Tell students that the Kinetic Molecular Theory is summarized in their textbook on pages 19 and 20 and they are responsible for knowing this material.

E. Atomic Theory (15 min)

1. We've talked a bit about how atoms behave depending on temperature, but what exactly is an atom? What is an element? Suggestions? (rhetorical if students don't answer)

2. Jigsaw: Number students 1-4 to create 4 groups of 4 + a few extras if needed. Each group must have at least 1 person of each number. Each person will read their assigned scientist, and then tell the other people in the group about what they read. They will get 4 min to read and 2 min to talk about what they read.
   a. Person 1 reads pp.28 and 29 to find out about Aristotle and the Alchemists

b. Person 2 reads pp. 29 and 30 on John Dalton
c. Person 3 reads p. 30 on J.J. Thomson
d. Person 4 reads p. 31 on Ernest Rutherford

3. Hand out pp. 14/15 from workbook as a summary after the activity. Students will have to look this over for homework. Note: Bohr will be covered later.

F. Parts of an Atom (15 min)

1. Questions: see what students already know
   a. What are the pieces of an atom?
   b. Where do the subatomic particles go?
   c. What is big and small – relatively?
   d. How big are atoms – can we see them with a microscope?

2. Play the Eureka video on electrons: http://www.youtube.com/watch?v=ZB7B_796mVs&feature=PlayList&p=05838CEE514F300D&playnext=1&index=1 (quite good, 5 min long)

3. Board Notes: Subatomic particles

   a. Define the subatomic particles (electrons, protons and neutrons)
   b. Draw a simplified diagram of where things go (P and N in nucleus, electrons in orbitals on the outside).
   c. Draw a big round circle on the board and put a dot in the middle representing the nucleus and another dot on the circumference that represents the electron. Tell students that a single electron can be anywhere inside the sphere at a given time, but if you stopped time, it would only be an insignificant speck. Therefore the atom is 99.99% empty space. Everything around us that looks solid actually isn't.
   d. The nucleus is dense, tiny and highly positive. Electrons are attracted to the nucleus like planets are to the sun.

G. Homework

   1. Read about liquid crystals p. 26 and answer questions 1-3
   2. Photocopy p17 workbook and assign all questions.

Appendix 3

Appendix 3A: Chemistry 9 Lesson 3 (Boys): Atomic Theory

Reminder: for all "Boy" lessons talk simply, in a loud, and authoritative tone. Avoid too much eye contact unless you want to challenge an individual student. Ensure the classroom temperature is slightly cool. Don't wait for volunteers. Tell students that you will pick someone at random. Don't let students opt out of answering easily. Give them a bit of a hard time (boys strive under small amounts of stress and like competition). Have very high expectations. Behaviour issues should be dealt with immediately and sternly – in front of student peers to show that you expect no misbehaviour. When asking questions and transitioning between topics, give a little bit longer for boys to answer. When possible, verbal and written instructions should be minimized in favour of diagrams and other visual presentations.

Physical Science: Atoms, Elements, and Compounds

It is expected that students will:

C1 use modern atomic theory to describe the structure and components of atoms and molecules
C2 use the periodic table to compare the characteristics and atomic structure of elements
C3 write and interpret chemical symbols of elements and formulae of ionic compounds
C4 describe changes in the properties of matter

Resources, Materials, and Prep:

Textbook: BC Science 9 (McGraw Hill Ryerson, 2007)
BC Science 9 Workbook
Access to an open floor space
Periodic Table handout

Overview and Objectives

This approximately 60 minute lesson introduces the organization of electrons and protons according to the Bohr atomic model.

By the end of this lesson students will know

g. where protons, neutrons and electrons go in an atom
h. that the number of protons equals the number of electrons in a neutral atom
i. how to fill up energy levels with the correct number of electrons

Assessment

Formative assessment will be made through observation, homework and a quiz. Summative assessment of these objectives will be made with a unit test.

