Feminist Science Education and the Québec Curriculum

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ABSTRACT

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Marianne Filion

Recent philosophical, socio-scientific, and feminist approaches to science have broadened the way that science has historically been conceived. Though historically science has been thought of as objective and value free, the social and cultural aspects of science are increasingly recognized. Concomitantly, science education in schools has undergone a shift away from canonical science instruction to humanistic science teaching. In this thesis, I explore recent socio-scientific and feminist critiques of science. I outline the ways in which these approaches to science contribute to the shifting landscape of science education. Taking concepts that are fundamental to these critiques as an ideological framework, I look specifically at science education in the Quebec context. The 2005 Quebec curriculum reform emphasizes the importance of critiques of science and technology as well as highlights the need for science literacy in students. Through an analysis of the Quebec Education Program as well as secondary cycle one science textbooks, I point out the merits and shortcomings of these texts in socio-scientific and feminist terms. I argue that while the QEP integrates some humanistic science content, it fails to acknowledge feminist critiques of science. In addition, because textbooks largely address humanistic concerns in an inadequate way, I suggest that further work must be done to ensure congruence between curriculum and texts. Finally, I suggest directions for future research into Quebec secondary science education.

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Introduction

Science, or perhaps it is more accurate to say the concept of science, has always fascinated me. A driven student in high school, I got good grades and did not shy away from challenges. As a result, when it came time to decide what optional courses to take in secondary five, in spite of the fact that I was only marginally interested in doing science, and far more taken by the languages and humanities, I was counseled by my teachers to choose chemistry and physics over the arts and Spanish. By opting for the sciences, I was told that I would keep all of my doors open. I would have the necessary prerequisites to be able to pursue science studies in CEGEP and university should I chose to do so. If not, I could just as easily melt into the humanities stream without any additional training. The assumption implicit in this advice is that the humanities require no formal preparation, whereas pursuing scientific studies involves much time consuming, indispensable, and specialized training.

This conception of science versus the humanities is prevalent. Scientists are generally conceived of as highly specialized experts. As such, scientific knowledge is not thought to be accessible in the same way as the social sciences and the humanities. Biologist Edward Wilson (1995), for example, claims that, "the process of discovery, the inner fire of the scientific enterprise, cannot be communicated effectively to the citizen who doesn't already know a substantial amount of science" (p. 75). For him, the lay citizen is incapable of independently forming a knowledgeable opinion about scientific matters. This type of claim is fairly common in the scientific community. Chemist Henry H. Bauer (1992), corroborates this story:

> The common view among scientists is that no one can appreciate science who has not actually *done* some science; hence the requirement that courses in science include laboratory or field work, and the common opinion that one becomes a scientist only after having done actual research and gained the Ph.D. degree—before that, one can be a technician but not a full-fledged professional. (p. 10)

Science, then, is conceived of as the rightful business of a select few highly specialized experts.

Whereas science enjoys a position of social prestige in schools and beyond, the arts and humanities are consistently treated as second-class spheres of inquiry (Aikenhead, 2006). Scientific progress is increasingly taken as a marker of a prestigious society. McEaneany (2004), for example, notes that we take "science, as a set of abstract principles, [as] one of the major conceptual yardsticks of progress" (p. 18).

Interestingly, despite promising job prospects in the science and technology sectors, for the past fifteen years Québec has seen a steady decline in student enrollment in post-secondary science programs (Université de Sherbrooke, 2012). This decreased interest in both study and careers in science and technology has prompted the Université de Montréal and the Université de Sherbrooke to partner in launching a Research Chair whose aim is the investigation of youth interest in science and technology. The chair seeks to discover the reasons behind decreasing interest, as well as to identify ways in which direct intervention in schools can increase enrollment in the sciences. Increased student interest in science and technology studies will presumably first and foremost support the development of expertise for the labor market. More broadly, however, the

Chair is geared towards understanding and shaping citizens' interest in, and engagement with science.

Science education is a significant educational and social objective, and there is assumed to be a strong relationship between science education and the development of the citizen. The recently reformed Québec Education Plan (QEP) emphasizes scientific, mathematical and technological education as having contributed "to our individual and collective well-being," while cautioning that "some of these advances have had a profound impact on our ability to maintain some sense of social, political and economic balance on our planet" (MELS, 2008, p. 184). The QEP underlines the importance of critically considering the multitude of ethical issues that arise out of scientific and technological developments. The capacity for citizens to engage with questions tied up with science is crucial within the curriculum.

This thesis consists of a critical evaluation of the science literacy and citizenship aims of the Québec curriculum and textbooks rooted in socio-scientific and feminist theory. It is broken down into three chapters. The first and second provide an overview of key thinkers in the philosophy of science. Chapter One traces the history and development of the concept of science. It delves into the question of citizen engagement with science, and science and technology studies. It traces the major trends in Canadian science education, as well as the concomitant conceptions of science literacy implied through these trends. Science literacy and citizenship are in constant conversation throughout my thesis.

Chapter Two involves a review of feminist contributions to the philosophy of science and technology, as well as to science itself. I examine the thought of major feminist thinkers, namely Evelyn Keller (1996), Sandra Harding (1991; 1996), Helen Longino (1994; 2001), Mary Tiles (1996), and Angela Calabrese-Barton (1997). Some of these thinkers contribute as insiders, while others come to critique science from their positions as outsiders to the scientific world. Both insider and outsider feminist concerns reshape the demands for, and debates surrounding, scientific literacy.

The third chapter of my thesis involves a critical examination of the Québec secondary cycle one science and technology curriculum, as well as a sample of five recommended science texts. I use Michael Apple's (1986) framework for textbook analysis, which consists in reading the texts with a particular analytical framework in mind. Taking Noah Feinstein's (2010) concept of the competent outsider as a starting point, I evaluate the Québec curriculum's articulation of science and technology education. I expose the conception of scientific literacy put forward in the Québec curriculum, and evaluate the ways in which the curriculum frames scientific knowledge and literacy. I examine and evaluate the extent to which feminist concerns are represented in the Québec curriculum. The selected texts will be reviewed in order to determine to what extent they advance the goals of a humanistic science curriculum. This thesis seeks to draw out the kinds of science skills that the Québec curriculum wishes to promote in training its citizens, and to evaluate the ability of the selected texts to accomplish these aims. Finally, I make suggestions for further research within the field.

Chapter One

Introduction

The way that we conceive of science, as well as the way in which science education is taught in schools, has shifted notably in the last fifty years. Whereas science was once seen as an incontestable product of pure objectivity, increasingly theorists recognize the role that a number of social factors such as culture, values, economics, and politics, play in the production and direction of science. This chapter provides an overview of key theorists who have contributed to science and historical approaches to science. Similarly, it traces the concomitant evolution of school science instruction.

History of Science Education

Historically, science education has mirrored the work of scientists. As such, it has long aimed to prepare students for scientific careers, with a vision towards increasing material prosperity, and economic and intellectual advancement (Hurd, 1992). It goes without saying that scientific occupations contribute to technological advances, industrial and economic growth, and national prosperity. Science and technology function symbiotically to form an integral component of the modern capitalist growth economy. On the surface, then, it is not entirely nonsensical that science education should inculcate students into the business of actually doing science. But undoubtedly there must be a greater aim for science education than material gain on the parts of individuals and nations. Educational philosopher John Dewey (1900) advanced experiential knowledge of science and technology as a key component to his conception of progressive citizen education towards a more democratic society (Waddington, 2010).

However, there is mounting evidence that the traditional science training in formal schooling is not as valuable as it was once assumed to be. Increasingly, traditional science education, which amounts to pre-professional training geared towards the student as a future scientist, is recognized as something that is useful only for some students. Several failures of the traditional science curriculum include declining student interest and enrollment in the sciences, discrimination and cultural alienation due to traditional science content, mythical ideals and dishonest images of scientists, and the increasing recognition that most students do not learn traditional science content in a meaningful way (Aikenhead, 2006). As the failures of canonical science education become more and more evident, historical and philosophical approaches to science are increasingly advanced as a superior approach to science education. This has been a long time in the making. Hurd (1992) asserts that 200 years of debate have led to:

> The current educational reform movement [which calls for] a reconceptualization of science to bring it into harmony with the ethos of modern science and technology. This [is not] simply a reform of science teaching but a renascence, a new vision for science courses. (p. 133)

Thus, we see an increased focus in science education on the historical and sociological aspects of science in North American schools, and the Quebec Education Program's science and technology curriculum is no exception.

The advent of the Science, Technology, and Society (STS) movement, which began in the late nineteen sixties and took hold in the seventies, engendered a shift in the prescribed methods for teaching school science. STS studies emerged in part as a response from the lay community to the work of scientists, which they perceived as increasingly divorced from and inattentive to human values. The development of atomic weapons was of particular concern for early participants in the STS movement. Nuclear power, environmental destruction, and rapid population growth, were also significant issues for the STS movement. STS studies grew in popularity, dramatically affecting the nature of science education in schools and eventually leading Hurd (1992) to assert that, "the central goal for education in the sciences in the 1990s is perceived as enculturation or scientific literacy" (p. 133). The trend towards educating for scientific literacy, which encompasses a broad range of competing ideas having to do with knowledge of science and understanding the way science functions in society, is to some extent an improvement on traditional science teaching, though it is not without its own problems.

Science shapes, to an overwhelming extent, how we conceive of a myriad of social problems, and more notably, how we come to consider their solutions. Oftentimes, science is wielded like a weapon in the interests of the dominant majority. The current Canadian context serves as an example of the potential for scientific information to yield power. While many independent scientists denounce the prime minister's environmental policy, the conservative government is careful to mobilize specific scientific findings in response. In this way, the power and credibility of science as an institution can be mobilized as a political and economic weapon. Some form of citizen science literacy might be able to mitigate this risk by helping us to distinguish between reliable and unreliable science. Yet in the excitement to promote scientific literacy in citizens, that very power inherent in scientific literacy has been both enthusiastically overstated and largely misunderstood.

Arguments in favor of the objective of educating for scientific literacy in schools as well as in society abound. Science literacy has been hailed repeatedly for everything from its capacity to help people make better, more ethical decisions, to its role in increasing economic prosperity and national security (Bauer, 1992). It is important then, to investigate the veracity of these claims. Does science literacy hold any real emancipatory potential for individuals and societies? If so, what types of science literacy hold promise for citizens? Finally, how can we bring about these types of literacies through schooling? I turn now to a brief discussion of science education in Canadian schools.

Two Camps in Science Education

In his thorough evaluation of science education for eleven to eighteen year olds Canada-wide, Glen Aikenhead (2006) outlines two main curriculum approaches to science education; the pipeline and the humanistic approaches. The pipeline approach funnels scientifically minded and intellectually capable students into careers in science, while the humanistic approach is geared towards historical and philosophical approaches to science. In pipeline science education, there is a great deal of emphasis on learning traditional, canonical science content. Students learn scientific facts and formulas. They perform experiments and report their findings. The work of pipeline science education is to train future scientists for their future careers in the field of science and technology.

Though a select few students do quite well within the pipeline approach to science, Aikenhead (2006) holds that arguably many more are excluded from, uncomfortable with, or out of sorts in its science-careers oriented ideology. Seen in this light, traditional science education can be thought of as largely educationally problematic. However, even in spite of the problems inherent in the pipeline approach, curriculum choices in the past have tended to favor traditional, canonical science content over a humanistic approach to science in schools (Aikenhead, 2006).

The humanistic approach to science, on the other hand, is thought of as a far more educationally sound alternative to canonical science (Aikenhead, 2006; Bauer, 1992). In science education, "humanistic perspectives have referred to values, the nature of science, the social aspects of science, the culture of science, and the human character of science revealed through sociology, history, and philosophy" (Aikenhead, 2006, p. 2). Humanistic science education is associated with the concerns rooted in the STS movement. Rather than pre-professional training, humanistic science education aims at citizenship preparation for everyday life. For example, humanistic science education is less likely to focus on conducting scientific experiments, but in learning about how scientific experiments contribute to society and culture. Rather than learning how atoms are split, humanistic science education might look at the historical conditions surrounding the advent of nuclear energy, and evaluate the advantages and disadvantages of a nuclear power for human beings.

