POSTMODERN IMAGINATIVE CONSTRUCTIVISM FOR STSE UNDERSTANDING

by

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Abstract

The influences of science and technology on society and the environment (STSE) have been an integral component of the formal educational curricula for four decades, and yet industrialized countries frequently struggle to balance the benefits of science and technology with the social justice and environmental issues inherent to contemporary society. Canadian citizens often fail to connect scientific and technological understandings with the subtle and yet ubiquitous personal, political, cultural, environmental, and social consequences that result from these understandings. This phenomenological research will explore potential discourses of control within education and society that may preclude authentic, contextual, and meaningful understandings of science and technology relative to their significant consequences, and an imaginative adaptation of Egan's Ironic Understanding and McGinn's Foreground and Background Dimensions to imaginatively express an awareness of postmodern STSE understandings. This research is designed to explore student understandings of how the diverse and complex influences of science and technology affect students through postmodern, imaginative, and constructivist photography. Participants demonstrated a limited Ironic Understanding of STSE, a critical awareness of specific modernist influences, increased personal and affective connections to science and technology, and an awareness of the duality of STSE. Participants' photographic artifacts can be utilized to inform teaching and learning strategies in order to purposefully craft curriculum and lesson plan design for personalized and engaging learning opportunities that incorporate students' awareness of STSE.

"We shape our tools and thereafter our tools shape us" Marshal McLuhan

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Chapter 1: Introduction

The impetus for this research is to explore the possibility of potential educational solutions to the social and environmental issues facing contemporary industrialized countries. Science and technology has had a dramatic influence on industrializing countries over the last 150 years. The ability to adapt the environment to the needs of society has fundamentally changed the lives of citizens around the globe. Although many benefits have resulted from the theoretical and practical utilization of scientific understandings, many crises of modernity currently threaten all life on the planet. Hodson (2003) offers an explanation for understanding the subtle complexity of the different forms that science and technology take in industrialized societies:

> A succession of human and environmental tragedies have sometimes cast science in the role of villain; disturbing social changes and deep ethical concerns arising from scientific and technological innovations have caused science to be viewed by many as a potential threat to familiar and comfortable ways of life; the increasing commercialization, industrialization and militarization of science have shown once and for all that science is not value-free and disinterested. The merger of science and technology into technoscience, the appropriation of the knowledge-making capacity of science to promote the interests of the rich and powerful, and the usurping of the scientific and technological endeavour for the goal of ever-increasing levels of material consumption, have profoundly changed the sociopolitical and moral-ethical contexts of scientific and technological practice (p. 649)

This research will explore a pedagogical strategy designed to balance the societal benefits of science and technology with the social justice and environmental issues that have resulted from the progression of modernism. A balanced perspective will demonstrate a holistic understanding

of both the positive and negative aspects of science and technology within an educational context.

A primary concern of this research is the prevalence of scientific and technological solutions and the educational, political, cultural, and economic influences that preclude their implementation. Scientific educational frameworks have attempted to embed social and environmental justice issues within curricular documents for four decades (Pedretti & Nazir, 2011), and yet modernist philosophies continue to determine policies regarding the development and application of scientific comprehension. This research was designed to critically analyze the modernist ideological origins of Western educational systems and offer a postmodern alternative that has the potential to change social and environmental practices. This research will also provide opportunities to analyze constructivist artifacts created through a postmodern educational assignment designed to create an awareness of the diverse and sophisticated influences of science and technology in the lives of secondary science students.

Research Question

How can the development and construction of imaginative photographic artifacts be utilized to create an awareness of postmodern understandings of how science and technology influences secondary science students?

Rationale of Research

The issue at the heart of this research is not the educational development of knowledge and logic but the disproportionate development of reasoning over empathetic, imaginative, and critical thinking. Knowledge and reasoning development within science education is cognitively significant and educationally valid when they are developed from an inclusive, critical, and contextual perspective. The goal of this research is not to disregard or eliminate knowledge and

logic from science education discourse, but to reframe students' scientific understanding from a perspective that emphasizes personalized, individualized, empathetic, ethical, and imaginative contexts where "all students, including future scientists, [are] to be educated to be critical consumers of scientific knowledge" (Osborne & Dillon, 2008, p. 8). Society may benefit if science educators recognize that "hope lies in finding a new way to live in the world, not in a modernistic faith that some technological solution exists" (Blades, 1997, p. 32). Science education may offer potential solutions to contemporary societal and environmental issues because students, when provided with opportunities to critically reflect, can access discourses of power, deconstruct the limitations of society, and imaginatively construct a more just future.

Chapter 2: Literature Review

Modernism

Scientific rationalism underlies the development of education and society toward a modernist paradigm that emerged from the ideological foundations of the Enlightenment and has been instrumental in defining the modern era (Littledyke, 2008). These philosophical principles have created positivist, objectivist, reductionist, determinist, mechanistic, value-free, and absolute truth discourses that have significantly altered industrialized societies (Littledyke, 2008). Modernist principles have been refined and embedded throughout society to prioritize technological and economic proliferation. Olssen, Codd, and O'Neill (2004) argue:

> In most modern societies, the education system is controlled by the state, but it works to maintain relations of power throughout the society as a whole. For this reason, the official discourse of the state relating to educational policies (for example, core curriculum, transition education, systems of assessment or school management) are obvious instances in which discourse becomes the instrument and object of power (p. 67).

Educational discourses within mandated curriculum documents, funding policies, and standardized testing designs have their origins in modernist philosophies.