Lesson Plan

A. Review and Updates (5-10 min)

1. HW and updates.

2. Review Questioning (allow volunteers to answer) (1 min)

   a. Which scientist discovered the electron? (Thomson) The proton? (Rutherford)
   b. What do we call the big chart on the wall (point at Periodic Table)
   c. What is the charge on an electron? Proton? Neutron?
   d. Where do protons belong in an atom?
   e. The atom is mostly what? (space)

B. Atomic Theory

4. Board Notes <u>The Neutral Atom (10 min)</u>

   a. Qu: How is the Periodic Table useful for telling us numbers of protons and electrons? (review from grade 8)
   b. Hand out a copy of the Periodic Table for each student
   c. Define atomic number (# protons).
   d. A neutral atom has equal numbers of protons and electrons. Their charges cancel one another to make an atom neutral. They can have different numbers of neutrons, which just add mass, but not charge to the atom.
   e. Joke: A neutron walks into a bar. He orders a glass of … milk. He asks the bartender – how much money do I owe you? The bartender replies – for you – no charge!
   f. The atomic mass is an average mass of the atom. Mass comes mostly from protons and neutrons, which basically weigh the same. Electrons are so puny, they weigh almost nothing.
   g. Examples
      →Which neutral element has 19 electrons?
      →How many protons does carbon have?
      →Which is heavier, an atom of silver or an atom of lead?
   h. Define an ion as a charged atom or group of atoms
   i. Tell students you can only gain or lose electrons (not protons → nuclear reaction!). Ask them to think about whether you end up with a positive or a negative charge if an atom gained electrons. Lost electrons?
   j. E.g. An ion has 30 protons and 28 electrons. What is its charge? How do you write the symbol of this atom with its charge?

5. Student Bohr Model (10 min)

   a. take students outdoors or to an open space area
   b. ask for a volunteer to stand in the center to act out the nucleus

c. ask students how they think 10 electrons would fit around the nucleus of an atom → have 10 volunteers attempt to act out being an electron around the nucleus (don't give them any directions)
d. tell them good try, but atoms are fussy. Electrons fill up in specific orders in rings around the nucleus. Place 2 volunteer students orbiting the first orbital (have them revolve around the nucleus). Place the remaining 8 volunteers in a 2^{nd} orbital.
e. Ask students why they think 2 electrons can fit in the first orbital, but 8 in the 2^{nd} orbital
f. Tell them that the 2^{nd} orbital is now full. What if 11 electrons needed to be filled. Where would the next electron go? Keep going until all the students in the class are spinning around your nucleus at the center.

6. Board Notes: <u>Bohr Energy Levels: (15 minutes)</u>

a. Scientist Niels Bohr theorized that electrons go into specific energy levels around the nucleus. When these levels fill up, a new level has to be started. Direct students to p. 32 diagram top left
b. Electrons fill up energy levels (aka orbitals, aka shells, aka rings) in a specific pattern. There are a maximum number of allowed electrons in each orbital
c. The pattern is 2, 8, 8, 18, 18 filling up from the closest to the nucleus first.
d. Do an example using an element like sodium. How many protons? electrons? Where do they go? Draw the diagram.
e. Ask the students to think about this 3-dimensionally. Electrons are spread out in "clouds" within their orbit. Direct students to think about airline traffic as an analogy – planes can circle an airport at different altitudes. Electrons do the same.
f. Do a few sample Bohr Diagram examples, such as carbon, lithium, etc. don't put in the neutrons, but mention they're there.
g. Do the Bohr Diagram for Li and for Neon. Ask students to look at the electron arrangement and guess which atom is more stable.
h. Have students label the Nobel Gases on their periodic table. Define these as being very stable and unreactive because their valance orbitals are full.
i. Define valence orbital as the last orbital ring.
j. Show the students where the 2 8 8 18 18 pattern comes from (number of elements in each row of the periodic table)
k. Show that every element in the same family has the same number of electrons in their valence shells
l. Pull up the applet and show them some of the elements with their whizzing electrons: http://www.colorado.edu/UCB/AcademicAffairs/ArtsSciences/physics/PhysicsInitiative/Physics2000/applets/a2.html

C: HW

- Questions p. 63 of text # 3-5, 9, 10-12, 14
- Read p. 52 about Dmitri Mendeleev and then p. 62 for Peculiar Periodic Tables

Appendix 3B Chemistry 9 Lesson 3 (Girls): Atomic Theory

Reminder: for all girls lessons, speak in a softer tone. Use eye contact and smile a lot. Make sure classroom is on the warm side. Ask for volunteers to answer questions, but call on students if there aren't enough volunteers. Allow them to get help from a partner or ask for another volunteer. If girls don't feel comfortable answering a question, don't make a big deal about it. Conversations about behaviour issues should be private with the individual.