Pipeline Persistence

Despite the mounting evidence against it, pipeline instruction continues to be the preferred method of science teaching in Western schools. In spite of humanistic science education's basis in educationally sound principles, pipeline science enjoys greater prestige both within schools and outside of formal education. There seem to be a number of factors that play into this preference. Aikenhead (2006) notes that educators who endorse canonical science instruction often appeal to the idea that it is necessary for citizens to be able to understand science well enough to appreciate its national importance. Indeed, these same educators argue that citizens must know science well enough to be able to receive, understand and interpret the scientific messages that they hear from experts in the field. Though it may well be true that citizens need to know a certain amount of science, what is less obvious is that the pipeline approach provides students with what they need to know.

Henry Bauer (1992) argues that it is unrealistic to expect that all students gain a broad knowledge base in science. However, what is more, he argues that even if college students took a broad range of scientific survey courses, simply knowing these scientific concepts would not adequately equip them for engagement with scientific questions as citizens. It should be noted, as well, that college level education is neither accessible nor necessarily desirable for a significant portion of the population. Furthermore, Bauer (1992) argues that the kind of scientific knowledge that citizens would need to have in order to weigh in on the actual science underlying particular questions would require far more specific scientific training than anyone outside of the field could reasonably be expected to have. In short, the scientific literacy that is presumed to come from learning scientific concepts, or canonical science education, is largely meaningless for Bauer (1992).

Noah Feinstein (2010) critiques contemporary science education on similar grounds. He argues that conventional science teaching leads to the development of marginal insiders; citizens with little more than a rudimentary understanding of what can be considered to be canonical science information. Feinstein (2010) argues instead that science education should lead to the development of competent outsiders, or “people who have learned to recognize the moments when science has some bearing on their needs and interests and to interact with sources of scientific expertise in ways that help them achieve their own goals" (Feinstein, 2010, p. 180). For Feinstein, then, science becomes fundamentally a question of relevance.

Aikenhead (2006) notes the tension between sound educational principles and the political and institutional realities that prioritize the learning that takes place within pipeline science. Despite the increasingly accepted advantages of humanistic science education, this educational alternative maintains its second-class position. He asserts that "Politically, the traditional science curriculum is far from being out of date," but educationally speaking, school science has got it all wrong (Aikenhead, 2006, p. 23). If nothing else, traditional science education serves to perpetuate the socially stratified status quo.

The political-educational tension between the pipeline and humanistic science curriculum is felt in the way that the courses corresponding to each respective stream are valued within schools themselves:

> Status in most schools is *high* for courses that are rigid in their course content, highly differentiated and insulated from other subjects, and academically and idealistically objective. On the other hand, status is low for courses that are flexible in their content to achieve relevance and timeliness, amenable to overlap with other subjects; and utilitarian, relevant, and subjective. Status is animated by the language used within a school, for example, "hard" and "soft" sciences, indicating high and low status, respectively. (Aikenhead, 2006, p.79).

Given these explicitly value-laden judgments on the two streams of science education, humanistic science education may have a problematic status. This difficulty is likely felt on the parts of school administrators, teachers, as well as students. Aikenhead (2006), for example, notes that low status of humanistic science courses has an impact on the expertise of the teachers willing to teach them. The inability to secure quality teachers for humanistic science courses may, in turn, keep the status of these courses low. And so humanistic science education, despite its promise for a far broader range of students than its traditional counterpart, seems to be relegated to the educational margins while pipeline science persists.

The changing nature of science education for science literacy mirrors a shift in philosophical approaches to science. While science was once seen as a purely objective endeavor, recently numerous theorists have called attention to the social aspects of science. I turn now to an outline of these social approaches to science.

The Evolution of the Concept of Science

In his revolutionary text, *The Structure of Scientific Revolutions*, Thomas Kuhn (1962) brings about a radical shift away from the way that science is traditionally conceived. Kuhn argues against the commonly held knowledge that scientific progress is a logical and highly objective process of accumulating facts and building theories. He introduces humanistic elements to Western science by insisting that paradigm shifts, the stuff of scientific revolutions, are at least partially socially determined.

Kuhn (1962) also differentiates between normal and revolutionary science. Normal science, on Kuhn's (1962) account, is the science of the everyday, which is "predicated on the assumption that the scientific community knows what the world is like" (p. 5). When one engages in normal science, there is no "aim at novelties of fact or theory and, when successful, [normal science] finds none" (p. 52). Normal science, then, is largely uneventful. Kuhn (1962) conceives of normal science as the act of puzzle solving. There is little glory in doing normal science, which he goes so far as to call 'mop-up' science. Kuhn (1962) explains that normal science is interrupted by times of revolution, or moments of anomaly, that cause the current paradigm to fall under significant scrutiny for its inability to explain particular phenomena.

Kuhn (1962) argues that paradigm shifts involve a conscientious decision on the part of the scientific community that is "always simultaneously the decision to accept another" paradigm (p. 77). What is more, "the judgment leading to that decision involves the comparison of both paradigms with nature *and* with each other" (p. 77). Contrary to the popular view of science as entirely objective, through his analysis Kuhn reveals how social factors play a critical role in paradigm shift, and of scientific progress more broadly.

Inherent in this analysis is the recognition of a certain the elitism of scientific activity. Kuhn(1962) asserts that, "The very existence of science depends upon vesting the power to choose between paradigms in the members of a special kind of community" (p. 167). Scientific truth, then, is located in the hands of a relatively small group of well-trained experts who are well-positioned to make decisions regarding scientific questions. This expert group does not act merely as mediums, allowing scientific truth to pass through them. Instead, scientists actively make decisions about when to reject old paradigms and which paradigms to accept in their place.

Kuhn (1962) rejects the notion of ultimate truth in science. He explains that, "to be accepted as a paradigm, a theory must seem better than its competitors, but it need not, and in fact never does, explain all the facts with which it can be confronted" (p. 18). In fact, "paradigms gain their status because they are more successful than their competitors in solving a few problems that the group of practitioners has come to recognize as acute" (p. 23). Thus for Kuhn (1962), rather than revealing ultimate truth, the scientific paradigm of the time is merely the best possible explanation available at the time, as decided by the experts.

One of Kuhn's (1962) key contributions to the scientific enterprise was largely to highlight the socially constructed components of science. Prior to *The Structure of Scientific Revolutions*, western science was unilaterally conceived of as an objective and authoritative quest for the truth. Since this time, several theorists have stepped forward to further argue the socially constructed nature of science.

Putting the Social into Science

In *Biology as Ideology*, R. C. Lewontin (1991) disrupts the overwhelmingly common understanding of science as an objective and value-neutral pursuit of the truth. For Lewontin (1991), science acts overwhelmingly as an institution of legitimation of the status quo. As Kuhn did, Lewontin (1991) draws out the socially constructed nature of science, but specifically by underlining the often political and economic motivations that drive the scientific enterprise. For Lewontin (1991), modern science legitimates dominant modes of thinking, and acts as a divisive force that compartmentalizes and ultimately limits the way that we see, think about, and behave in the world.

Lewontin (1991) pays particular attention to the influence that financial interests have in determining the direction of scientific inquiry. He cites agriculture as the "bestdocumented example that we have of purely commercial interest driving what is said to be a fundamental discovery about nature" (Lewontin, 1991, p. 53). Lewontin (1991) uses the example of hybrid corn's popularity among farmers due to the substantially larger yield it provides over its conventional counterpart. However, a hybrid's yield diminishes significantly after the first year, forcing farmers to purchase the commercial producer's seed year after year. Lewontin (1991) notes that, "the invention of hybrid corn was, in fact, a deliberate use of the principles of genetics to create a copy-protected product" (p. 55). The economic success of hybrid corn has heralded the introduction of hybridization into agriculture across the board. There is no money in selecting seeds that could produce yields comparable to hybrids, which is precisely why no scientific research is aimed at this project (Lewontin, 1991). As a result, despite well-published information to the contrary, it is widely believed that hybrids are intrinsically better than "selected" corn. This demonstrates the fact that what appears to be scientific fact is also a matter of politics and economics. Corn is just one of a seemingly infinite number of examples of economic interests driving the direction of science. Others include medical treatments, nuclear research and weapons research, to name a few.

Biology as Ideology is clearly steeped in politics, and so calls into question the role that politics play in science. Lewontin's (1991) scientific beliefs have been dismissed on account of what taken to be their ideological basis. I would argue instead that Lewontin (1991) should be taken seriously precisely *because* he recognizes and addresses the politics often involved, but seldom acknowledged, in science. His stance is similar to Kuhn's recognition of the social forces that come into play in the event of paradigm shift. I contend that Lewontin (1991) quite effectively unmasks the socio-political and economic agendas that, to varying degrees, drive scientific research and claims. Lewontin (1991) makes a strong argument in favor of a sustained critical examination of science, and his arguments demonstrate both faith in science and attention to lived human experience.

Oftentimes scientists who seek to reveal the social, political, and economic forces that contribute to the direction of scientific work are discredited for not being sufficiently scientific. However, Lewontin (1991) is a scientist who is entirely committed to science. Far from revoking his professional path, Lewontin (1991) endeavors throughout *Biology as Ideology* to contribute to a richer understanding of the world through a critical view of science. His claim is that politics are already tied up with the sciences. Rather than turn a blind eye to the social forces that shape scientific activity, Lewontin (1991) wants to be clear about the nature of, and role that these politics play in determining the course of scientific pursuit and the formation of scientific knowledge.

Constructing Science

Latour and Woolgar (1986) go a step further than Lewontin (1991) in their radical constructivist view of science. Unlike Lewontin (1991), who claims that the scientific endeavor is largely shaped by political and economic forces, Latour and Woolgar (1986) simply deny the existence of any scientific realities out there. Instead they claim that scientists effectively construct what is largely taken to be an unmediated, objective reality by claiming to uncover some fundamental truth that independently exists in the world. This position represents an even more stark contrast to the popular view that scientists uncover objective truths that are laying around, waiting to be discovered.

Latour and Woolgar (1986) argue that the construction of scientific facts happens largely through various forms of inscriptive practices, and as such, is predicated on the material realities of the laboratory. It is through the material reality of the laboratory that the so-called objective scientific discoveries are constructed. For Latour and Woolgar (1986), there is no scientific fact before scientists construct it through the material realities of their laboratory. What is most curious for Latour and Woolgar (1986) is that "without the material environment of the laboratory none of the objects [of scientific discovery] could be said to exist, and yet the material environment very rarely receives mention" (p. 69). Scientific facts are not out there waiting to be discovered, but are instead, on Latour and Woolgar's (1986) view, created by scientists.

Latour and Woolgar (1986) argue that scientists are skillful at convincing people that the ideas they put forward constitute scientific fact. Much of this convincing takes place through the production of scientific literature. In fact, the function of literary inscription is the successful persuasion of readers, but the readers are only fully convinced when all the sources of persuasion have disappeared" (Latour & Woolgar, 1986, p.76). Indeed, the validity of scientific claims is established, at least in part, on the basis of whether or not it is believed. Similar to the way in which scientists overlook the material realities of the production of inscriptions, so too do they ignore the process of literary inscription once information is taken to be scientific fact. For Latour and Woolgar (1986), "the function of literary inscription is the successful persuasion of readers, but the readers are only fully convinced when all sources of persuasion seem to have disappeared" (p. 76). Latour and Woolgar (1986) effectively argue that scientific knowledge does not acknowledge, and in fact effectively hides, the processes that are involved in its own production.

It may not be entirely convincing that science is *entirely* constructed. Even if Latour and Woolgar (1986) were successful, the view that science is entirely constructed is problematic in its own way. However, a more moderate critique that science is unaware of the process by which it is produced, and is at least in part directed and influenced by social, economic, and other interests, seems likely a relatively acceptable notion. The rise of social studies approaches to science has arisen simultaneously with interest in the ways in which the lay public takes up and interacts with science.

The Citizen's Role in Science

The public's understanding of science, or science literacy, has long been understood in terms of a deficit theory (Irwin & Michael, 2003). Within this deficit model, conventional wisdom suggests that increasing citizen *acceptance* of science and technology is simply a matter of increasing their *knowledge* about science and scientific concepts. On this model, ignorance of scientific information is the only conceivable cause for disagreement with the ultimate wisdom that is science.

Despite recent shifts away from this model, anecdotal evidence of the idea of a public deficit of scientific information abound. In the event of patient resistance to medical interventions, for example, healthcare professionals routinely provide scientific information in support of their proposed treatment. Arguments in favor or against Canada's tar sands project are frequently propped up by scientific research that demonstrates either the neutral or unfavorable environmental impacts of the endeavor. Nuclear energy, climate change, and countless other debates are routinely rooted in scientific evidence. Whether in favor of or against a particular project, scientific information is frequently mobilized as authoritative proof in support of a given point of view.