Modernist foundations of science education. The modernist perspective developed primarily from European philosophers of the Enlightenment who believed humanity could most efficiently understand the physical universe through observation and facts. These philosophers described a scientific and reductionist mode of technical thinking that is dominated by ostensibly objective, universal, and value-free models of knowledge (Littledyke, 2008). From a scientific perspective, Western philosophies have developed from the fundamental idea that "natural philosophy would deal only with objective rational knowledge acquired through direct

experience with nature, and in return, natural philosophy would provide other social institutions with power and domination over nature … science [was] declared objective and value free" (Aikenhead, 1994, n.p.). From a societal perspective this mode of thinking has accelerated scientific, technological, and economic developments that have radically changed society over a relatively short period of time. Modernist beliefs, embedded in western societies, have developed normative attitudes toward the exploitation of nature through the increased application of scientific and technological understanding in order to improve the human condition.

From a global perspective the scientific, technological, and economic developments that have resulted from the modernist enterprise have provided a number of advantages for industrialized countries because "foundational to this metaphysics of modernity is the belief that a rational subject can truly come to know objective reality and this knowledge can be used to further human progress" (Blades, 1997, p. 17). The ability to dictate domestic and foreign policy, national security due to militaristic dominance, and opportunities to provide medical and social technologies that increase life span and improve quality of life are among the primary benefits of modernist ideologies. Due to these relative advantages, the development of modernist thinking has become a primary goal of governments in order to guarantee scientific, technological, and economic dominance in a world that continues to globalize at an accelerating rate. By extension this pervasive penetration of modernist themes leads inexorably toward establishing 'metanarratives', that unify thoughts and reduce the diversity of individual expression (Blades, 1997). Foucault suggests that it is these metanarratives, which "normalize individuals through increasingly rational means, by turning them into meaningful subjects and docile objects" (Foucault as cited in Dreyfus and Rabinow, 1982, p. xxvii). Therefore, modernist metanarratives that permeate educational frameworks and perpetuate scientific discourses often

fail to authentically deal with social factors such as the impact of scientific understanding on how humans behave and relate to one another, and work to disconnect learners from complex social justice and global environmental issues that represent the most critical aspects of the influences of modernism.

The prioritization of scientific knowledge and logic over other educational goals has resulted in the reproduction of technical and reductionist thinking and:

> if we, as teachers are serious about making a positive change in our school curricula, toward a transformational education that promotes a more equitable and just society, we must confront and critique the political philosophy of the government and society at large (Pignatelli, 1993). Otherwise, we do not teach our students how to engage when social structures are unjust but rather to endure. We emulate a dead curriculum rather than a pedagogy of freedom, thus producing what Friere (1998) has called a disengagement, not only from history, but an absence from ourselves (Barrett & Pedretti, 2006, p. 244).

A mechanistic and emotionally detached attitude creates an analytical understanding of nature that is ostensibly objective, theoretical, universal and value free. These traditional characteristics of scientific and technological understanding potentially create learning environments where educational outcomes are often misleadingly perceived as compartmentalized and socially benign. This attitude toward educational experience gives students the impression that "whilst science might be perceived as quite interesting, it is seen as 'not for me' by many young people as it is identified with becoming a scientist or engineer - careers which are strongly associated with the advancement of technology rather than aiding people" (Osborne & Dillon, 2008, p. 17). Scientific reductionism potentially creates a cognitive dissonance with the personal and affective framework of student learning.

The science curricula and standardized assessments developed, and maintained by educational authorities, continue to exhibit the "inadequacy of earlier approaches to policy that have their origins in the hegemonic dominance of liberalism underlying traditional educational discourses" (Olssen et al., 2004, p. 2). Although science curriculum documents often include references to progressive, contextual, and authentic learning strategies it is important to differentiate between explicit and implicit policy meaning. Student engagement is low because science education has become a sterile, compartmentalized, and abstract representation of modernist science goals that are emotionally and ethically detached from students' interests and experiences (Littledyke, 2008). Pedagogically this could preclude the empathetic, moral, and/or ethical development necessary to utilize science and technology for the benefit of humankind. Modernist pedagogy fails to connect science courses to the environmental and societal issues that threaten humanity in the 21st century (Blades, 1997).

Failures of modernism. It is necessary for contemporary educational philosophy to address the social issues that have developed as a response to modernist thinking. The representation of knowledge as objective, universal, and value-free emotionally detaches students from learning goals. Students are not often provided with authentic opportunities to contextualize, or develop, a sense of responsibility for the utilization of scientific and technological understandings from a perspective of social justice and environmental sustainability. Humanity faces many social and environmental crises such as starvation, disease control, energy consumption, potable water supplies, global climate change, nuclear disasters, chemical warfare, deforestation, desertification, urbanization, and militarization. Clearly science education has a "crucial role to play in teaching [students] how to exercise the enormous power of technology responsibly, carefully and compassionately, and in the interests of all living

creatures" (Hodson, 2003, p. 663). Educational systems designed to reproduce modernist thinking may be inadequate to solve the social and environmental issues that resulted from the same modernist rationalizations that created the problems.

The ontological product of modernist educational design can be seen in the affective and ethical detachment of individuals from nature and simply changing curriculum knowledge objectives is inadequate to compensate for the technical and reductionist modes of thinking that are an inherent by-product of a modernist pedagogy because "attempts to change secondary school science education curricula are defined and thus limited by the positivistic, technical-rational assumptions of the discourse of modernity" (Blades, 1997, p. 2). Other philosophical designs should be explored in order to provide opportunities for students to develop a predisposition toward epistemological characteristics that will support the development of science and technology, social justice, and the sustainability of the environment and economy in the 21st century. One ideology that has the potential to free students from the defining discourses of modernity within science education is postmodernism.