Physical Science: Atoms, Elements, and Compounds

It is expected that students will:

C1 use modern atomic theory to describe the structure and components of atoms and molecules
C2 use the periodic table to compare the characteristics and atomic structure of elements
C3 write and interpret chemical symbols of elements and formulae of ionic compounds
C4 describe changes in the properties of matter

Resources, Materials, and Prep:

Textbook: BC Science 9 (McGraw Hill Ryerson, 2007)
BC Science 9 Workbook
Handouts: Periodic Table
Internet and projection
Black light and some bank notes (e.g. $5 bill)
Desk lamp

Overview and Objectives

This approximately 60 minute lesson introduces the organization of electrons and protons according to the Bohr atomic model.

By the end of this lesson students will know

a. where protons, neutrons and electrons go in an atom
b. that the number of protons equals the number of electrons in a neutral atom
c. how to fill up energy levels with the correct number of electrons

Assessment

Formative assessment will be made through observation, homework and a quiz. Summative assessment of these objectives will be made with a unit test.

Lesson Plan

A. Review and Updates (5-10 min)

1. HW and updates.

2. Review Questioning (allow volunteers to answer) (1 min)
    a. Which scientist discovered the electron? (Thomson) The proton? (Rutherford)
    b. What do we call the big chart on the wall (point at Periodic Table)
    c. What is the charge on an electron? Proton? Neutron?
    d. Where do protons belong in an atom?
    e. The atom is mostly what? (space)

B. Atomic Theory

1. Board Notes <u>The Neutral Atom (10 min)</u>

    a. Qu: How is the Periodic Table useful for telling us numbers of protons and electrons? (review from grade 8)
    b. Hand out a copy of the Periodic Table for each student
    c. Define atomic number (# protons).
    d. A neutral atom has equal numbers of protons and electrons. Their charges cancel one another to make an atom neutral. They can have different numbers of neutrons, which just add mass, but not charge to the atom.
    e. Joke: A neutron walks into a bar. He orders a glass of … milk. He asks the bartender – how much money do I owe you? The bartender replies – for you – no charge!
    f. The atomic mass is an average mass of the atom. Mass comes mostly from protons and neutrons, which basically weigh the same. Electrons are so puny, they weigh almost nothing.
    g. Examples
        → Which neutral element has 19 electrons?
        → How many protons does carbon have?
        → Which is heavier, an atom of silver or an atom of lead?
    h. Define an ion as a charged atom or group of atoms
    i. Tell students you can only gain or lose electrons (not protons → nuclear reaction!). Ask them to think about whether you end up with a positive or a negative charge if an atom gained electrons. Lost electrons?
    j. E.g. An ion has 30 protons and 28 electrons. What is its charge? How do you write the symbol of this atom with its charge?

2. Have students do questions p. 63 of text # 3-5, 9, 10-12, 14 (5-10 min to get started)

3. Board Notes: <u>Bohr Energy Levels: (20 minutes)</u>

    a. Scientist Niels Bohr theorized that electrons go into specific energy levels around the nucleus. When these levels fill up, a new level has to be started. Direct students to p. 32 diagram top left
    b. Electrons fill up energy levels (aka orbitals, aka shells, aka rings) in a specific pattern. There are a maximum number of allowed electrons in each orbital
    c. The pattern is 2, 8, 8, 18, 18 filling up from the closest to the nucleus first.

d. Do an example using an element like sodium. How many protons? electrons? Where do they go? Draw the diagram.
e. Ask the students to think about this 3-dimensionally. Electrons are spread out in "clouds" within their orbit. Direct students to think about airline traffic as an analogy – planes can circle an airport at different altitudes. Electrons do the same.
f. Pull up the applet and show them some of the elements with their whizzing electrons: http://www.colorado.edu/UCB/AcademicAffairs/ArtsSciences/physics/PhysicsInitiative/Physics2000/applets/a2.html

4. Demo: Electron Energy Levels (5 min)

a. get a volunteer who is wearing a white shirt
b. turn off the lights and shine the desk lamp on their light – no big deal
c. ask students if they have ever played with a black light
d. shine the black light on the student's white shirt
e. explain what is happening is the electrons in her shirt are being fed a lot more energy than they get with normal light. Normally electrons sit in their happy energy levels. But given higher energy uv light, the electrons jump up to a higher orbital and then have to fall back home. When they fall back home it releases a photon of light – depending on how far it is to fall, in some materials this creates fluorescence.
f. Ask students how this fluorescence can be used in real life – apart from dances. E.g. finding blood splatters (CSI)
g. Show students how bank notes have hidden dyes that fluoresce under black light – alternate desk lamp and uv light.