On the conventional deficit view, dissent from the findings of science was, and often still is, understood to result directly from either inadequate information, or from an insufficient comprehension of scientific concepts on the parts of the citizen. On this view, dissent should be effectively remedied, which is to say turned into consent, through the provision of adequate scientific information by the expert to the citizen. This model quite obviously privileges a particular worldview constituted by ways of knowing based in rational, objective, Western science. It asserts that scientific truth is the ultimate truth. Once scientific information has been provided, there is no room to argue against it.

There are, however, many instances in which the provision of scientific information does not result in acquiescence to the course of action prescribed by scientific experts. Parents frequently refuse the administration of vaccines to their children in spite of an overwhelming store of medical literature that expounds the safety, even the necessity, of vaccination. Sheep farmers in Cumbria, after the Chernobyl nuclear explosion, were not easily convinced that nuclear fallout would not harm their sheep, despite reassurances from the scientific community that nothing was amiss (Wynne, 1996). Resistance to nuclear energy and to the Canadian tar sands project is widely felt, in spite of scientific assurance that these projects pose no significant threat. The deficit model seems to presume that citizens need only know enough about science to know that science is right. Roth and Lee (2002) have gone so far as to state that, "scientific literacy currently means to question nature in ways such that do not, reflexively, also question science and scientists” (p. 11). Within the deficit model, citizens need to understand very little about science. Instead, they need simply to accept its authority.

Science Literacy

Arguments in favor of teaching scientific literacy in schools, as well increasing science literacy in society abound, while the definition of science literacy remains contested. Science literacy has been hailed repeatedly for everything from its capacity to help people make better, more ethical decisions, to its role in increasing economic prosperity and national security (Bauer, 1992). It is important then, to investigate the veracity of these claims. Does science literacy hold any real emancipatory potential for individuals and societies?

For some theorists, science literacy means precious little. Science literacy has generally been comprised of both (descriptive) visions of what a scientifically literate society might look like, as well as (prescriptive) instructions for how such a society might be achieved (Feinstein, 2008). Ironically however, there is scant evidence demonstrating “that any science taught in school, from Newton’s laws to natural selection, helps people lead happier, more successful, or more politically savvy lives” (Feinstein, 2010, p. 169). Indeed, Noah Feinstein (2010) argues that amidst generous praise for science literacy’s usefulness, the very concept of science literacy has been rendered devoid of meaning; it has come to mean at once everything and nothing at all. Feinstein (2010) underlines that we are ready to argue in support of science literacy without actually agreeing on what science literacy truly means, or proof that it is actually good for us. This leads Feinstein (2010) to focus on the usefulness of science literacy. Usefulness is both testable, and holds political influence; “people, particularly people with money and resources, seem to believe in it" (p. 169).

Henry Bauer (1992) holds a similarly skeptical view of scientific literacy, arguing that "conventional wisdom is […] misguided in its assessment of scientific literacy and […] wrong in its teaching of what scientific activity involves" (p. 12). Bauer (1992) outlines three commonly accepted components of scientific literacy:

1) Knowledge of the substantive concepts of science,

2) An understanding of what scientific activity is about, and

3) An understanding the role of science in society and culture.

On Bauer's view, it is unrealistic to expect that every university level student should or would take enough courses in science to gain an understanding of the substantive concepts of science. Even if they did, however, Bauer argues that this would not constitute sufficient training to be able to claim a truly broad understanding of science. What is more, on Bauer's account, some understanding of science is not necessarily better than none at all. He cautions that inadequate, partial, and limited understandings of scientific information can actually be more dangerous than none whatsoever, leading people to assume that they are capable of making scientific decisions as experts based on what is really only a partial understanding of science.

When it comes to learning what science is all about, Bauer argues that this can be readily accomplished by learning science-technology-society (STS) studies instead of learning actual science. Prioritizing STS rather than learning about hard science facts is the business of what Aikenhead (2006) calls the humanistic approach to science education. Aikenhead (2006) holds a similar view of the sound educational principles involved in the humanistic curriculum. Like Aikenhead (2006), Bauer (1992) laments the misguided nature of pipeline science education, asserting that:

> Though the claim is often made, especially by scientists, that one learns about science, about the scientific approach, about how to be scientific, through studying the content of science, all the evidence says otherwise. Through learning textbook science, one is misled about the nature of scientific activity by learning only about relatively successful science. (p. 11)

The determination to pursue traditional science curriculum in spite of mounting evidence against its pedagogical effectiveness is indeed questionable. It is also important to note that Bauer underlines the *misleading* nature of textbook science. Not only does traditional textbook science underserve the students it purports to teach by providing them little in the way of useful scientific knowledge, it also *misguides* students as to the business of everyday science. Textbook science, Kuhn (1962) would argue, makes science seem to be all revolution, with little to no normal, mopping up science involved. Kuhn (1962) explains that though, “The scientific enterprise as a whole does from time to time prove useful, [and] open up new territory […] *The individual* engaged on a normal research problem *is almost never doing any one of these things”* (p. 38). Through learning traditional textbook science, students are either attracted to, or deterred from, pursuing studies in science based on a misrepresentation of what science really is, and on a skewed conception of what being a scientist is actually like. Many concerns about this misrepresentation of science are taken up later in this chapter, as well as by the feminist critiques of science found in Chapter Two of this thesis.

Bauer (1992) outlines five major arguments that have been put forward in favor scientific literacy. First, science literacy is commonly thought to be good because knowing science helps people to make better decisions. It has been claimed that understanding technology brings about economic success and helps improve national security. Scientific knowledge is thought to displace superstition, and learning to think scientifically is assumed to help human beings to be more rational. Finally, it is claimed that being familiar with the scientific method will help citizens to behave more ethically. However, Bauer discredits these five claims in favor of scientific literacy, arguing instead that, "the individual behavior of most human beings, including scientists, and the collective behavior of humankind are not directly or effectively governed by intellect" (p. 14). In short, scientific literacy does not actually help us to be better people in our daily lives. Nonetheless, Bauer (1992) is not willing to altogether dismiss the worth of scientific literacy. He claims that "the more we learn of the history of science and about current scientific activity, and the more we examine in particular instances what the evidence indicates about a particular phenomenon and its explanation," the more sophisticated we become (Bauer, 1992, p. 18). In short, for Bauer (1992), scientific literacy helps us to be able to better understand and evaluate the work of science.

Roth and Lee (2002) also critique scientific literacy, arguing that, "classical approaches to scientific literacy […] are based on an untenable, individualistic (neo-liberal) ideology that does not account for the fundamental relationship between individual and society" (p. 11). Human beings do not think or act in isolation. Instead, knowledge, views, and opinions on questions that concern the public are socially negotiated and constructed. Thus "the reigning ideology expressed in the recent US science education reform documents [which] portrays scientific literacy as an individual property and characteristic of students in science” is not only unhelpful, but also inaccurate (p. 11). Instead, Roth and Lee (2002) argue that science literacy is and should be conceived of as a collective and cooperative process.

The Problem with Public Uptake: Popularization

The popularization of scientific information and concepts is closely tied to the deficit theory. While not everyone is a scientist, the public is to a large degree interested in, and concerned and affected by, questions involving science. Scientific information is thus regularly made available and accessible to lay citizens through a variety of other sources, from science experts, teachers to the media. Hiltgartner (1990) notes that the “culturally dominant view of the popularization of science is rooted in the idealized notion of pure, genuine scientific knowledge against which popularized knowledge is contrasted” (p. 519). Hiltgartner (1990) argues that:

> The dominant view holds that any differences between genuine and popularized science must be caused by ‘distortion’ or ‘degradation’ of the original truths. Thus popularization is, at best, ‘appropriate simplification’ –a necessary (albeit low status) educational activity of simplifying science for non-specialists. At worst, popularization is ‘pollution’, the ‘distortion of science by such outsiders as journalists, and by a public that misunderstands much of what it reads. (p. 519)

It is clear that the popularization of scientific concepts and information is commonly thought of as an inconvenient necessity. While citizens like to be kept abreast of scientific information, this is commonly seen as an incommodious, if not entirely useless chore on the parts of the scientific community. On this view, any truth to the science represented through popularization is thought by the scientific community to be simplified to the extent that it loses all value and meaning.

Hiltgartner (1990) claims that this dominant way of thinking about popularization serves scientists and others who gain authority from science as “a political resource in public discourse” (p. 520). The scientist thus retains his position of privilege through distinctions between ‘real knowledge’ and mere interpretation. We see this type of thought present in Wilson’s (1995) argument that lay citizens are ill positioned to understand scientific concepts.

Hiltgartner (1990) points to the inadequacy of this conception of the popularization, arguing that simplification is “important in scientific work, both within the laboratory, and in communicating with students, funding sources, and specialists in adjacent fields” (p. 522). Others still would argue that even if it is the case that popularization results in some legitimate distortion of truth, “scientifically incorrect understandings or misconceptions should not be lightly dismissed. They have been well tested in the context of experience and action” (Jenkins, 1999, p. 705). Jenkins (1999) gives the example of workers in a computer factory who think of electricity as a fluid. On a model that is useful to them, this fluid can either accumulate into static electricity or be flow back into the earth via the earthed metal bracelets that chain the workers to their desks. While the workers’ understanding of electricity is scientifically incorrect, it nonetheless helps them to conceive of electricity in such a way as to work safely without damaging sensitive computer parts or hurting themselves. Seen in this light, popularization, even slight distortion, can serve the citizen. After all, lay people “chose a level of explanation which meets their needs” (Jenkins, 1999, p. 705).

This calls attention to the question of whose interests are, and ought to be, served by science. The problems associated with popularization, and with the deficit theory of public science knowledge, are closely tied. Both represent simplistic and inadequate models for representing citizen engagement with science. Irwin and Michael (2003) view the deficit theory as itself deficient, arguing instead that citizen's views, and their concomitant interests, are not simply the result of a lack of information or misinformation, but must be taken seriously on their own terms. This involves developing new models of the relationship between science and the lay public. Though the citizen is more often than not *not* a scientific expert, he or she holds other valid forms of expertise that are worthy of both weight and attention in decision-making processes (Irwin & Michael, 2003). Let us return once again to the sheep farmers in Cumbria who expressed concern after the Chernobyl nuclear explosion. Wynne (1996) notes that these farmers were "reserved in their skepticism towards the scientists on scientific matters, [but] abrupt and outspoken about them when they saw the extent of the scientists' ignorance of hill-farming environments, practices, and decision-making" (p. 36). Perhaps a worse offence than sheer ignorance, however, "was the way that the outsider experts did not recognize the value of the farmers' own expertise, nor see the need to integrate it with the science in order to manage the emergency properly" (Wynne, 1996, p. 26). This example calls attention to the necessity of recognizing the validity of concerns that fall outside of science proper.

Saving Scientific Literacy

At this point, it may seem that the project of scientific literacy, void of content, meaning, and even of achievable goals, should be abandoned. But let us not throw the baby out with the bathwater just yet. Bauer (1992) asserts, and I would agree, that just because “the commonly cited benefits of scientific literacy are illusory does not mean that it is not good to be scientifically literate” (p. 16). Instead, he argues that “once the claimed economic, technological, and social imperatives have been exposed as spurious, it becomes a little easier to suggest what an attainably useful acquaintance with science might be” (p. 16). Bauer (1992) advocates STS education in schools, arguing that “it is clear that no bits of specific information about one or more of the sciences could be nearly as meaningful as a sense of what position science and technology play, and have played, within human culture” (p. 17). Bauer (1992) argues, in effect, for the widespread implementation of STS studies. He claims that, “we can think intelligently about science even if we know little about the substance of science” (p. 18). This is promising news, given that most people will not become frontier scientists.

Roth and Lee (2002) conceive of scientific literacy as emerging when “scientists, science-related professionals, and people from other walks of life and with different backgrounds engage each other over contentious and personally relevant issues” (p. 16). Thus, science literacy is not something that individuals own; instead, it becomes a collective praxis that humans enact in community with one another. Roth and Lee (2002) argue that rethinking concepts of science literacy, learning, and ways of knowing in terms of collective contributions:

> Leads us to radically different conclusions about what and how curriculum should be designed and enacted. When learning is no longer identified with grey-matter between the ears but with the relations between people and with doing things together, our views of teaching will change.