Postmodernism

Introduction to postmodernism. Although postmodernist thinkers often avoid explanations of specific philosophical tenets except as a general response to the influences of modernism, Henry Giroux (1995, xiv) summarizes the following:

> The 'postmodern debate' has spurned little consensus and a great deal of confusion and animosity. The themes are, by now, well known: master narratives and traditions of knowledge grounded in first principles are spurned; philosophical principles of canonicity and the notion of the sacred have become suspect; epistemic certainty and the fixed boundaries of academic knowledge have been challenged by a 'war on totality' and a

> disavowal of all-encompassing, single world views; … the Enlightenment correspondence between history and progress and the modernist faith in rationality, science, and freedom have incurred a deep-rooted skepticism; the fixed and unified identity of the humanist subject has been replaced by a call for narrative space that is pluralized and fluid; and finally, though far from complete, history is spurned as a linear process that moves the West progressively toward a final realization of freedom.

Early postmodernists recognized the negative influence of grand universalizing metanarratives that purported to explain reality and they were incredulous toward all metanarratives and critical of claims of absolute truth like those represented in modern science education discourse.

> Deconstructive postmodern writers such as Derrida, Lyotard and Rorty contest the idea of absolute truth claims of science with its objective descriptions of the universe, and propose that all ideas are ultimately confined within the constraints of human language systems and culture (Lyon, 1994; Clark, 2006), leading to a relativistic view, which proposes that all knowledge is culturally bound (Littledyke, 2008, p. 4).

Postmodernism postulates that a purely universal, objective, and absolute reality is not accessible by human observation or understanding because knowledge and comprehension are created by and subject to individual experience. Postmodernism abandons the ostensible neutrality of the scientific enterprise and presents understandings that are relative to personal, social, and cultural bias, therefore, "*epistemic relativism* which claims that all beliefs or knowledge are socially constructed, so that knowledge is contingent, neither the truth values nor criteria of rationality exist outside of historical time" (Olssen et al., 2004, p. 21). Ethics, values, and affective connections to knowledge are understood through personal experience. Postmodernism is an

important philosophy to consider in education because it incorporates contextual, meaningful, and purposeful understandings that are personally created within the learning process.

Importance of postmodernism. One of the most significant postulates of postmodernism is the idea that all knowledge is socially, culturally, and personally situated. Foucault attempts to advance a:

> consistent social constructionist view of the constitution of the human subject. By social constructionism Foucault means that the subject is constituted discursively in history. It is by 'decentring' the subject in this way that he rejects essentialist views based on conceptions of 'human nature' or 'biology' or 'psychology' (Olssen et al., 2004, p. 22).

Foucault's postmodern paradigm resonates with John Dewey's idea that "knowledge is a function of association and communication, [and] it depends upon tradition, upon tools and methods socially transmitted, developed and sanctioned" (Dewey as cited in Olssen et al., 2004, p. 231). Discourses of power within education are therefore inherently subject to critical analysis in an attempt to facilitate social reconstruction as opposed to social reproduction of ostensibly universal and objective social norms.

The social and cultural influence on education is inextricably linked to social morays because ethical decisions can only be understood within the context of a community (Olssen et al., 2004). Postmodernism does not attempt to arbitrarily separate knowledge from ethics and morality. Power relationships within education must be deconstructed and critically analyzed in order to recognize that "if the self is socially and historically created, then the development of our identities depends upon state action and community support" (Olssen et al., 2004, p. 232). Educational frameworks that are contextualized from a socially and culturally derived

perspective may encourage discussions regarding the ethos of a community and its influence on individuals.

Postmodernism doesn't provide a single, unified, and/or universal perspective on facts or truth. Foucault proposes a "non-reductive, holistic, analysis of social life" (Olssen et al., 2004, p. 51) which, if applied to science education, might allow for a more individualized, diversified, and subjective understanding of science through personalized learning opportunities. Postmodernism embraces the individuality and personal connection of knowledge to its social and cultural context as opposed to the conformist nature of modernist universal metanarratives. Interests in developing knowledge and logic skills could be more balanced with other educationally valid goals such as the development of social justice, imagination, ethics, and affective connections to holistic student learning. These goals could be explored through reflective constructivist learning opportunities that connect with students on a personal level.

Education could provide more opportunities for students to reflect on the meaning, purpose, ethics, and belief systems relative to their epistemic understandings because "adolescence is a period of identity formation and there is good evidence that a critical issue for young people is how their subject choice frames their sense of self-identity - in particular, how it reflects their personal values" (Osborne & Dillon, 2008, p. 8). These reflective learning opportunities may help to create an awareness of how science and technology affect students' lives and a better understanding of the pervasive influences of science and technology. Education has "changed from an issue of being '*What* do you want to *do* when you grow up? to one of '*Who* do you want to *be* when you grow up?' Education in such a context becomes a means of self-actualization and finding personal meaning" (Osborne & Dillon, 2008, p. 17). The inclusion of postmodern elements within the construction of student learning may provide

important opportunities for self-realizations with regard to the context of social justice and environmental issues.

The inclusion of subjective, social, and cultural perspectives of science and technology has many implications for postmodern science education reform. Although there are many diverse, sophisticated, and interconnected causes of social justice and environmental issues (e.g., social, political, economic, philosophical, and legal discourses) incorporating postmodern perspectives within science education may facilitate a greater level of critical scientific literacy and independent thinking essential for improved sustainability because "environmental education is about the construction of ethical awareness that includes critical understanding of one's deep, perhaps contradictory and inconsistent, personal knowledge structures and beliefs, recognition of personal assumptions, predispositions and biases, cultural blinders, and ideological boundaries" (Hart, 2002, p. 1248). The Science and Technology in Society and the Environment (STSE) interplay with postmodernism provides an educational environment where scientific and technological development can be considered from a humanistic, sociological, and philosophical perspective. A change in the ontological attitude from the relatively isolated development of technical and rational thinking of modernism has the potential to produce the cognitive understandings necessary to provide imaginative and inspired solutions that might move humanity toward a more just and sustainable future.