5. Board Notes: Bohr Model Practice (10 min)

a. Do a few sample Bohr Diagram examples, such as carbon, lithium, etc. don't put in the neutrons, but mention they're there.
b. Do the Bohr Diagram for Li and for Neon. Ask students to look at the electron arrangement and guess which atom is more stable.
c. Have students label the Nobel Gases on their periodic table. Define these as being very stable and unreactive because their valance orbitals are full.
d. Define valence orbital as the last orbital ring.
e. Show the students where the 2 8 8 18 18 pattern comes from (number of elements in each row of the periodic table)
f. Show that every element in the same family has the same number of electrons in their valence shells

C. HW:

a. finish assigned work on p. 63.
b. Read p. 52 about Dmitri Mendeleev and then p. 62 for Peculiar Periodic Tables

Appendix 4

Appendix 4A: Chemistry 9 Lesson 4 (Boys): Elements and the Periodic Table

Reminder: for all “Boy” lessons talk simply, in a loud, and authoritative tone. Avoid too much eye contact unless you want to challenge an individual student. Ensure the classroom temperature is slightly cool. Don’t wait for volunteers. Tell students that you will pick someone at random. Don’t let students opt out of answering easily. Give them a bit of a hard time (boys strive under small amounts of stress and like competition). Have very high expectations. Behaviour issues should be dealt with immediately and sternly – in front of student peers to show that you expect no misbehaviour. When asking questions and transitioning between topics, give a little bit longer for boys to answer. When possible, verbal and written instructions should be minimized in favour of diagrams and other visual presentations.

Physical Science: Atoms, Elements, and Compounds

It is expected that students will:

C1 use modern atomic theory to describe the structure and components of atoms and molecules
C2 use the periodic table to compare the characteristics and atomic structure of elements
C3 write and interpret chemical symbols of elements and formulae of ionic compounds
C4 describe changes in the properties of matter

Resources, Materials, and Prep:

Textbook: BC Science 9 (McGraw Hill Ryerson, 2007)
Internet and projection
Element cards
Materials for Lab 2-1B on p. 48 text

Overview and Objectives

This 60 minute lesson continues with atomic theory and the organization of the Periodic Table of Elements. Students will do their first lab experiment in the chemistry unit.

By the end of this lesson students will know

a. the contributions of Mendeleev to the modern organization of the Periodic Table
b. the major families of the Periodic Table and some of their characteristics
c. how to take observations in the chemistry lab and the correct format for lab reports

Assessment

Formative assessment will be made through observation, homework and a quiz. Summative assessment of these objectives will be made with a unit test.

Lesson Plan

A. Updates (2 min)
B. Review / Seatwork (5-10 min)

- Students should do p. 71 #13 as a review exercise warm up

C. The Periodic Table (PT)

1. History of the PT (5-10 min)

   a. Currently we have the PT with approximately 116 known elements.
   b. But how did we get this PT arrangement? The PT arrangement of elements is the work of many scientists – trial and error + luck and insight
   c. Get 3 volunteers from different houses to come to the front. Place three sets of the sticky PT cards (from Appendix 4C) with some of the elements physical properties on them and the atomic mass randomly on the board. Tell students that this is the puzzle (but even larger) that faced scientists. How to arrange the elements. See who can do this the fastest on the board (race/competition for house points). Make sure they can't see the PT.
   d. Ask: Who can tell me from the reading how Mendeleev solved this puzzle of how to arrange elements to form the PT
   e. Board Notes: The Periodic Law – when elements are arranged in order or increasing atomic number, regular and repeating patterns of similar physical and chemical properties occur for elements in the same family.