> Scientific literacy is then no longer something that is acquired by the child and carried into other settings within and outside of schools. Rather, scientific literacy is something that emerges as a recognizable and analyzable feature of (collective) human action and interaction in which the child is but one part. (Roth & Lee, 2002, p. 18)

We will see feminist theorists engage similar interest in learning as a collective and dialectical practice in the coming chapter.

Noah Feinstein's (2010) conception of science literacy is primarily concerned with the usefulness of science in everyday life, hinging on the notion that "that science education can help people solve personally meaningful problems […], shape their behavior, and inform their most significant practical and political decisions" (p. 169). Rather than focusing on what science literacy should look like or how it might be accomplished, Feinstein (2010) proposes that making science relevant is something that students learn to do, rather than a task with which teachers ought to be charged (p. 180). In this sense, science literacy should be thought of as an outcome rather than as a pedagogical tool.

Feinstein (2010) advances an ideal of scientific literacy in his model of the citizen as a competent outsider. Competent outsiders, non-scientists, are "people who have learned to recognize the moments when science has some bearing on their needs and interests and to interact with sources of scientific expertise in ways that help them achieve their goals" (Feinstein, 2010, p. 180). In this model, a key component of scientific literacy is the capacity of the citizen to identify the relevance of science, or "learning to see how science is or could be significant to the things you care about most"

(p. 180). Feinstein (2010) draws on the work of Roth, Layton & Jenkins, and Calabrese-Barton to paint a portrait of the science literate person as someone "who can connect science with their own curiosities and crises in ways that are satisfying to them" (p. 177). A competent outsider is a citizen capable of adapting to the personal and social situations that life presents.

Numerous feminist theorists have taken up, engaged, and expanded on socio-scientific perspectives on science and humanistic science education. Keeping in mind socio-scientific critiques of science, as well as well as the useful conceptions of science literacy and science education that we have seen, I now turn to an overview of the major feminist critiques of science. These perspectives, though sometimes in disagreement, share a number of ideological overlap. Taken together, they will serve as the conceptual framework for my critique of the Québec science and technology curriculum and textbooks in the third chapter of this thesis.

Chapter Two

Introduction

The previous chapter provided a historical overview of increasingly popular conceptions of science as something rooted in, and at least partially constructed by, social and political values. In spite of the increasing popularity of this notion of science as socially produced, and the concomitant interest in humanistic science education, the scientific community largely tends toward the assumption that the specific knowledge required of scientific experts justifies the limited scope of their inquiry. We have seen several theorists argue against the assumed value-neutrality and objective cloak of science (Kuhn, 1962; Bauer, 1992; Latour, 1986; Lewontin, 1991). Many feminist theorists of science equally argue against the notion that science is objective and neutral (Harding, 1996; Longino, 2001; Calabrese-Barton, 1997). These debates tend to pit pro-scientists against dissenters, with little evidence of compromise on the horizon.

Feminist theorists argue that far from being neutral, science tends to be representative of the interests of a predominantly white, Western, male and middle class constituency of scientists (Harding, 1991). Science's hallmark claim, that it is a fundamentally objective enterprise, has meant that scientists have consistently refused to so much as consider the role that culture and values play in science. Feminist critics of science, on the other hand, recognize the necessity, and value of admitting the inevitable subjectivity of the scientist, and in turn, of the scientific enterprise. Feminist critiques of science arise from a wide array of voices, and cover a broad range of territory. Philosopher Mary Tiles (1996) notes that in spite of their differences, there remains an underlying common call on the parts of feminist critics for the "development of science with a human face, science that aims more at co-operating with than at conquering Nature, which learns more by conversing or conducting a dialogue with Nature than by putting it on the rack" (p. 221). Feminist philosophers of science seek to reorient the questions and concerns of science in the name of democracy and social justice. Through feminist analysis, habitually overlooked biases are uncovered, and the scope of the scientific enterprise is significantly widened. My aim in this chapter is twofold. First, I cover the range of critique, from liberal objections to more radical critics of western science. Second, I will provide a sketch of what feminist science education might look like.

The Feminist Critique

Feminist critiques, unfortunately, remain largely on the outskirts of scientific discourse, and are rarely taken seriously by mainstream Western scientists. It is telling that in a number of edited volumes consulted in research for this thesis, if feminist perspectives were included at all, they were more likely than not relegated to the final chapter of the book. Barry Gross (1994) speaks disparagingly of the impossibility of a feminist science. In his quest to discredit its sheer feasibility, he reminds us that it is scientists, not philosophers, who are responsible for scientific discovery and advances. He critiques feminist philosophers of science, most notably Sandra Harding, for being unable to so much as portray an adequate representation of feminist science.

However, I would argue that Harding's conception of feminist science is in fact quite well defined. Sandra Harding (1996) argues that far from straying from science's ultimate goal, feminist science calls for more stringent criteria for objectivity than does conventional science. Feminist science demands:

> Sciences that are competent at detecting the culture-side presuppositions that shape the dominant conceptual frameworks of disciplines and public discourse. Such presuppositions, if unexamined, function as evidence, 'laundering' sexism or racism or class interests by transporting them from the social order into 'the natural order'. […] Concepts such as objectivity, rationality, good method, and science need to be re-appropriated, reoccupied, and reinvigorated for democracy-advancing projects. (Harding, 1996, p. 19-20)

Effectively, Harding holds that scientists are both unaware of their own subjectivity, and consequently ignorant of the assumptions that underlie the nature and direction of their work. Scientists are charged with being biased without even knowing it. This prevents them from striving effectively for their goal of objectivity. Harding articulates a radical critique of science, a case for a revision of the fundamental conceptual ideals that function within Western science to re-inscribe inequitable power relations between men and women, to be sure, but also between dominant and marginalized groups.

Overall, feminist theorists of science dispute the assumed value-neutral and objective reality that is regularly claimed on behalf of individual scientists, as well as by science as a broader field of inquiry. Feminist critics take issue with the hallmark scientific claim to objectivity. Canceran (2007) notes that, in testimony to the natural world, the scientist:

> Purges the traces of his subjectivity which can prejudice the world and therefore invalidates scientific invalidity. […] Through his observation, the scientist speaks on behalf of the world and produces the truth of the world. (p. 360)

The ideal scientist, as Canceran (2007) makes clear, must keep his subjectivity from marring the objectivity of his work. In revoking subjectivity, the scientist sets himself, and by association his work, apart from and above other human activity.

There is an obvious value judgment inherent in the scientific claim to objectivity. Feminist theorists have long called attention to dichotomous modes of thought that oppose masculinity and femininity, devaluing that which is considered feminine and attributing value to that which is considered masculine. The objectivity of the scientist serves, then, to legitimate the truth claims regularly made by science. Scientific facts are verifiable, not just in the here and now, but for all time. What is more, scientific facts are supposed to remain true independent of context. In spite of recent theorizing that shakes its claim to objectivity, it is clear that science still maintains a reasonable degree of authority and credibility from the assertion of its own objectivity.

Along the Spectrum of Critique

In order to evaluate the feminist critique, it is important to trace the range of feminist analysis of conventional science. Though all feminist analyses “claim that science embodies a strong androcentric bias, the meanings attached to this charge vary widely” (Keller, 1996, p. 28). Feminist theorists range in the scope and depth of their critique of modern science. This section will provide an overview of the range of this critique.

Sandra Harding (1991) asserts that feminist analyses of scientific knowledge generally take three main forms; empiricism, standpoint theory, and postcolonial standpoint theory. Feminist empiricists critique western science by arguing that, “sexist and androcentric results of research are simply the consequence of ‘bad science’” (p. 48).

From this perspective, the empiricist's claim is that science is simply failing at the (unobjectionable) goals that it has set for itself. In short, science simply needs to do a better job of doing what it has set out to do. This view, notably, does not assert any critical evaluation of the conventional way of doing science. Kourany (2009) argues that this approach is especially prominent amongst biomedical feminist scientists who claim largely that more stringent attention to method is all that is required to even out any inequalities in science.

Evelyn Keller (1996) provides a useful outline of the range of feminist critique of science along the political spectrum. The liberal feminist assessment of conventional science is similar to the empiricist's critique in that it "in no way conflicts either with traditional conceptions of science or with current liberal, egalitarian politics" (Keller, 1996, p. 29). On Keller's (1996) account, the liberal appraisal is centered almost entirely around a critique of the inequitable employment conditions in science. Feminist liberal critics assert, for example, that women are underemployed in scientific careers and lament that women contribute significantly less than men (if at all) to the production of scientific knowledge.

Seen in this light, the liberal critique of science betrays noticeable similarities to the first wave feminist movement. First wave feminists argued predominantly against women's exclusion from the public spheres of Western society, focusing the bulk of their efforts on women's suffrage and other similar equality struggles. Without denying the obviously problematic nature of women's exclusion from the public sphere, nor from their active participation in the scientific enterprise, it is important to note that liberal critiques merely scratch the surface of a far more deeply rooted problem. The problematic assumption underlying the first wave feminist movement is that equality is somehow commensurate with equity. Liberal critiques of science hold the same underlying assumption. This analysis assumes that the problems with science can be remedied simply by employing more women, and by involving more women in the scientific enterprise. Similar arguments are commonly seen in politics, and typically run something like this; if more women were elected to office, politics would be more representative of women and /or women's interests, which would lead to an improvement in women's situations. While on the surface this may seem like an attractive idea, we need only look to Sarah Palin or Margaret Thatcher's leadership to see that female representation in the political sphere far from equates with feminist values in politics.

Ever so slightly to the left of the liberal critique of science, some feminist critics "find claims of bias in the actual design and interpretation of experiments" (Keller, 1996, p. 29). In fact, medical science lends itself reasonably well to this type of feminist critique. The medicalization of childbirth and control of women's reproductive capacities are perhaps the most obvious targets of feminist criticism, but the list does not end there. The medical sciences, for example, have historically excluded female bodies from experimentation. Though this exclusion has been enacted likely often out of well-intentioned concern over issues ranging from avoiding the inconveniences of having to work around menstrual cycles to fears about harming potential offspring, the exclusive use of male bodies has meant that science has ignored the particularities of female-bodied subjects. As a consequence, the male body is upheld as the gold standard for science, while in turn far less knowledge has been produced about females. This has been disadvantageous to women in a number ways, as research into women's health has been slow compared to that of men. Heart disease, for example, though equally fatal in men and women, was seen exclusively as a male disease until the 1990s. The lack of attention paid to the experience of heart disease in women meant that this disease was often detected late and improperly managed (Kourany, 2009).

Keller (1996) asserts the inadequacy of the liberal critique, arguing that it affects neither "our conception of what science is, nor our confidence in the neutrality of science" (p. 29). In a similar vein, Harding (1991) cautions against simply "adding" women into the existing science. Angela Calabrese-Barton (1997) cautions specifically against compensatory programs in science education that aim to insert women into an already dysfunctional system. Instead, she argues the necessity of rethinking "the nature of science and science education," thereby refocusing the reform of science education to a recognition of the "deficiencies and discriminatory practices in science and education" (Calabrese-Barton, 1997, p. 146). Women cannot, and indeed should not simply argue for access to a system that is fraught with problems. In order to truly effect change, the scientific enterprise itself must be transformed.

A second, more serious approach is to argue that the problem with science is more extensive than the empiricists find it necessary to admit. This theory, which is called standpoint theory, argues that "the dominant conceptual schemes of the natural and social sciences fit the experiences of Western men of the elite classes and races have of themselves and the world around them" (Harding, 1991, p. 48). Feminist standpoint theorists argue that knowledge is always situated. They claim that all knowledge is "positioned in a particular time and place," and that as a result, individual people are only ever capable of a partial understanding of other people's experience (Kourany, 2009, p.

210). Because Western science has been, and continues to be a male dominated field, standpoint theorists argue that science stems from and represents only a select portion of the human population. Standpoint theorists argue, then, that to redress this wrong, scientific research must take women's lives as a starting point. Standpoint theorists argue that standpoint of those in marginal positions have a better capacity for critically analyzing the experience of those occupying the dominant standpoint (Kourany, 2009). Thus, examining science from the standpoint of women makes a critical analysis of the purportedly neutral character of science possible (Longino, 1994). Standpoint theory claims that if we begin "research from women's lives, we can arrive at empirically and theoretically more adequate prescriptions and explanations- at less partial and distorting ones" (Harding, 1991, p. 48). While standpoint theory may hold some promise for socially just science reform, some theorists argue that it does not go far enough.