Solutions to 21st century STSE issues will likely involve sophisticated, critical, and collaborative thinking. An education system, that includes postmodern elements, might foster the unique characteristics of a pluralist society and endeavour to limit modernist metanarratives. To develop solutions: "we must forget our perfect offerings. There is no ideal science education curriculum-discourse, no generalizable formula for changing a discourse, no method that works

in every situation" (Blades, 1997, p. 218). Creativity is necessary to re-imagine a model of scientific education that is grounded in ideologies of environmental sustainability and social justice. In order to develop solutions to contemporary STSE issues, society will need the efforts of people thinking independently, imaginatively, and collaboratively to create potential solutions. A postmodernist STSE pedagogy seeks "to appropriate from science, and from the history, philosophy, and sociology of science, knowledge that empowers students (a critical citizen's ideology) to gain a more insightful and socially powerful outlook on the world in which they live" (Gaskell, 2001, p. 390). These reforms may help to facilitate a scientific and educational awareness that promotes a maturity of thought that values wisdom rather than mere knowledge (Hodson, 2003). From a research perspective it can be valuable to explore philosophical and pedagogical concepts in order to evaluate their potential to develop wisdom and provide solutions to the contemporary issues of industrializing societies.

The propagation of postmodern perspectives within science education may help to build a more subjective and personal awareness of how science and technology influence students. The valuing of the social, ethical, cultural, and historic perspective of students within their learning might facilitate a more holistic understanding of science and technology relative to society and the environment, and help to create an awareness of modernist metanarratives. Modernist metanarratives work to propagate objective, technical, and rational modes of thinking while postmodernism works to encourage a more subjective awareness of our world. In order to build postmodern educational elements within a modernist society, it is critical to include imaginative design elements in order to create opportunities for creative and unique expressions of science and technology.

Imaginative Understandings

An important step in the development and implementation of postmodern elements within pedagogical planning is to develop the imaginative capacity to envision new possibilities. Osborne and Dillon (2008) make an argument for the reorganization of science education for the 21st century when they state that the challenge for educational systems "is to re-imagine science education: to consider how it can be made fit for the modern world and how it can meet the needs of all students; those who will go on to work in scientific and technological subjects, and those who will not" (p. 5). Science education might be a more powerful influence for social justice if it can be authentically combined with empathetic, self-reflective, meaningful, imaginative, and critical pedagogy based on postmodern philosophies. This research explores the possibility of making secondary schooling analogous to an "imaginative and heroic journey for students [who] might take heart in seeing their own present struggles as also a heroic journey, through the tangles of debased educational language and the obstacles in institutionalized commitments to narrow conformity and utility, in the direction of something more wonderful" (Egan, Stout, & Takaya, 2007, p. 20). Students have the potential to develop a more relevant and sophisticated awareness of STSE when their educational experiences are framed from an imaginative and postmodern perspective.

The imaginative expression of STSE issues is central to this research. The knowledge, skills, and attitudes relevant to artistic disciplines such as photography develop the imagination, making new sciences, technologies, and understandings possible (Root-Bernstein & Root-Bernstein, 2013). As Greene suggests, the purpose of forming narratives "is to engage in a journey of consciousness, [which is] an attempt to 'go beyond', to reach towards imagined possibility" (Greene as cited in Blades, 1997, p. 7). Photography provides postmodern

opportunities to express imagination, which "in this sense, is closely connected to the forming of mental images" (Bailin, 2007, p. 102). The goal is to create an educational atmosphere where students are encouraged to develop their personal, holistic, and affective awareness of the influences of STSE. Imaginative photographic activities may give students a voice to critique and reflect on the influence of science and technology in their lives. This research is designed to encourage student imaginative self-expression and self-exploration.

Importance of imaginative development. Hegemonic influences in education and society are often pervasive and difficult to identify. One mechanism for critical and independent thought relative to STSE topics is the development of imaginative capacities for the purpose of envisioning alternate realities and critical analysis of current perceptions. An imaginative postmodern education could empower students to resist being influenced by traditional appearances, ideas, beliefs, practices, and discourses (Egan et al., 2007). Imaginative development provides opportunities to emphasize creative production and divergent thinking, or the capacity to create multiple potential ideas and/or solutions, rather than convergent or reductionist thinking, or the capacity to glean a single answer from multiple variables. Imagination is critical for "students to envision a better future for themselves and is thus a personally and politically liberating force, as well as an affective and intellectual one" (Stout, 2007, p. 42). Building imaginative capacity within science education should allow students to envision more creative and diverse solutions for the social and environmental issues challenging contemporary society.

Learning and perception can be significantly constrained by the limits of our imagination. In order for people to recognize new possibilities and creative solutions, and to appreciate different points of view, imaginative capacities are important. Imagination is key to social

reconstruction because it creates flexible mental functioning that can be utilized for envisioning new social configurations. Although science is inherently creative, this is often lost in the planning and design of science education. Stout (2007) advocates for imaginative pedagogy "since our work is most importantly about liberating the mind, allowing us to imagine - and realize - a future better than the present" (p. 42). Imaginative pedagogy is essential to improve the utilization of science and technology in a manner that further benefits students' lives and society. In order to help create a citizenry capable of making local, regional, and widespread global changes, students must be prepared with the cognitive and ethical frameworks to support social reconstruction. STSE issues taught through imaginative instructional practices could be more frequent in core academic science courses. There is a metacognitive aspect to imaginative development because "learning how to learn and being able to use what one has learned (for social reconstruction, perhaps) are considered superior to amassing academic knowledge" (Aikenhead, 2003, p. 11). STSE could provide multiple potential frameworks for social reconstruction through a personally and emotionally connected curriculum that emphasizes a social and environmental value-based science education (Pedretti & Nazir, 2011). Utilizing the philosophical framework of postmodernism within imaginative constructivism, secondary students can be provided opportunities to imaginatively express how science and technology affects their lives and, by extension, society in general.