2. Groups of the PT (15-20 min)

   a. Provide felt pens, pencil crayons or prompt the students to use and share their own.
   b. Get students to label the PT nicely (so they can keep it all year long and add to it – creating ownership) in the following ways (you may wish to model this on the smartboard or tablet PC at the same time)
      → use a strong colour to divide the metals from the non-metals. Label both regions somehow. As you do this, ask students what they remember about how metals and non-metals differ. Discuss conductivity and shininess. P. 55 of the textbook has a good summary.
      → use another colour to box the Alkali metals and label this group, also call them group 1. state a few properties from p. 56 of the book verbally (reinforce vocab with activities for boys)
      → label the Alkaline Earth metals (group 2) stating properties (p. 56), and repeat for the metalloids (aka semi-metals – see p. 54 text). The closer the metals get to the staircase, the less metallic they get. The semi-metals are a hybrid.
      →Point out the rare earth metals (lanthanide and actinide series). State that all elements after uranium are man-made, unstable, and radioactive.
      →Lastly do the Halogens and the Nobel Gases. Remind students that when they did their Bohr diagrams they saw that the electron orbitals of Nobel Gases were full. This aspect makes all Nobel Gases very stable.

3. How to Perform Chemistry Experiments (15 min)

a. Demo of hydrogen gas production (mirroring lab on p. 48 text) → student volunteers can assist with demo while class learns how to take notes on what happens
b. During the demo, the teacher discusses how to observe chemical reactions, including physical properties (such as state, colour, temperature, mass, volume) and chemical properties (describing how and with what a substance reacts). Good observations should involve both types of descriptions. Observations before (of reactants), during (of the reaction), and after the reaction (products) are needed for completeness.

D. Homework

a. p. 72 #6, 17-19, 28
b. quiz in 2 classes

Appendix 4B: Chemistry 9 Lesson 4 (Girls): Elements and the Periodic Table

Reminder: for all girls lessons, speak in a softer tone. Use eye contact and smile a lot. Make sure classroom is on the warm side. Ask for volunteers to answer questions, but call on students if there aren't enough volunteers. Allow them to get help from a partner or ask for another volunteer. If girls don't feel comfortable answering a question, don't make a big deal about it. Conversations about behaviour issues should be private with the individual.

Physical Science: Atoms, Elements, and Compounds

It is expected that students will:

C1 use modern atomic theory to describe the structure and components of atoms and molecules
C2 use the periodic table to compare the characteristics and atomic structure of elements
C3 write and interpret chemical symbols of elements and formulae of ionic compounds
C4 describe changes in the properties of matter

Resources, Materials, and Prep:

Textbook: BC Science 9 (McGraw Hill Ryerson, 2007)
Internet and projection
Access to Brain Pop → login: qmsfaculty password: brainpop
Jeopardy powerpoint – written for this lesson and webhosted on http://magon-downloads.wikispaces.com/Science
Periodic Table outfit
Materials for Lab 2-1B on p. 48 text

Overview and Objectives

This approximately 60 minute lesson continues with atomic theory and the organization of the Periodic Table of Elements. Students will do their first lab experiment in the chemistry unit.

By the end of this lesson students will know
a. the contributions of Mendeleev to the modern organization of the Periodic Table
b. the major families of the Periodic Table and some of their characteristics
c. how to take observations in the chemistry lab and the correct format for lab reports

Assessment

Formative assessment will be made through observation, homework and a quiz. Summative assessment of these objectives will be made with a unit test.

Lesson Plan

A. HW and Updates (2 min)

B. Review (5 – 10 min)

- Students should do p. 71 #13

C. The Periodic Table (PT)

1. History of the PT (5 min)

a. Currently we have the PT with approximately 116 known elements.
b. Play the youtube video: http://www.youtube.com/watch?v=ssaUusY6hWM&feature=related (element song animated)
c. While the song is playing, slip on the PT cape outfit for the rest of class. Mention Mendeleev and how his work led to this stunning fashion statement.
d. But how did we get this PT arrangement? The PT arrangement of elements is the work of many scientists – trial and error + luck and insight
e. Ask: Who can tell me from the reading what was Mendeleev's contribution to the modern PT?
f. Remind students of the nice looking PT in their textbook that shows pics of the elements in their natural unreacted states p. 60/61
g. Board Notes: The Periodic Law – when elements are arranged in order or increasing atomic number, regular and repeating patterns of similar physical and chemical properties occur for elements in the same family.