A third feminist approach takes the problem with science to be more extensive still. On Harding's (1991) account, standpoint theory is inadequate because it adheres "too closely to damaging Enlightenment beliefs about the possibility of producing one true story about a reality that is out there and ready to be reflected in the mirror of our minds" (p. 48). Because both empiricism and standpoint theories fail to adequately address a multiplicity of truths, Harding (1991) argues that feminist critiques of science would do well to take a postmodernist standpoint approach. The postmodernist standpoint approach argues that there is no one truth, but rather a multitude of perfectly valid perspectives, narratives, and truths, that require simultaneous representation.

Keller (1996) explains that a radical critique of science "attempts to locate androcentric bias even in the 'hard' sciences, indeed in scientific ideology itself" (p. 31).

Unlike liberal critiques that call into question the mechanics of how science is or has been done, as well as who is involved in doing science, radical critiques of science insist that we “question the very assumption of objectivity and rationality that underlie the scientific enterprise” (p. 30). Tiles (1996) similarly locates the problem with modern sciences not with the content of its theories, but in its “methods and in the attitudes which lie behind their use in the normative definition of science and the scientific” (p. 221). According to radical critiques of science, the crux of the problem lies in the ideological underpinnings of the scientific enterprise, on which research is based and results are interpreted.

Science Defends Itself

Modern western science sets out to defend itself against criticism in a number of ways. In the first instance, scientists have outright denied the accusation that values play any role in science whatsoever (Tiles, 1996). If it could be successfully argued that values simply have no place in science, this position would adequately defend against feminist critique. Some scientists do in fact take this approach, arguing steadfastly that values and meaning simply have no place in science. Wilson (1995), for example, asserts that scientists have no choice but to restrict the scope of their investigation in the name of their quest for the truth. He asserts that scientists “learn what they have to know, often remaining poorly informed about the rest of the world, in order to get to the frontier of knowledge” (Wilson, 1995, p. 74). Scientists often fail to recognize the expertise of non-scientists as they pursue knowledge according to their own frameworks (Irwin & Michael, 2003; Wynne, 1996). On Wilson’s account, this is neither objectionable nor inadequate; instead it is purposeful, necessary, and constitutes good science. Wilson

(1995) explains that admission into the coveted rank of scientist requires that scientists make discoveries. The distinction between scientist and non-scientist is crucial for Wilson (1995), and rests largely on the scope of one's inquiry. Thus, Wilson (1995) argues that it is only natural that "when a scientist [...] begins to sort out knowledge in order to look for meaning, and especially when he carries that knowledge outside the circles of discoverers, he becomes a humanist" (p. 74). Humanism might as well be a dirty word, a characterization to be avoided at all costs in order to preserve scientific prestige.

However, Tiles (1996) argues that problem with the defense that argues that values have no place in science ultimately fails because it assumes that the subject of feminist critique is the theoretical content of science. In fact, Tiles (1996) argues, feminist critics are largely concerned with "the implementation of […] method and on its formative role in science, rather than falling directly on theoretical content" (p. 221). Feminist critics do not argue specifically against the findings of science. Rather, they question the role of method in determining the questions that science asks and the way that science is done.

Another way that the institution of science argues against feminist critique is to simply distance itself from the branches of science that are liable of admitting bias. Feminist critiques of the sciences are accepted (as in the case of the soft medical sciences) or vehemently argued against (as in the case of hard physics) based on the degree to which specific branches of science are taken to be ultimately scientific. For instance, it is much easier to find evidence of bias in observations and experiments in sciences that are socially oriented (Keller, 1996). As a result, critiques which:

> …maintain that a substantive effect on scientific theory [result] from the predominance of men in the field, are almost exclusively aimed at the 'softer', even the 'softest', sciences. Thus they can still be accommodated within the traditional framework [of objective science] by the simple arguments that the critiques, if justified, merely reflect the fact that these subjects are not sufficiently scientific. (Keller, 1996, p. 30)

Keller's (1996) argument underlines the notion that if a branch of science can be rightfully accused of admitting of any bias, it is simply discredited as unscientific. Science is willing to cut off a branch rather than allow its fundamental objectivity to fall under scrutiny. Thus the subject of critique admits no weakness to the scientific enterprise; it is simply deemed to *not* be science.

It may be increasingly accepted that economic and political forces, coupled with the predominance of white male scientists, can serve to influence the research questions and topics with which scientists are concerned (Tiles, 1996). However, though science might be willing to admit that its questions have been influenced by external influences such as value judgments and cultural presupposition, science generally remains resistant to the notion that any of the results of scientific research may have been affected by these factors. While science responds with relative ease to liberal critiques, it has considerably more trouble responding adequately to radical critiques. It is commonly understood that the results of scientific research, "if acceptable at all, should be acceptable to anyone, regardless of his concerns, because the ultimate standard of acceptability is empirical adequacy" (Tiles, 1996, p. 224). The assumption is that regardless of who is asking the questions or why, the answers brought about using good science are valid nonetheless. This validity is based on the allegedly objective nature of scientific research.

The next step in defending science against feminist critiques consists in suggesting, then, that, "all potentially radical critiques of science in fact fall on those factors which determine the direction of scientific research, and not on factors determining the results of that research once its direction is determined" (Tiles, 1996, p. 224). Here, for example, the fault lies with the political and social forces that have the capacity to influence science in a certain direction, rather than "science or its methods as such" (Tiles, 1996, p. 224). If, then, scientists research atomic rather than renewable energy, or cancer treatments rather than cancer prevention, the problem is simply that social and political forces have conspired to direct their research towards this work. If research has been directed toward developing hybrid corn, this is simply because economic forces have led science in this direction. In all these cases, because it is the forces outside of science that are responsible for its direction, science *itself* escapes critique.

The Trouble with Divorcing Science

Given what has been outlined above, there is certain amount of understandable tension between the camp that argues that science puts forward purely objective fact, and that which argues that science is, to varying degrees, socially constructed. Keller (1996) laments that, in response to the danger of science being conceived as a purely social product, some feminists have opted instead to separate themselves from science. These feminists choose to give up their "claim for representation in scientific culture and, in its place, to invite a return to a purely 'female' subjectivity, leaving rationality and objectivity in the male domain" (Keller, 2006, p. 31). Keller, amongst others, recognizes both the intellectual and political danger inherent of conceiving of science in this way; if science came to be understood as entirely socially constructed, it would risk losing its meaning. Keller (1996) warns that "in the resulting cultural relativism, any emancipatory function of modern science [would be] negated, and the arbitration of truth [would recede] into the political domain" (p. 31). This offers some insight into the preference for distance from, rather than discrediting, science.

While there may be some basis to suggesting that women have particular ways of knowing, Longino (1994) warns us that this may not, philosophically speaking, get us very far. In effect, it constitutes an argument in favor of gender essentialism. Essentialism is "the idea that a thing possesses an essence consisting of a defining set of properties" (Richardson, 2011). I would argue that essentialism is a fundamentally problematic notion that has been mobilized in support of inequitable treatment of women as well as a myriad of marginalized groups. Essentialist conceptions of women, for example that women are naturally weaker than men, or irrational, have contributed to the legitimation and perpetuation of numerous patriarchal institutions. Essentialism functions to exclude women and other marginalized groups by positioning them as inherently different, and often as a function of that difference, inferior. If science embodies values to which women inherently do not have access, then it becomes impossible for women to engage in meaningful dialogue and critique of science. Thus, divorcing science on the basis of rationality being a male way of knowing "nullifies the radical potential of feminist criticism for our understanding of science" (Keller, 1996, p. 31).

What is more, acceptance of the notion that particular values and ways of knowing are distinctly feminine is problematic on another count. Longino (2001) argues that:

> While it is important to reject the traditional derogation of the virtues assigned to women, it is also important to remember that women are constructed to occupy positions of social subordinates. We should not uncritically embrace the feminine. (p. 217).

Equally, Longino (2001) recognizes that there are a number of competing conceptions of femininity. Just as we cannot automatically conflate feminine with feminist, nor can we uncritically embrace or adhere to the qualities that have been traditionally associated with femininity.

A potential solution to this divisiveness lies in moving away from the polarized views of science as something that must be either removed from, or completely created by, the social. Harding (2001) rejects what she conceives of as a false division between science and society, asserting that, "There is no such thing as 'pure science,' and there probably never was" (p. 38). Instead of being removed from the world that science inhabits and affects, "scientific institutions should be required to exhibit the concern for the causes and consequences of their own beliefs and behaviors that they insist on for everyone else's" (Harding, 2001, p. 38). As such, it is essential that science be engaged with the social world with which it is undeniably a part. Incidentally, language is a crucial component of the social world inhabited by science.

The Importance of Language in Scientific Discourse

Feminist theorists have commented at length on the importance of language in shaping the aims and directions of science, as well as the attitudes of individual scientists. The way that we talk about, and the language that we use in science, has an effect on both what can think and say about science (Cohn, 1987, Calabrese-Barton, 1997). Indeed, feminist theorists often argue the need for a new language of science that accurately reflects the nature of feminist science.

Helen Longino (2001) notes that "the use of the passive voice" and the "attribution of agency to the data" shape the way that we understand scientific information, as well as our role in relation to it (p. 218). In common scientific parlance, data are frequently attributed with agency. Scientists, for example, use phrases such as 'the data show' or 'research implies,' as if somehow it is the data and research exercise agency in and of themselves. These choices of phrasing contribute to the perception that scientific findings exist *out there* in the world. Thus, attention is shifted away from the work of the individuals and research teams who are responsible for producing this data.

Carol Cohn (1987) writes extensively and convincingly on the role of language in shaping thought. Cohn asserts that the technostrategic language of defense intellectuals serves a dual function; it "both reflects and shapes the nature of the American nuclear strategic project" (p. 690). Documenting her experience as a participant observer in a university center for defense technology and arms control, Cohn (1987) highlights the gendered and religious imagery, and the sexist ideals of technostrategic language, which uses "abstraction and euphemism" to obscure the realities of nuclear war (p. 690).

Indeed, the language of modern western science can be alienating to many who do not see their lived experiences reflected in it (Calabrese-Barton, 1997). Angela Calabrese-Barton (1997) underlines the sense of alienation felt by many of her chemistry students due to the language of science, a language frequently characterized by aggression, and competition. In chemistry, for example, atoms are described as being 'attacked' and 'destroyed,' while chemical reactions are not ended, but 'killed'. The scientific processes of chemistry then, are habitually described using quite violent imagery. This language, while taken for granted in modern western science, can be difficult for some students (Calabrese-Barton, 1997).

What is more, there is no real way of maintaining credibility as a scientist without being inculcated into and regularly using the accepted language of science. Cohn (1987) recounts the difficulty she encounters when attempting to converse about nuclear war in plain English with defense intellectuals accustomed to technostrategic jargon. When speaking in plain English, the defense intellectuals took Cohn to be ignorant or dense. Conversely, when using technostrategic language, Cohn experienced difficulty expressing her concerns about nuclear war due to the constraints imposed by the language. She explains her difficulty:

> Those of us who find U. S. nuclear policy desperately misguided appear to face a serious quandary. If we refuse to learn the language, we are virtually guaranteed that our voices will remain outside the 'politically relevant' spectrum of opinion. Yet, if we do learn and speak it, we not only severely limit what we can say but we also invite the transformation, the militarization, of our own thinking" (p. 714).

Cohn's ability to infiltrate the world of defense intellectuals was largely based on her capacity to speak on their terms, but infiltrating their world simultaneously shifted her own.

Similarly, Calabrese-Barton (1997) explains how she felt compelled to accept a student's explanation of a chemical reaction despite wanting to underline the problematic nature of the language used. Specifically, Calabrese-Barton (1997) did not want to alienate that student from the scientific community by questioning her choice of words. Her concern is not unsubstantiated. One of the three competencies in the Quebec Education Program on which students are evaluated in the science and technology program is use of the languages of science and technology. Success, particularly in school science, is determined on the basis of how well a student fits in, not on their capacity to stand out.