The key to developing postmodern and imaginative modes of thinking is to provide opportunities for students to "pose questions, [to] seek out explanations, [to] look for reasons, [and to] construct meaning" (Greene as cited in Egan et al., 2007, p. 58). Imagination allows students to gain perspectives of STSE that extend beyond the compartmentalized facts and skills of modernist curricular designs. An imaginative, creative, and constructive education might

prepare students to create a better future from their past and present understandings (Hetland, 2013). What is important to the trajectory of a student's educational experience is that they have opportunities to create a meaningful awareness of the material and understandings they are actively developing. The affective involvement and active construction of STSE within education provides multiple possibilities for imaginative and inspirational learning opportunities that extend beyond the traditional modernist educational framework.

In order to design a postmodern and imaginative learning experience for science students, a pedagogical model must be chosen that is fundamentally grounded in imaginative and postmodern principles. Egan's (1997) Cognitive Tool Model integrates postmodernist and imaginative learning elements in order to create an Ironic Understanding that has the potential to provide students the opportunity to personally explore the influences of science and technology. Specifically, Egan's (1997) description of Ironic Understanding provides a pedagogical model that has the potential to create an awareness of postmodern scientific understandings through imaginative educational design. This intersection of postmodernism and imaginative education expressed in Egan's (1997) Ironic Understanding might provide opportunities for students to understand science and technology from a perspective that is contextually and authentically situated with contemporary social and environmental issues.

Egan's Cognitive Tool Model

Egan's (1997) Cognitive Tool Model reflects many of the core postmodern criticisms of contemporary educational discourse. The emphasis on knowledge transmission as "the central building block of education creates the problem of determining what knowledge, and how much breadth and depth of that knowledge, is required to become adequately educated" (Egan, 1997, p.25). Egan's (1997) model also illuminates the postmodern criticisms of factual objectivity and

social constructions of knowledge that are inaccurately presented as universal absolutes of truth. Egan (1997) believes that "by displacing 'knowledge' with the category of 'kind of understanding,' we will not be throwing knowledge overboard. The development of kinds of understanding requires particular kinds of knowledge" (p. 25). The issue concerning modern educational frameworks is that, even under ideal circumstances, they do not effectively develop holistic forms of understanding. Egan's (1997) model postulates that students have the potential to develop an Ironic Understanding that embraces postmodernism and imaginative learning.

Ironic Understanding. The perpetuation of ostensibly absolute, compartmentalized, and universal curriculum topics may preclude a personalized, contextualized, meaningful, and critical application of knowledge. Ironic Understanding develops when students create an awareness of and learn to move past the influences of modernist metanarratives. Irony, where the meaning of language is different from the literal representation, allows individuals to become comfortable with the ambiguity of language to represent ideas. Egan's (1997) model postulates that "irony, combining artistic imagination and scientific rationality, can enable us to make our way, using our artistic creations as stepping stones, beyond the chaos of this world" (p. 147). This model can be adapted to science education by framing an Ironic Understanding of the dichotomy between scientific and technological knowledge and skills, and social justice and environmental sustainability issues. An opportunity to develop an Ironic Understanding of STSE might provide an educational context where the social and environmental issues inherent to scientific and technological capacities are authentically combined for reflection and critical analysis. The expression of an Ironic Understanding through artistic constructivism should provide an opportunity for students to be self-reflective, expressive, and critical; which could stimulate students to develop their awareness of the influences of science and technology.

According to Egan's (1997) Cognitive Tool Model, Ironic Understanding is the key to creating a postmodern image of one's life separate from metanarratives where students can flexibly create and redefine cognitive frameworks. Ironic Understanding deconstructs modernistic modes of thinking and the destructive effect that they can have on society, and allows for multiple perspectives of knowledge. This insight is based on Egan's (1997) "belief that the kind of truth long sought in Western intellectual activity is illusory, [and that a sense of irony is] tactically and rhetorically useful in breaking up metanarratives that work for some at the cost of others" (p. 152). Education's pedagogical representations of objective and universal knowledge take on different perspectives for individuals that exhibit an Ironic Understanding. Ironists come to the realization that truth is just a reference to beliefs that are widely and easily shared, but not necessarily corresponding with reality (Egan, 1997). Ironists value imagination and storytelling more than the rational and technical pursuit to accurately represent reality and their ultimate goal is to develop consensus through the mutual construction of meaning (Egan, 1997). Ironic Understanding may represent a mode of thinking that could provide an effective means for recognizing modernist educational hegemonies and an important cognitive tool to create an awareness of postmodern understandings of how of science and technology influence the lives of science students.

Taking Egan's (1997) principles of Ironic Understanding and applying them to science education may create opportunities to develop a more engaged, authentic, and holistic perspective of STSE. The achievement of Ironic Understanding results in greater flexibility to utilize scientific knowledge without becoming deluded by the perceived objectivity and universality of modernist metanarratives. An Ironic Understanding might allow students to identify the discourses of modernity and recognize these influences within their STSE education.

For the postmodern educator, irony is the primary characteristic of a mode of thinking that encourages students to "construct meanings, and so 'solidarity,' with others for the purposes of living well and not causing pain" (Egan, 1997, p. 154). This type of understanding is critical for students to move past the modernist construction of their knowledge and the application of technical and rational modes of thinking that have the potential to negatively influence the social and environmental aspects of society.