2. Groups of the PT (15 min)

a. Play the Brain Pop video called Periodic Table of elements (4.5 min)
b. Have students take out their PT's and point out the staircase that divides metals and non metals. Ask them what this staircase it means.
c. Get students to label the main groups: Alkali metals (refer to them also as group 1), Alkaline Earth metals (group 2), the Halogens and the Nobel Gases. (the transition metals will be talked about later during naming). Point out the rare earth metals (lanthanide and actinide series). State that all elements after uranium are man-made, unstable, and radioactive.
d. Have students turn to p. 54 in their textbooks. Point out the metalloids and discuss how these are hybrids – acting in some ways like metals and other ways like non metals.
e. Transition: but what are the general properties of metals and non metals? What are some of the characteristics of the main families?
f. Tell students that they will be playing jeopardy in 5 minutes that will ask them about properties of the main groups of the PT. They will play in table teams and the top table finishers will get housepoints for each person at the table. They should read over pp. 55-57 to get a sense of the chemical properties of these families.

3. Jeopardy (10 min)

   a. After labeling the PT, have students form teams (keep them at existing tables) to play the jeopardy PT game.
   b. Students can use their own PT’s.
   c. On rotation, each team will be directed a question and have 10 seconds to answer exclusively. If they miss it, the other teams have a chance to steal by picking a number between 1 and 10 and being the closest to the teacher’s pick.

D. How to Perform Chemistry Experiments (20 min)

   a. Discuss how to observe chemical reactions. Include a brief description of the difference between physical properties (such as state, colour, temperature, mass, volume) and chemical properties (describing how and with what a substance reacts). Good observations should involve both types of descriptions. Observations before (of reactants), during (of the reaction), and after the reaction (products) are needed for completeness.
   b. Discuss lab report formats (lab rubric) and expectations
   c. Demo of hydrogen gas production (mirroring lab on p. 48 text) → student volunteers can assist with demo. Students are individually questions about what kinds of observations they would make based on what they’ve just been taught.

E. Homework

   a. p. 72 #6, 17-19, 28
   b. Notice: quiz in 2 classes

Appendix 4C: Periodic Table Cards

Sodium Dull, oxide coating Soft metal – cut with a knife Reacts violently with water Mass = 23.0
Potassium Dull, oxide coating Soft metal – cut with a knife Reacts violently with water Mass = 39.1
Rubidium Dull, oxide coating Soft metal – cut with a knife Reacts violently with water Mass = 85.5

Magnesium Brittle metal Burn if heated Reacts with water to form alkaline solutions Mass = 9.0
Calcium Brittle metal Burn if heated Reacts with water to form alkaline solutions Mass = 9.0
Strontium Brittle metal Burn if heated Reacts with water to form alkaline solutions Mass = 40.1

Aluminum Dull metal but polishes up shiny silver Loses 3 electrons to form ions Forms acidic ions in solution Mass = 27.0
Unknown Element Should be a dull metal that polishes up shiny silver Loses 3 electrons to form ions Forms acidic ions in solution Mass should be between 66-73
Indium Dull metal but polishes up shiny silver Loses 3 electrons to form ions Forms acidic ions in solution Mass = 114.8

Silicon A semi conductor Dull and not very malleable Metal poor Mass = 28.1
Germanium A semi conductor Dull and not very malleable Metal poor Mass = 72.6
Tin A semi conductor Dull and not very malleable Metal poor Mass = 118.7

Appendix 5

Science 9 Chemistry Quiz #2

Multiple Choice. (1 mark each)

1. Which of the following hazard label symbols warn that the chemical is poisonous?

A. 

B. 

C. 

D. 