Calabrese-Barton (1997) argues that learning and uncritically adopting the language of science is inadequate. To begin with, the language of science promotes a view of the world based in hierarchy and dichotomy where man is opposed to woman, logic to emotion, and so on. In this dichotomous worldview, "the former, the masculine, is acceptable and even desirable while the latter, the feminine, ought to be avoided at all costs" (Calabrese-Barton, 1997, p. 157). It is unsurprising that the language of science reflects the dominant positivistic worldview in which is has been developed. Calabrese-Barton (1997) argues that:

> Just as science, through its mechanistic view of nature developed in tandem with the industrial revolution and the growth of capitalism in the Western world, embodies power relations manifested through

> dichotomies, the language in the science classroom, in both content and style, is also an exercise in power. (p. 155)

Feminists must pay attention, however, to the language used in science, as it plays an important role in determining who we can communicate with as well as what we can say (Cohn, 1987). In educational contexts, because "scientific meaning is created in the classroom through a language imbued with dominant beliefs, in order to articulate a new science and a new way of teaching and learning about science, new language is required" (Calabrese-Barton, 1997. p. 158).

Doing Science as a Feminist

While science has been resistant to the notion of a feminist science, there may be a more palatable solution to this problem. Longino (2001) focuses on "science as practice rather than content, as process rather than product; hence, not on feminist science, but as doing science as a feminist" (p. 217). Doing science as a feminist involves looking at the many activities involved in doing science through a feminist lens. This notion of doing science as a feminist recalls bell hooks' (1984) notion of doing feminism rather than being a feminist. hooks argues that "focusing on feminism as political commitment, we resist the emphasis on individual identity and lifestyle. […]. Such resistance engages us in revolutionary praxis" (p. 30). Feminism, as a practice, is open to both men and women. It does not involve subsuming oneself under the identity of feminist, but instead shifts feminism into a political commitment that anyone can hold, notably in tandem with other political commitments. There is no one formulation for doing science as a feminist. When we engage in science as feminists, rather than do feminist science, we approach and treat different types of science, and the many components of scientific activity, differently based on context (Longino, 1994).

For Longino (2001), science is a function of the society in which it has developed. Thus, “science displaying masculine bias is not *ipso facto* improper or bad science, [because] scientific inquiry should be expected to display the deep metaphysical and normative commitments of the culture in which it flourishes” (Longino, 2001, p. 218). It is far from surprising, then, that the normative commitments of the Western scientific enterprise reflect the values of the dominant culture. Longino (2001) equally asserts that feminist science is not committed to a science that exists apart from the values and culture, but argues that to do feminist science, “we must change the social and political context in which science is done” (Longino, 2001, p. 222). In short, we cannot do feminism in science only. Instead, we must commit to effecting change on a broader scale. This inevitably includes, but cannot be limited to the way that we do science.

A Vision for Feminist Science Education

We have seen, throughout this chapter, the varying types and degrees of feminist critique of modern western science. Feminist philosophers of science have made a number of charges against science. Science functions to maintain the power imbalances of the status quo by excluding women from the production of science, as well as by consistently asserting that its knowledge is above, and thus unaffected by, culture (Jones & Scantlebury, 2001). Just as socio-scientific approaches to science have served in part to change the nature of science education in schools, so too do feminist philosophical critiques have suggestions for feminist science education.

Just as a number of Western women have seen their interests increasingly represented in the political sphere and enjoy a higher level of social equality since the advent of the women's movement, science education for girls has come a long way in a relatively short period of time. The women's movement can in large part be credited with significantly influencing the direction of women's education in the sciences (Calabrese-Barton, 1997). Nonetheless, it remains necessary to critically consider science education for girls, as well as science education in general. Indeed, "if 'science education for girls' means the same kinds of educational opportunities and supportive environments available to their brothers, the implication is that boys' science education is just fine" (Harding, 1991, p. 30). This, of course, is simply not the case. We have seen a number of problems with traditional science education. Just as the liberal feminist critique of science is insufficient due to the fact that it locates the problem with modern western science in its exclusion of women, so too is allowing girls access to a science education that is fundamentally inadequate an equally flawed solution.

Calabrese-Barton (1997) asks a series of provocative questions about feminist science education:

> What does it mean to teach science to diverse students when the science itself embodies only one-way of understanding the world? What does it mean to value the ideas of all students when the teacher-student relationship is built on a hierarchical arrangement […]? What does it mean to create mutual meaning among teachers and students when the discourses of science and education are guided by a discourse that does

> not include the essences of our lives as gendered, raced, and classed students and teachers? (p. 143)

In response, feminist philosophers of science have argued for a critique of science, a new language for and in the sciences, and for a recognition of the role that positionality plays in creating and perpetuating inequalities (Calabrese-Barton, 1997). Thus we see fundamental overlaps between feminist science education and humanistic science education. In much the same way that Roth and Lee (2002) argue that science literacy is not the property of individual students but instead constitutes a communal practice, Longino (2001) asserts that "scientific discovery has to be reconceived as function of the communal structure of scientific inquiry rather than as a property of individual scientists" (p. 217).

Just as there is no one way to do science as a feminist, nor is there one way to practice feminist science education. Jones and Scantlebury (2001), both science educators working in natural science departments, use a transformational agenda in their roles as educators. As scientists teaching both pedagogy and science content, Jones and Scantlebury (2001) critically engage their students with the "myth of a universal 'Western' scientific way of thinking and the handicaps imposed by its exclusionary image" (p. 141). They do this by calling attention to culturally diverse representations of scientific activity, by engaging in critical discussion with students, and by emphasizing the social and personal relevance of science to students' lives. Similarly, Calabrese-Barton (1997) recounts her attempts to engage in science education as a feminist when she asks her college level chemistry class to critically consider how scientific materials are designated as either male or female pieces. In this instance, doing science as a feminist meant calling attention to the gendered language of science, as well as its origins.

Thus we see that the feminist science education has little to do with denying or devaluing science. Instead, feminist critics insist that sciences are permeated in different ways and to varying degrees with the values and priorities of the historical context in which they come about. This is neither objectionable nor inherently problematic. What is troubling is that science has historically, and to a large degree continues to deny much needed attention to the fundamentally social nature of the scientific project. This has meant that socio-scientific and feminist perspectives have been largely devalued in educational institutions, as well as in society more broadly. Yet, humanistic science education has been shown to be educationally sound, engaging, and inclusive. What is more, humanistic, and specifically feminist science education contributes more productively to needs of students by engaging them in a thorough critical analysis of the scientific enterprise. With these visions of humanistic and feminist science education in mind, I turn to my attention to an analysis of science education in Québec.

Chapter 3

A Critical Evaluation of the QEP and Secondary One Science Texts

The previous two chapters of this thesis have summarized the thought of numerous theorists on science, science literacy, and science education. Chapter One looked at science education in light of recent theorizing on science literacy. We saw how the evolution of the philosophical and social studies approaches to science have gone hand in hand with the development of humanistic science curricula in schools. Chapter Two put forward a summary of feminist philosophical critiques of science, examining the myriad ways in which feminist thinkers have taken up and engaged with science. The feminist and socio-scientific critiques work together to broaden our conception of science as a system of knowledge production, as well as contribute to our understanding of what meaningful science education can and should look like.

The aim of this final chapter is to offer a critique of the Québec Education Plan, as well as a selection of ministry appointed science texts, in light of the social science and feminist critiques of science. My analysis will be based on the extent to which the QEP, as well as selected science texts, reflect consideration of the socio-scientific and feminist approaches to science that we have seen in the past two chapters. I formulate a qualitative analytical lens on the basis of these theories, through which selected elements of these texts will be examined and evaluated.

Given the fact that I will look closely at both the QEP and a selection of secondary science texts approved for use in Québec schools, there will be two stages to this chapter. My analysis of the QEP will serve as a starting point for my textbook analysis. I set out the intentions of the Québec curriculum, as well as critique the science curriculum from the perspective of both socio-scientific and feminist approaches to science. The QEP elaborates the content and fundamental principles of what is to be taught in schools. Yet because there are a number of factors that play into what actually reaches students in the classroom, it is unlikely that we can gain adequate insights into science education in Québec secondary schools based on the curriculum alone. Given that classroom learning is in large part based on the content of the textbook (Apple, 1986), I will investigate the intentions of the QEP as they are enacted through the science texts.

Overview of the Curriculum

In order to situate the secondary cycle one science and technology course within Québec's broader education plan, it is useful to first provide an overview of the curriculum as a whole. This outline of the QEP will be followed by a more targeted critique of the science curriculum.

Québec schools have a threefold mission; to provide instructions in a knowledge-based world, to socialize students in a pluralistic world, and to provide qualifications in a changing world (MELS, 2004). Québec schools are particularly interested in helping students learn how to acquire knowledge, be agents of social cohesion, and to develop the ability to learn and adapt throughout their lives (MELS, 2004). Thus we see a vision of an adaptive citizen, one who can respond to the needs and challenges of both personal and social life, suggested through the goals of Québec schools.

The Québec Education Program has three aims; to empower students, and to help them construct both their worldview and their identities. Students take courses in five subject areas over their time in school; language, social sciences, arts education, personal development, and mathematics, science and technology. They are expected to develop nine cross-curricular competencies throughout their studies. In keeping with the goal of helping students to develop their capacity to adapt to the personal and social challenges that they will encounter over the course of their lives, competencies are defined as:

> The ability to act effectively or respond appropriately in situations of a certain complexity. [Thus] promoting the development of competencies thus involves encouraging students to view knowledge in a different way and to focus instead on learning *how* to think and developing their autonomy. (MELS, 2004, p. 9).

The nine competencies are grouped into four main categories, namely methodological, personal and social, communication-related and intellectual competencies. Each subject area is associated with the development of a specific set of competencies. With this broad description of the program in mind, I now turn to a description and critique of the science and technology curriculum.

The Science and Technology Curriculum and Critique

The science and technology program is meant to contribute to student's broader learning through the development of "rigour, reasoning ability, intuition, creativity and critical thinking skills" (MELS, 2004, p. 61). The cycle one science and technology curriculum builds on the core knowledge developed at the elementary level. Students are meant to develop their scientific and technological literacy through the competencies as well as through "building a body of knowledge" of science-specific subject matter (MELS, 2004, p. 240). As such, the curriculum retains a certain amount of interest in traditional science content. Students are also expected to develop scientific literacy skills that they can use in their everyday lives, as well as build on in pursuit of further studies.

There are three specific competencies related to the secondary science and technology program. Students are evaluated based on their capacity to:

> 1. Seek answers or solutions to scientific or technological problems.
> 2. Makes the most of his/her knowledge of science and technology.
> 3. Communicates in the languages used in science and technology. (MELS, 2004, p. 226).

The first competency aims to develop students' capacity for methodological thought and work using the inquiry process that characterizes modern Western science. Thus, through the development of this competency, the curriculum seems to suggest that students should be inculcated into the business of doing traditional science, or at least doing science in the traditional way. Nonetheless, the QEP does recognize the role of creativity in the methods and procedures involved in science and technology. Unfortunately the curriculum does not elaborate on this point, but it seems that there may be some fertile territory for feminist critique in this regard. Students might be asked to consider the application of alternative forms of knowledge, for example, to solve a particular problem. However, this direction is far from guaranteed given the lack of specifications in the curriculum.

Making the most of one's knowledge of science and technology means not only applying scientific knowledge to everyday life, but also "examining the very nature of scientific and technological knowledge, its evolution and its numerous social and economic consequences" (MELS, 2004, p. 226). Seen in this light, this competency is perhaps the most promising for a humanistic, feminist science curriculum. A truly critical examination of the evolution and consequences of science and technology leaves room for students to consider how science and technology have evolved in a capitalist patriarchal society, and as such function to perpetuate the inequality and injustice on which these systems are predicated. Again, however, the direction and depth of this analysis will depend on both the chosen class text and on the teacher.

The third competency is geared towards developing the student's capacity for communication. While the importance of communication is undeniable, this particular competency constitutes a notable missed opportunity for the application of feminist critiques. Given the attention that feminist theorists (Calabrese-Barton, 1997; Cohn, 1987; Longino, 2001) have paid to the importance of language in shaping expert and lay conceptions of science, it is disappointing that the curriculum has failed entirely to recognize this contribution. The QEP goes so far as to assert "Young people become more empowered by mastering the languages of mathematics, science, and technology, which makes it easier to process information" (MELS, 2004, p. 61). Feminist theorists, particularly Calabrese-Barton (1997), have called into question the assumed virtue of inculcating students into a system predicated on inequality. Although the QEP aims to help students develop their capacity for critical judgment and reasoning, I would argue that this goal can only be partially accomplished in the absence of critical attention to the (gendered, dichotomous, and hierarchical) language commonly employed in science and technology.