The flexibility and incredulity of Egan's (1997) postmodern Ironic Understanding might allow students to deconstruct modernist metanarratives of the utilization of science and technology in society. The critical deconstruction of these metanarratives vacates intellectual spaces where individuals become responsible for the construction of their own meanings of science and technology in their lives. "We may consciously make up our own contingent stories, constructing meanings that are good to believe for living well, but [free of] the confusion of thinking that these meanings derive from the reality on which we impose them" (Egan, 1997, p. 161). In order to create a postmodern awareness of STSE, through an Ironic Understanding, students were provided with a humanistic and holistic framework to analyze STSE. McGinn's (1991) Foreground and Background Dimensions of STSE provided the social and cultural perspectives in order for students to more comprehensively identify, analyze, and express the STSE influences in their lives.

Science and Technology Defined with Society and the Environment (STSE)

In order for students to create a postmodern awareness of STSE, it would be beneficial to provide a framework in order to identify the multitude of scientific and technological influences in their lives. Scientific literacy is essential for a comprehensive understanding of how science and technology influence the societal and environmental dimensions. A reflection of scientific

and technological influences as a mechanism to recognize social and environmental justice issues must consider the sophisticated interconnections and rich social contexts. This research will use McGinn's (1991) definitions of science and technology to expand student perception of how science and technology affect their lives because "however well entrenched [science and technology] are in modern life, they could in fact be otherwise, although it might take a major military, [environmental] or economic catastrophe, [or] profound transformation in cultural attitudes, … suffices to show that its autonomous character not withstanding, the process of technological change is not inherently so" (McGinn, 1991, p. 73). Even though technology is often perceived as ostensibly independent from external or internal controls, at the centre of all scientific and technological developments are people who bring specific understandings that are often developed in part through their scientific education. The influence of science and technology on students' lives will be presented from McGinn's (1991) socio-cultural framework.

McGinn's definition of science and technology. McGinn's (1991) book "Science, Technology and Society" outlines a methodology for evaluating the "formative influences on each other exercised by science and technology on the one hand and modern Western society and culture on the other" (p. 13). McGinn describes 'technics' as "material products of human making or fabrication" and 'technology' as "the complex of knowledge, methods, materials, and, if applicable, constituent parts (themselves technics) used in making a certain kind of technic" (McGinn, 1991, p. 14). McGinn's definition of science and technology includes humanistic, social, and cultural considerations where "the complex of knowledge, people, skills, organizations, facilities, technics, physical resources, methods, and technologies that, taken together and in relationship to one another, are devoted to the research, development, production, and operation of technics (at a given point in time in a particular societal unit, be it national or

global in scope)" (p. 15). McGinn's definition of science and technology provides a foundation for his socially and culturally constructed Foreground and Background Dimensions that will provide a holistic and detailed framework for students to analyze how science and technology influences their lives.

McGinn's foreground analysis. There are three important Foreground Dimensions of STSE analysis that McGinn (1991) refers to as the "Social-Cultural-Environmental System [that] fosters systemic, comprehensive, and perceptive thinking about science and technology in society" (p. 50). The Practitioner Dimension takes into account the factors that personally motivate the development of technologies such as the economic profit that corporations, scientists, and engineers acquire (McGinn, 1991). The Technical Dimension refers to innovations that improve a pre-existing technical system, from pre-adopted technical goals, and/or that are predicted to satisfy needs or requirements such as important increases in product, output, handling capacity, or qualitative performance (McGinn, 1991). The Political-Economic Dimension concentrates on the local, provincial, national, and international constellation of political and economic influences that affected the development of the technology in question (McGinn, 1991). These Foreground Dimensions will be combined with Background Dimensions to provide a complex and rich perceptual matrix for the analysis of STSE.

McGinn's background analysis. The practitioner, technical, and political/economic aspects of science and technology comprise the Foreground Dimensions but McGinn also outlines Background Dimensions that are equally important for understanding their influences. The first is the Cultural Dimension that calls "into question … the deeply rooted cultural assumption that technological progress is always socially benign" (McGinn, 1991, p. 56). McGinn (1991) defines the Cultural Dimension as the "total way of life as it is inherited from

preceding generations" (p. 56). The Cultural Dimension presents as a backdrop for contemporary industrialized societies, and transfers that cultural heritage, usually in altered form, to the next generation. Consideration of the Environmental Dimension is important when attempting to understand the causes and consequences of the influences of science and technology because the "character of its natural environment often affects the inventory of technics a society evolves to enable its members to cope with that environment (e.g., snowshoes or air conditioners)" (McGinn, 1991, p. 57). The Ideational Subsystem of the Environmental Dimension consists of characteristic cognitive phenomena, such as:

> core ideas, world views, recognized bodies of knowledge, core beliefs, central values, and behavioural norms [for example] the ideas of success and democracy, the body of currently accepted scientific knowledge, the values of freedom and justice, [and] prevailing attitudes toward work and nature" (McGinn, 1991, p. 58).

McGinn (1991) states that the Societal Subsystem of the Environmental Dimension includes institutions, communities (geographical and cultural), political parties, movements, roles, organizations, classes, and rituals. The Material Subsystem consists of technics, technologies, ways of making things, and human-made environments (McGinn, 1991). The Personality and Behavioural Subsystem of the Environmental Dimension is where modern science and technology have altered behaviour patterns (McGinn, 1991). These Foreground and Background Dimensions (see Figure 1) comprised the Social-Cultural-Environmental System (McGinn, 1991) that students utilized to reflect on the complex influences of science and technology.