2. Which theory explains the relative energy and movement of particles based on their state
   A. the vibrational impact theory
   B. the atomic molecular theory
   C. the kinetic molecular theory
   D. the energetic movement theory

3. The more energy that particles have
   A. the faster they move
   B. the slower they move
   C. the higher the mass of the object
   D. the more likely they are to form a solid

4. Which scientist discovered the proton?
   A. Rutherford
   B. Thomson
   C. Mendeleev
   D. Bohr

5. Which scientist came up with the idea to organize the Periodic Table according to increasing atomic mass?
   A. Rutherford
   B. Thomson
   C. Mendeleev
   D. Bohr

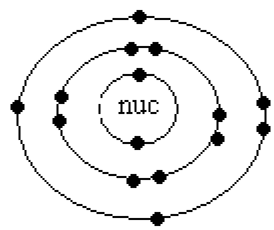
6. Which best describes the nucleus?
   A. contains protons and electrons; electrically neutral
   B. contains protons and electrons; positively charged
   C. contains protons and neutrons; positively charged
   D. contains neutrons and electrons; negatively charged

7. What is a period in the Periodic Table?
   A. a vertical column
   B. a horizontal row
   C. a family of elements with similar properties
   D. the mass of the protons and neutrons

8. What do the noble gases He and Kr have in common?
   A. They are both unstable
   B. The same number of valence electrons
   C. Filled valence energy levels
   D. The same number of protons

9. An atom has 11 protons, 12 neutrons and 10 electrons. What is the element and what is its charge?
   A. sodium, -1
   B. sodium, +1
   C. magnesium, -1
   D. magnesium, +1

10. The following diagram shows a partial Bohr model diagram of a neutral atom. The electrons only are shown. Which atom is it?
   A. Arsenic
   B. Silicon
   C. Phosphorus
   D. Sulfur



Matching.

Match the term on the left with the best descriptor on the right. Each descriptor may be used only once. You will not use all the descriptors. (1 mark each)	
Term	Descriptor
____ 11. atomic number ____ 12. Noble gases ____ 13. WHMIS ____ 14. electron ____ 15. alchemist	A. tried to turn lead into gold B. the number of protons in an atom C. Work and Home Materials Information Source D. reacts violently with water E. a negatively charged particle F. the mass of an average atom of an element G. family of chemically unreactive gases H. Workplace Hazardous Materials Information System I. contains the element fluorine J. a positively charged particle

Appendix 6: Nonparametric Analysis of Quiz #2 Results

A Chi-square (χ^2) test for independence on each question on Quiz #2 was performed (with questions 9, 11, and 14 removed), and the results are given, along with probability values in the last column of Table 1.

Table 1. *Per Question Quiz #2 Results For 9X and 9Y* *(17 students in 9X and 16 students in 9Y wrote)*

Question	Learning Outcome	Lesson # (Targeted Gender)	9X Average on Question (number of students with correct answer)	9Y Average on Question (number of students with correct answer)	Chi-square (p value)
1	WHMIS symbols	1 (Boys) →	58.8% (10/17)		3.06
		1 (Girls) →		81.3% (13/16)	(0.08)
2	KMT	2 (Boys) →	88.2% (15/17)		0.004
		2 (Girls) →		87.5% (14/16)	(0.95)
3	KMT	2 (Boys) →	88.2% (15/17)		0.004
		2 (Girls) →		87.5% (14/16)	(0.95)
4	History of Atomic	2 (Boys) →	64.7% (11/17)		0.061
	Model	2 (Girls) →		68.8% (11/16)	(0.81)
5	Mendeleev and	3 HW (Boys) →		50% (8/16)	0.26
	Periodic Table	3 HW (Girls) →	58.8% (10/17)		(0.26)
6	Organization of	3 (Boys) →		81.3% (13/16)	0.007
	Subatomic Particles	3 (Girls) →	82.4% (14/17)		(0.93)
7	Organization of the	4 (Boys) →		43.8% (7/16)	0.02
	Periodic Table	4 (Girls) →	41.2% (7/17)		(0.88)
8	Properties of Main	4 (Boys) →		75.0 % (12/16)	0.41
	Group Elements	4 (Girls) →	64.7% (11/17)		(0.52)
10	Bohr Model	3 (Boys) →		81.3% (13/16)	0.31
		3 (Girls) →	88.2% (15/17)		(0.58)
12	Properties of Main	4 (Boys) →		100% (16/16)	0.97
	Group Elements	4 (Girls) →	94.1% (16/17)		(0.32)
13	WHMIS acronym	1 (Boys) →	100% (17/17)		0
		1 (Girls) →		100% (16/16)	
15	History of Atomic	2 (Boys) →	64.7% (11/17)		2.3
	Model	2 (Girls) →		87.5% (14/16)	(0.13)

As can be seen from the results in Table 1, only questions 1 and 15 had probabilities that indicated significant learning attainment differences between the two class results. However, as differences can sometimes accrue gradually, additional statistical analyses were performed on the overall student results for each section (separated by boy/girl targeted instruction). The summary performance data is given here again in Table 2. Tables 3 and 4 give the resultant matrices for the χ^2 analysis, and Table 5 gives the χ^2 results.