The Québec secondary curriculum is divided into cycle one and cycle two studies. In cycle one, all students progress together through a general science and technology program. In cycle two, students are divided into the regular or the applied science and technology streams. In cycle one, however, the science and technology program integrates both scientific (e.g. chemistry, physics, geology) and technological fields (e.g. food and mining technology, mechanical design). This strategy is rooted in "the necessity of integrating different information from a number of fields in order to solve problems" (MELS, 2004, p. 225). MELS takes science and technology to be inextricably linked. They are in fact "so interdependent that it is often difficult to make a clear distinction between the two" (MELS, 2004, p. 225). Secondary one science, then, sets the tone for the science that students will engage with over the course of their secondary education, providing the common foundation on which students will build their future studies. Students will opt to study applied or general stream science in the final three years of their secondary studies, a decision which is likely largely based on their experience of science and technology during cycle one.

MELS (2004) asserts that science is important to lay people and scientists alike, given that in order to "remain autonomous, each individual needs to understand the living and material environment with which she interacts, to retrace the origins of life and its evolution, and to learn to appreciate the complex relationships between living things and their surroundings" (p. 225). In short, all people need to know engage with, as well as need to know something about, science. It is interesting to note that here science literacy is prized for its role in developing in citizens' autonomy. What this autonomy is meant to be *from* is unclear, but possible interpretations include one scientific experts, fellow citizens, the influence of the media, corporate interests, or even one another. In light of recent interest in the collective nature of science literacy (Roth & Lee, 2002), it is curious to see this emphasis on autonomy.

The QEP seems to take the notion that lay people's can engage with science seriously, stating specifically that "the field of science and technology is not the preserve of a small group of experts, and one can take interest in it without necessarily aiming for a scientific or technological career" (MELS, 2004, p. 225-6). We see the notion of meaningful citizen engagement with science reflected through the curriculum. Thus, both the applied and the general science and technology programs at the secondary level:

> Help students develop their scientific and technological literacy, enabling them to become active, critical and informed participants in debates on social issues, to use the products of science and technology responsibly and to take concrete, practical and innovative action in these areas. (MELS, 2004, p. 4)

Both programs aimed at the development of student science literacy. Whereas the science and technology program envisions a more humanistic approach to the study of the sciences, the applied science and technology program focuses more heavily on technology, or specifically, on the application of technology. In this way, it is clear the QEP seeks to extend its reach over the two major forms of science education; what Aikenhead (2006) has labeled the "pipeline" and the "humanistic" approaches to science in schools. Again, where the humanistic approach favors a developing a historical and philosophical approach to science, the pipeline directs students towards careers that make *applied* use of the sciences or technology. It is worth noting that technology is taken, in the QEP, to have grown out of science. Technology is conceived of as being an applied use of science that is simultaneously dependent on and pushed forward by with scientific progress. This is thought by some scholars to be an erroneous view (Ellul, 1964; Heidegger, 1977).

The QEP recognizes the extent to which mathematics, science, and technology represent human thought, make up cultural heritage, and contribute to shaping culture. It acknowledges the social aspects of science, asserting that:

> Scientific and technological activities are not fundamentally different from other human activities [but] part of a social and cultural context and are the result of a community's efforts to work together to build new knowledge on the basis of previously acquired knowledge. (MELS, 2004, p. 225)

The QEP reflects an acute awareness of the influence that social, cultural and political context has on the production and direction of scientific knowledge. Equally, it seems to recognize that science is made up of everyday science, what Kuhn (1962) designates as periods of stagnation or normal science, and those of great advancement, or revolutionary science.

Overall, it is clear that the QEP has taken into account a number of important elements of the philosophical and socio-scientific approaches to science education. Specifically, it seems to recognize that science and technology, in spite of their merits, do not constitute a unilaterally positive force in society. Thus, the QEP highlights the importance of engaging students in critical consideration of the role and uses of science and technology in society. In addition, the science and technology program, and more broadly the whole curriculum, is aims to help students develop their capacity to adapt to personal and social challenges. We see Feinstein's (2010) model of the competent outsider, one who recognizes when instances when science can be useful and who knows how to make use of scientific information in ways that are helpful to them, reflected here. However, despite the fact that, broadly speaking, feminist analyses of science are not incompatible with humanistic science education, explicit recognition of feminist philosophical contributions to science are conspicuously, and disappointingly, absent from the QEP.

What is more, it is difficult to glean the extent to which the socio-scientific principles make their way into the classroom. Given the importance attributed to ethical questions in the QEP, one would expect to see a strong humanistic approach to the study of science reflected in science texts, as well as in teachers' approaches to science and technology in the classroom. Thus in the next section, I turn to a critical analysis of the secondary cycle one textbooks.

Textbooks as a Research Cite

The taught curriculum reaches students directly through texts, and "comprises the classroom materials that support humanistic science teaching and the teachers' orientations that determine what they will implement in their school science" (Aikenhead, 2006. p. 5). Though 'texts' makes obvious reference to actual textbooks, the definition can be understood broadly to include written material as well and other forms of proposals that are intended to reach both educators as well as the general public (Apple 1986). The QEP prescribes basic information about the ideological content of what should be taught in Québec schools. Textbooks, however, play a fundamental role in legitimating knowledge as well as making it available within schools (Apple, 1986). In fact, in *Teachers and Texts*, Michael Apple (1986) chooses the textbook as his starting point for examination because:

> It is the textbook which establishes so much of the material conditions for teaching and learning in classroom in many countries throughout the world, and […] it is the textbook that often defines what is elite and legitimate culture to pass on. (p. 81)

It is clear that the textbook plays an authoritative role in science education, legitimating knowledge for both students and teachers.

Apple (1986) asserts that the textbook publication industry is not unlike other large capitalist industries. Decisions about textbook content are made predominantly by men whose "background will complement the existing market structure that dominates text production. Financial capital, short-term perspectives, and high profit margins will be seen as major goals" (p. 94). Apple (1986) reminds us that men make most of the decisions about the information legitimized in textbooks. But even when women make the decisions, they are made from the perspective of dominant capitalist patriarchal concerns. Additionally, textbooks are often thought of as instruments of standardization across a board of differently qualified and experienced teachers (Apple, 1986; McEneaney, 2004). This is not specific to Québec science students, but extends across both national and disciplinary boundaries. Thus economics and politics constitute major players in the production of textbooks.

Québec schools can use only the primary texts and instructional materials that have been approved by MELS. Alternative texts may constitute only peripheral classroom materials. MELS makes textbooks available to Québec schools based on the extent to which they demonstrate consistency with the content of the Québec Education Program (MELS, 2012). Thus the QEP and textbooks function together in the production and legitimation of knowledge in Québec schools.

MELS evaluates the suitability of textbooks for use in Québec schools on the basis of six major criteria; pedagogical, socio-cultural, material, advertising, confessional, and conventional aspects. While most of these criteria are relatively straightforward (texts must be free from product placement, religious affiliation, and so on), it is worth mentioning some of the specific elements that MELS applies in its evaluations of pedagogical criteria. In terms of pedagogical consistency, amongst other requirements, texts must also be consistent with the orientations and prescribed elements of the QEP in their treatment of the content, and contribute to "expanding cultural horizons and improving the quality of language" (MELS, 2012, p. vi). The texts that MELS has approved for secondary cycle one science are *Eureka!* and *Connection* for English language instruction, and *Gallileo*, *Action*, and *Univers* for the French system.

Critical Evaluation of the Texts

Waddington and Imbriglio (2011) paint a relatively bleak portrait of the texts used in Quebec secondary one science education. They conclude that while the secondary cycle one textbooks do include general STSE themes, ultimately they fall short in their critical integration of this content (Waddington & Imbriglio, 2011). As a result, they assert that students are "not being adequately trained to face the difficult social choices surrounding science and technology that will confront them as citizens" (Waddington & Imbriglio, 2011, p. 173). I concur that the critical perspectives on STS content in most of the texts is insufficient. However, this inadequacy pales in comparison to the complete lack of attention to feminist critiques of science in the textbooks. Because the QEP pays no explicit attention to feminist contributions to scientific thought, my expectations for the textbooks' treatment of both women and feminist theory are low. I turn now to a brief discussion of the representation of women in science textbooks.

None of the secondary cycle one textbooks show any explicit recognition of feminist critiques of science, from liberal to radical perspectives. Perhaps the most striking demonstration of this inattention to feminist concerns lies in the representation of women in the texts. It is unsurprising that important figures in the history of science are frequently pictured throughout most of the books. While *Galileo* shows only two images (both men), the rest of the texts show between fourteen and twenty-three images of revolutionary scientists with a brief discussion of their accomplishments. On average, for every thirteen photos of male scientists, only three women are shown.

What does such an uneven portrayal of men and women in the sciences tell students about science in general? Some may argue that this inequality is nothing more than accurate representation of the history of science. Far more men than women have participated in actually doing western science, thus it stands to reason that they are overrepresented, and women are underrepresented, in science texts. The problem is, of course, not specifically with the uneven representation of men and women in the texts, but with the absence of any critical uptake of this inequality. Far from the subject of critique, this imbalanced representation of men and women is never explicitly acknowledged by the texts.

Encouragingly however, in all of the texts, images of women engaging in science as well as in technological careers abound. There are ample photos of girls holding test tubes and taking measurements, and of women engaging in historically male-dominated careers. If the images of historical scientists indicate that the sciences used to be predominantly the business of men, then images of women and girls engaging in science throughout the texts may suggest that science is currently open to female participation. Although the inclusion of women in science does little to address the fundamental inequalities inherent in science, it is nonetheless encouraging to see an aim at more balanced representations of men and women engaging in science in the textbooks. Unfortunately, given that neither the QEP nor the texts pay explicit attention to the question of women in science, the onus rests on the teacher to call attention to the historic exclusion of women from science.

In *Teachers and Texts*, Michael Apple (1986) presents the critique of texts against a particular ideological framework. Drawing on this model, I critique the secondary cycle one textbooks against a series of criteria drawn directly from socio-scientific and feminist perspectives on science presented in my thesis. Given the origins of the STS movement, questions concerning environmental and reproductive issues should be crucial to a humanistic curriculum.

When examining the treatment of environmental issues and reproduction in the texts, I use the following questions as a framework for critique:

1. Do the texts provide students with the opportunity to consider economic, political, and other social forces that influence the production and dissemination of scientific knowledge?
2. Do the texts encourage students to think about whose interests are privileged and whose are ignored in the presentation of scientific information?

3. Do the texts call into question the social consequences of scientific thought and technological activity?
4. How do the texts encourage students to critically consider how cultural or other values have played into the production of scientific knowledge put forward in the texts?
5. Do the texts put forward alternatives (feminist, Indigenous) to the dominant male Western values?
6. To what extent do these texts encourage students to construct their own views and interpretations of science?

Overview of the Texts

It is useful to give a brief picture of the structure of the science textbooks. In keeping with curriculum stipulations, each text is organized into themes integrating a broad range of content and touching on a number of branches of science. The texts include a number individual and group activities to promote student learning. *Galileo*, for example, is broken down into four sections, each of which is organized around a research question. Students are meant to have the opportunity to exchange ideas and knowledge with their fellow classmates in relation to each learning situation. In theory, this gives them the opportunity to both express their knowledge, and to reflect on what others have to say. These skills represent fundamental elements of the Quebec curriculum.

Connection is broken down into six themes, each of which has two parts. At the beginning of each theme, links between the theme and the students' career aspirations, as well as to culture, life in general, and experimentation (science and technology) are made explicit. Equally, both the cross-curricular and subject-specific competencies that are targeted in that theme are highlighted.

Univers is divided into sections on the material universe, the living universe, the earth and space, and the technological universe. Like in the other texts, each chapter suggests activities relating to ideas covered in that chapter, links the chapter with different professions, suggests a research question for reflection, and offers questions for reviewing the content of the chapter. *Action* and *Eureka* are similarly divided into theme-based sections broaching a topic in light of a number of considerations and approaches.

Socio-Scientific and Feminist Evaluation of Textbook Content

1. *Connection*

Content dealing with environmental concerns in *Connection* is severely lacking. The text, for example, deals only briefly with the issue of endangered species. This seems like an obvious place to consider both the vast impact of science, as well as the ways in which the development and proliferation of technology have affected animal habitats. Indeed, a humanistic science curriculum would likely also pay attention to the economic, political, and gendered interests that have been major factors in contributing to exploding extinction rates. However, here the text opts for another, far less interesting approach. Inexplicably, the discussion of endangered species is limited to a brief description of the work of Jane Goodall and Dian Fossey. While it might be minimally conceived of as positive that two female scientists find representation in this section, there are a number of more informative and engaging approaches that the text might have taken in dealing with endangered species.