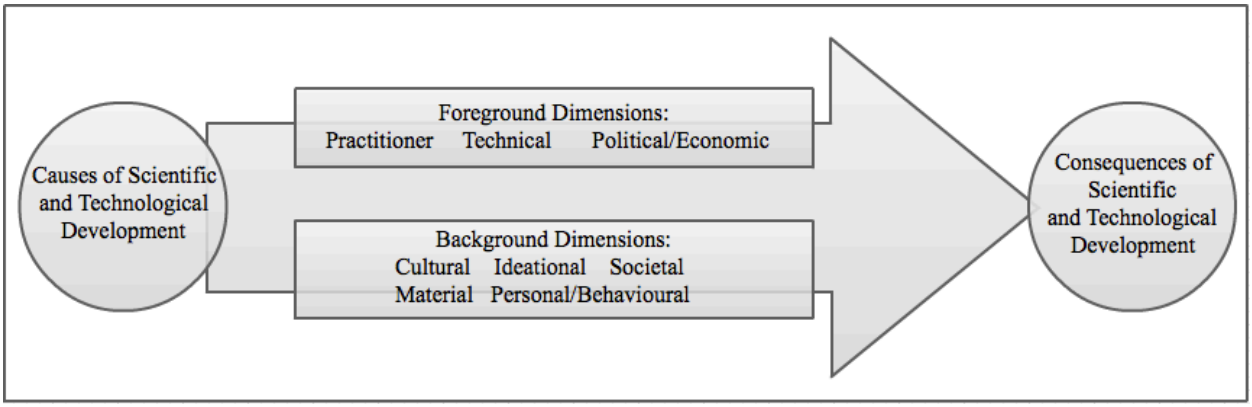

Figure 1. Graphic Organizer of McGinn's (1991) Foreground and Background Dimensions

Conclusion

Postmodern and imaginative constructivism, expressed through Egan's (1997) Ironic Understanding, should allow students to create an awareness of the pervasive and complex understandings of STSE and provide an opportunity to critically reflect on the influences of science and technology in their lives. The educational design of this research employs "Foucault's notion of critique [which] also parallels Heidegger in that he aims to 'denaturalize' the phenomenal world, and turn it into a matter for reflection" (Olssen et al., 2004, p. 42). Egan (1997) states that the imaginative development of Ironic Understanding can only be achieved if "students perceive themselves to be parts of natural, social, [and] historical [processes where] their understanding of themselves and their roles in the world depends on their knowledge of how these processes work" (p. 125). Postmodern and imaginative constructivism could provide students with an opportunity to view themselves as part of the environment, one that has a historical, cultural, and social nature. McGinn's (1991) Foreground and Background Dimensional analysis provided a framework for the social, cultural, and personal interaction of science and technology in society. Egan's (1997) Ironic Understanding provided the framework to synchronously analyze and express the benefits and disadvantages of the influences of STSE in the lives of students. The methodology chapter and methods section will specifically outline

how these design elements and frameworks will be integrated into a constructivist activity involving the student development and production of a photographic artifact that visually and linguistically expresses a postmodern awareness of how STSE influences their lives.

Chapter 3: Methodology

It is essential in contemporary, democratic, and industrialized societies to take the time to explore the nature of the scientific and technological understandings that are created through 12 years of science education. Students graduating from secondary schools will comprise the majority of citizens who will have an influence on the future direction of society. These students will not only directly contribute to scientific and technological endeavours (following college or university post secondary education) and utilization (as citizens directly connected to consumption and economic production) but more importantly, they will have the responsibility as citizens to democratically influence political, social, and economic policies. For these reasons, it is critical that research time and energy be utilized to understand the nature of the scientific and technological understanding created through educational discourse.

Qualitative research is important when analysis of complex, multifaceted, and contextual phenomena is necessary. The essence of students' understanding is difficult to quantify with surveys and statistical analysis. The methodology utilized in this study was not about quantification, or compartmentalization; it was based on the pedagogical ideology of personalized and individualized learning that attempted to appreciate the complexity, beauty, and holistic sophistication of our existence. This research can be described in three interconnected parts. First, a qualitative study can be defined in terms of how an investigation will be practically performed (Merriam, 1998, p. 34). In this case, secondary science students were asked to create a unique autobiographical digital photograph that expressed how they have experienced science and technology according to McGinn (1991) and Egan's (1997) frameworks. Participants then wrote a short explanation as to why they organized their image and how it described what science and technology means to them personally. Second, the unit of

analysis was the collection of photographic artifacts and what they expressed in terms of what science and technology means to each participant (Merriam, 1998). Third, the End Product was an "intensive, holistic description and analysis of a single [phenomenon]" (Merriam, 1998, p. 34). This qualitative process created the phenomenological expression of the meaning of science and technology relative to this research.

Phenomenology

Phenomenology was selected as the appropriate methodology because this approach allowed for an "in-depth inquiry of participants sharing a common experience … to examine the interrelated dimensions of the human experience and to address [a] universal research question" (Bambara, Harbour, Davies, & Athey, 2009, p. 222). Phenomenology is methodologically unique relative to other forms of research inquiry in that:

> there is no single method, just as there is no uncontested truth. Rather, the reason for reflecting on method is to discover the historical approaches and suppositions that may hold promise in rendering human experience interpretable and understandable in our present time and place (van Manen, 1997, p. 346).

This phenomenological activity provided an opportunity to explore the educational experience of students as they wrestled with questions such as: What does science mean to them? How does science and technology affect them? What opportunities and dangers are inherent to scientific and technological applications? What influences affect the utilization of science and technology in society? The phenomenological focus of this research was purposeful because I was specifically interested in "insight, discovery, and interpretation rather than hypothesis testing … by concentrating on a single phenomenon or entity, [I aimed] to uncover the interaction of significant factors [that are] characteristic of [STSE] understanding" (adapted from Merriam,

1998, p. 28-9). A complex and contextual analysis of what science and technology means to students can provide valuable information regarding the influence of their science education and the nature of their understandings.