Table 2. *Quiz #2 Overall Student Results*

	Overall Class Average on Quiz + Standard Deviation (SD)	Class Average and Standard Deviation on Questions Taught Using Boy Methods	Class Average and Standard Deviation on Questions Taught Using Girl Methods
9X (17 students wrote)	Average: 78.4% SD: 18.7%	(Lessons 1 & 2: questions 1-4, 13, 15) 77.5% average 22.8% SD	(Lessons 3 & 4: questions 5-8, 10, 12) 72.5% average 26.8% SD
9Y (16 students wrote)	Average : 81.7% SD : 16.4%	(Lessons 3 & 4: questions 5-8, 10, 12) 71.9% average 21.0% SD	(Lessons 1 & 2: questions 1-4, 13, 15) 85.4% average 19.4% SD

Note: questions 9, 11, and 14 (non gender-differentiated) were omitted from this analysis.

Table 3. *Chi-Square Analysis of Combined Results for Questions 1-4, 13, and 15*

	Number of Correct Answers	Number of Incorrect Answers	Total
9X (17 students)	79	23	102
9Y (16 students)	82	14	96
total	161	37	198

Table 4. *Chi-Square Analysis of Combined Results for Questions 5-8, 10, 12*

	Number of Correct Answers	Number of Incorrect Answers	Total
9X (17 students)	73	29	102
9Y (16 students)	69	27	96
total	142	56	198

Table 5. *Chi-Square Results From Overall Student Performance*

	χ^2 Result	Probability
Questions 1-4, 13 and 15	2.06	0.15
Questions 5-8, 10, and 12	0.002	0.96

We establish (by statistical convention):

H_0: There is no difference in performance between the two classes on Quiz #2 questions 1-4, 13, and 15 and

H_1: Students in 1 class outperformed the students in the other class on Quiz #2

Thus, we see from the χ^2 probability results in Table 5 that only for the first set of questions (1-4, 13 and 15) is there a small amount of evidence supporting a difference in quiz performance using this nonparametric test as a measuring stick. That is to say, there is some slight statistical evidence that we are certain students in 9Y, who received the girl-targeted instructional material for these learning outcomes, outperformed the students in 9X, who received boy-targeted instruction. However, the chi-square analysis does not account for past performance history of these two student groups. Historical evidence supports that 9X and 9Y class averages have been close to identical the entire year on quizzes and tests. Yet, the class averages for the first set of questions were 85.4% and 77.5% for 9Y and 9X respectively. Thus, I feel that a performance difference of nearly 8% over the first set of questions is significant in this context, and indicates a positive correlation between girl-targeted instruction and girl performance results.

Appendix 7: Copy of the Human Research Ethics Board Certificate of Approval

University of Victoria

Human Research Ethics Board

Office of Research Services
University of Victoria
Administrative Services Building - 2nd Floor
Tel (250) 472-4545 Fax (250) 721-8960
Email ethics@uvic.ca Web www.research.uvic.ca

Human Research Ethics Board
Certificate of Approval

Principal Investigator	Department/School	Supervisor
Angela Magon Master's Student	EPLS	Dr. Paul Shaw

Co-Investigator(s):

Project Title: **Gender, The Brain, and Education: Do Boys and Girls Learn Differently?**

Protocol No.	Approval Date	Start Date	Expiry Date
09-061	02-Mar-09	27-Feb-09	26-Feb-10

Certification

This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.

This Certificate of Approval is valid for the above term provided there is no change in the protocol. Extensions and/or amendments may be approved with the submission of a "Request for Annual Renewal or Modification" form.

[redacted]

Dr. Richard Keeler
Associate Vice-President, Research

09-061 Magon, Angela