Connection puts forwards very little content evaluating the impacts of science and technology on the natural world. One exception is asking students to consider the impacts of an oil spill on ocean life. Though it is certainly important for citizens to understand the enormous impacts of oil spills, particularly in light of current debates over tar sand extraction and cross-Canadian oil pipeline construction, it is unlikely that students can do much with information about oil spills in the absence of a broader discussion of the oil industry's economic and political stronghold.

Like most of the texts, human reproduction in not featured in *Connection*. Interestingly, though, the text makes note of inventor Anton van Leeuwenhoek, who apart from having developed the first microscope, is also credited with popularizing the notion that human sperm contains a human soul. The text glosses over this fact, focusing its attention instead on the uses of modern microscopes. In so doing, the text fails to explore fertile ground for doing science as a feminist. Students might be asked, for example, what consequences for women's reproductive rights might stem from the idea that human sperm contains a soul. Where a fruitful discussion of the impact of science and technology on women's bodies might have ensued, the text misses this opportunity in favor of providing factual information about the function of microscopes.

2. *Eureka!*

One of *Eureka*'s four units, *My Planet: Its Resources and Its Limits*, begins with a conversation between two characters engaged in a debate as to whether or not their municipal council should form an environmental committee. One is concerned about global warming and sustainable development, while the other is convinced that more pressing priorities mean that money and effort would be better spent elsewhere. This conversation provides a framework for the unit. It is interesting to note the stereotypical representation of masculinity and femininity in this instance. Unsurprisingly, a white male character argues that the concerns for the global climate are exaggerated. In his brief statement he cites statistics on life expectancy, makes arguments rooted in economics, and touts the many advantages of technological advancements. On the other hand, the character arguing in favor of climate action is a worried-looking female character pictured wringing her hands in fear. This representation perpetuates sexist stereotypes, but also aligns the view that climate change is not a significant concern with rational argument, while positioning concern for the environment as emotional and irrational.

This unit covers waste disposal, energy, and recycling. In one exercise, students are asked to research and evaluate energy transformation methods. Based on their findings, they must then choose a preferred heating system for their homes. It is positive, from a humanistic studies perspective, that students research and evaluate energy transformation, and outline their preferences based on their collective research. However, there seem to be a number of crucial issues that might be explored here, but are not. For example, the origins of nuclear energy might open up a discussion of the relationship between politics and the directions of scientific research. In addition, the text presents Quebec as a leading producer of hydroelectricity, but without any critical evaluation of the impact of this technology on the natural environment. This oversight should be addressed. The open-ended nature of the 'research into energy' exercise leaves room for a critical discussion of energy transformation, but it by no means guarantees that such a discussion will ensue.

While *Eureka!* highlights a number of environmental considerations, water pollution, climate change, and waste disposal to name a few, there is relatively little critical discussion throughout the text. Although it is undoubtedly positive that students are encouraged to develop and express their ideas surrounding climate health, they are given very little critical material with which to work in the development of these ideas.

Notably, *Eureka!* provides the most thorough information on human reproduction of all the textbooks. While the other texts mostly limit their discussion to a comparison of plant and animal reproduction, *Eureka!* talks at length about human reproduction from family planning to conception, right up to child development. *Eureka!* is the only text to broach the topic of contraception. While the text provides factual explanations of various contraceptive devices and methods, there is no mention of the fundamental inequalities surrounding the question of birth control. A humanistic and feminist perspective would likely include some critical perspective on the fact that all but one method of contraception are targeted at the female body. The political, economic, and gendered aspects of the control of human reproduction are simply ignored in this text.

3. *Action*

The last chapter of *Action*, which deals with citizenship and life in society, announces that human beings have "mastered certain aspects of their environment with the goal of facilitating social life" (Gagné, C., Bachand, L., Durocher, R., & Samson, G., 2005, p. 173). This phrase encapsulates the tone for the discussion of environmental concerns throughout the text. Although *Action* underlines a number of environmental concerns, the text largely fails to present critical humanistic perspectives on these issues. For example, the text highlights the fact that though Quebec produces raspberries during the summer months, these berries must be imported for consumption throughout the winter. Predictably, technology is credited with making this possible, but disappointingly, the discussion ends there. This moment is a missed opportunity for *Action*. The text might have called into question the ethical implications of importing fruit through a critical consideration of economic and gastronomical benefits weighed against environmental costs. Similarly, a discussion of the direction of scientific innovation towards the development of transport technologies might serve to highlight the power of political and economic interests over science and technology. Instead, technology receives its usual praise.

In a similar missed opportunity, *Action* asserts that though historically individuals and families made their own bread, in industrialized countries most food is now produced on farms using the latest technological innovations. Given that historically women have largely been responsible for food preparation within the home, it would be notably more accurate to mention specifically *which* individuals made bread in the past. It might also be worthwhile to compare industrialized countries with developing nations in terms of their current use of technologies surrounding food production. Additionally, this would be an ideal moment to consider how, and whose political, social, and economic interests have shaped the nature of food production. Instead, the changing nature of food production in the west is presented simply as an uncontroversial given.

In an exercise that does, encouragingly, have the potential to yield some critical discussion, students are asked to discover how a food they enjoy regularly is produced. The instructions for this exercise are sufficiently open-ended in the text that the direction and quality of any ensuing discussion is far from guaranteed. While students are asked to find out about the production of their favorite food, they are not asked to evaluate its merits. A more critical exercise might instead ask students to debate the merits of oranges (imported) versus apples (local), or pastured versus factory-farmed animals.

Action emphasizes the necessity of water for life. The text mentions water scarcity and unequal distribution of water the world over. Equally, it mentions that Quebecers have the second highest water consumption rate in North America. While this seems like an ideal starting point for a critical discussion of water consumption, the text does little more than mention provincial plans aimed at reducing the water consumption of Quebecers. Students are asked to write an article to help sensitize citizens to water waste. Given the lack of critical analysis of water consumption in the text coupled with the broad directives of the exercise, there is no guarantee that the ensuing discussion will yield any notable demonstration of critical thought.

Fortunately, *Action* shows strength in its examination of city living with a view to minimizing pollution. Here the text insists on student participation, asking students to identify, in their estimation and with reference to a number of factors, the best mode of city transport. They are asked to consider the value of establishing pedestrian streets in cities. Similarly, students are asked to weigh in on the ways in which pollution might be minimized in cities.

4. *Galileo*

Chapter 4 in *Galileo* is geared towards evaluating the impact of pollution. In a surprisingly provocative turn in what is otherwise a relatively uneventful read, the text compares human beings to yeast. Because yeast is incapable of stopping itself from consuming resources in its environment, it can actually die from overconsumption. Students are left with a looming question; could the consequences be the same for human beings? Given the critical, and downright ominous nature of this question, it is both surprising and disappointing when the text abruptly shifts the discussion away from the critical question of resource exhaustion to the importance of limiting dietary sugar intake.

Broadly speaking, the coverage of environmental concerns in *Galileo* is disappointing. While *Galileo* broaches the topic of recycling in a unit on trees, the text does little more than assert that Quebec recycles only a quarter of its paper waste, and that materials cannot be recycled indefinitely. The text points out that while the actions of individuals matter, the capacity of large groups to impact the environment is larger. While this seems like a reasonable place to bring up the question of recycling standards in industrial contexts, for example, the text suggests instead that students should make ecological cards out of recycled paper. Waddington and Imbriglio (2011) have also commented on *Galileo*'s questionable discussion of trees. They note that the text presents a distorted vision of the threats to our forests, highlighting forest fires and insects as imminent threats while downplaying the role of industry in deforestation. The inattention to social, political and economic interests is notable throughout the text.

5. *Univers*

Univers provides some of the most coverage of environmental concerns out of all the secondary cycle one textbooks. Global warming is accurately and consistently addressed, and the text "dedicates at least two pages per chapter to frank, effective discussions of particular socioscientific issues" (Waddington & Imbriglio, 2011, p. 171). For example, the text draws explicit links between industrialism and the steady and alarming increase in carbon dioxide in the atmosphere. *Univers* is notably the only text that outright asserts the relationship between industrialism and global climate change. In addition, students are asked to consider ways in which carbon emissions and energy use, both on a broad scale as well as personally, might be reduced.

In spite of the fact *Univers* attempts to deal with significant environmental concerns, for example about the impact of large scales industry on the climate, there is nonetheless ample room for improvement within the text. Students might be asked to consider, for example, which industries are most responsible for using dirty energy, or what might constitute cleaner alternatives. Students might equally be asked to consider which populations are most vulnerable to the effects of climate change, as well as why. It is worth mentioning that those who are the least well positioned to deal with the effects of climate change are those who are living in poverty or otherwise precarious situations.

Disturbingly, *Univers* glosses over the problems inherent in Québec's hydroelectric power. The text mentions the importance of respecting the ways of life of Indigenous peoples, as well as of respecting the environment in the development and production of hydroelectricity. However, far from mentioning the negative impacts that hydroelectric power has had, and continues to have on natural environments and First Nations communities, the project is uncritically presented as one of Québec's great successes.

The text's treatment of green plastics is also problematic. Cost is argued to be the only downside of plastic made from corn, but the text is quick to reassure students that even these high prices will soon fall. After a two page-long discussion presenting green plastics as overwhelmingly positive (given that they biodegrade relatively quickly, are made of organic materials, and so on), students are asked to position themselves with regards to this type of plastic. Here the text does remind students about the polluting nature of intensive corn production. Nonetheless, it is difficult to see how students might reasonably be expected to position themselves against green plastic, given the nature of the information they have just read. A feminist perspective might argue against the dichotomous nature of the debate. Rather than arguing the merits of green over conventional plastic, it might be useful to look for alternative ways of dealing with the question of plastics.

Conclusion

Overall, in spite of the critical focus on science and technology elaborated in the QEP, secondary cycle one textbooks demonstrate only marginal attention to the contributions of socio-scientific approaches to science education. The majority of the textbooks' content is composed of seemingly objective presentations of scientific fact. While *Univers*, *Action* and *Eureka!* pay the most attention to environmental issues of the ministry appointed texts, their critical appraisal of these issues from a socio-scientific perspective is significantly lacking. It is unfortunate that the QEP fails to acknowledge the contributions of feminist theorists to the philosophy of science. Also notably absent are other marginalized forms of knowledge, particularly, given the Québec context, that of First Nations peoples. However, this inattention to feminist contributions is at least consistent from the curriculum to the textbooks. Where the texts align with the QEP's lack of attention to the question of women and science, there is significant discord between the socio-scientific prescriptions in the curriculum and the content of the textbooks.

Given the capacity for humanistic and feminist science education to provide students with meaningful and inclusive experiences of science, it seems advisable that the

Québec science and technology curriculum adopt these approaches fully. Though the curriculum contains humanistic elements, these are not adequately reflected in the science texts approved for use in Québec schools. As such, humanistic science perspectives are not constructed as legitimate knowledge in schools. Neither the QEP nor the science textbooks pay explicit attention to feminist concerns in science. As such, the contributions of feminist theorists are rendered invisible. I propose that the QEP, consistent with its critical perspective on science and technology, revise its curriculum to include feminist perspectives on science. There should be particular attention paid to the question of language in science. Including feminist perspectives in the QEP would necessitate their inclusion in science textbooks. As we have seen with socio-scientific approaches to science, attention in the QEP does not necessarily translate directly into adequate textbook content. Thus, it is necessary that further work be done to ensure that textbooks prioritize feminist and socio-scientific science content in meaningful ways.

Limitations and Directions for Future Research

I recognize that there are limits to my analysis of the texts. First, my focus mainly on the representation of women and environmental and reproductive issues takes into consideration only a fraction of the content of the texts. In spite of the relevance of these concerns for this thesis, it would certainly be valuable to examine the way in which additional content is broached throughout the textbooks.

In addition, while a study of the curriculum and textbooks can tell us something about what actually reaches students in Québec secondary cycle one classrooms, it by no means provides a complete picture of the state of science education in Québec. As I reiterated throughout my analysis, the direction that classroom learning takes is largely dependent on the teachers' orientations as well. Thus it will be useful for future research to study not only the textbooks, but to look at the ways in which teachers use these texts in Québec classrooms. Another important aspect of science education is what the students actually take away from it. Thus it will be useful to study student perceptions of their science and technology curriculum, with particular attention to the ways in which both teachers and texts bring this curriculum into the classroom.

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