The goal of this research was not to develop universal theories from the student artifacts but to create a learning strategy where students were empowered to critically reflect on their education and what science and technology has come to mean through the lens of their own experiences. It could provide an avenue for students to gain a greater understanding of how science and technology influences their lives, and creates the cognitive potential for students to evaluate the positive and negative effects of science and technology in society and on the environment. This research had the potential to provide insights about science and technology that "enrich our perceptiveness and … contribute to our reflective understandings of the possible meaning and significance of everyday experiences" (van Manen, 1997, p. 350). Conrad (2004) demonstrated how "a critical consciousness allow[s] people to question the nature of their historical and social situation - to read their world - with the goal of acting as subjects in the creation of a democratic society" (p. 5). Education could benefit from "practical phenomenologies ... that open up possibilities for creating formative relations between being and acting, self and other, interiorities and exteriorities, between who we are and how we act" (van Manen, 2007, p. 11). The phenomenological descriptions of science and technology could help develop and promote a more socially just form of science education discourse; one that effectively emphasizes the social benefit of scientific and technological applications by embedding more critical and personal constructions of knowledge into the educational process.

Justification

van Manen (1997) explored the subtlety and complexity of expression within phenomenological inquiry when he wrote about "mantic meaning [which] refers to that imagery of language that can bring about, in the reader, a phenomenological reverberation …[or] resonance that the word can effect" (p. 345). Scientific language may have its uses in experimental descriptions and explanations but educational realities are more dynamic, holistic, interconnected, and multifaceted. Phenomenology encourages understandings that are "distinctly existential, emotive, embodied, situational, and nontheoretic" (van Manen, 1997, p. 346). It is a methodology that combines the science and art of research inquiry, which "thrives on a certain irrevocable tension between what is unique and what is shared, between particular and transcendent meaning, and between the reflective and the prereflective spheres of the lifeworld" (van Manen, 1997, p. 346). van Manen's (1997) explanation of mantic expression goes beyond the technical, semantic, or linguistic understanding of text by trying to "capture *how* the text speaks, how the text divines and inspirits our understanding" (p. 346). It is in this context that language and, by extension, artistic creations such as photographs really begin to resonate with significance that extends beyond literal descriptions.

Reductionist thinking, statistical and quantitative analysis lack the expressive ability to accurately describe lived and meaningful experiences. Artistic expression is essential because:

> often an appeal to poetry and literature is almost unavoidable in that poetic language with its use of symbolism is able to refer beyond the realm of what can be said 'clearly and distinctly'. In other words … in human reality there are certain phenomena which reach so deeply into a [person]'s life and the world in which he lives that poetic language is the only adequate way through which to point to and to make present a meaning which we

> are unable to express clearly in any other way (Kocklemans as cited in van Manen, 1997, p. 348).

Due to the phenomenological nature of this research, it was necessary to provide a framework for interpreting the imaginative photographic artifacts created by the participants. The phenomenological inquiry here is: "in what sense do the inclusion of pieces of literature, poetry, anecdotal portrayals, and images play a part in seeing of meaning and in the power of the text to show, present, and clarify meaning?" (van Manen, 1997, p. 349). What do the imaginative photographic artifacts indicate about the meaning of science and technology to students who are completing their final year of science education before they become autonomous citizens of the world? These are the phenomenological expressions that potentially hold insights into whether the products of a particular pedagogical discourse align with the cognitive expression of the students.

The phenomenological perspective necessary for a broad understanding of how science education creates understandings involves an analytical distancing from socially and culturally entrenched discourses of scientism and positivism. This research was interested in philosophies that require a suspension of presuppositions, or in the words of Husserl, an "epoche" (Creswell, 2007). There was an intentionality of consciousness where the "reality of an object, is inextricably related to one's consciousness of it" (Creswell, 2007, p. 59), and where perceptions of nature involve imaginative constructions of understanding. The analysis was an expression of reality that was perceived within the meaning of the scientific and technological experience of the participants (Creswell, 2007). The interpretation of meaning, by the students, allowed for a holistic comprehension of STSE influences.

The 'tone' of the photographic artifacts is also an important aspect of this research. van Manen (1997) describes how:

> in phenomenologically composed texts, the human being recognizes, creates, and imagines forms of being, significations of humanness. This means that phenomenology does not only explain what something is; it also explores what this phenomenon can mean by offering possible interpretations (p. 360).

It is the participants and researcher's interpretation of what each photographic artifact represents which becomes the important benchmark of understanding. Hermeneutic or interpretive explanations are essential to the researcher's analysis but also for participants, who then get a chance to view, critique, celebrate, and reflect on other submissions. The 'tone' of the photographs provides multiple discussions around the personal interpretations and meanings of each student's image of scientific and technological influences. A student's photographic artifact may have a 'tone' that is "formal, informal, intimate, solemn, sombre, playful, serious, ironic, condescending, or any of many possible attitudes" (van Manen, 1997, p. 364). van Manen's (1997) mantic expressions create possibilities to represent multiple "tonalities: inner and outer [significance], primary and secondary meanings" (p. 363). The end goal of creating a photographic artifact that utilizes van Manen's mantic expressions is to provide educational time and space to create an awareness of the sophisticated and dynamic influences of science and technology in the lives of the participants.

The accumulation and public sharing of all the participants' photographic artifacts in the classroom also provided opportunities for further dialogue and intellectual growth after the initial photo design and construction. van Manen (1984) demonstrates how the "essence of the nature of an experience has been adequately described … when the description reawakens or shows us

the lived meaning of significance of the experience in a fuller or deeper manner" (p. 38). As students attempt to understand and interpret other participant's photographic artifacts, peer interaction and communication provided opportunities for further analysis. The class mosaic of STSE photographs and captions potentially allow students to explore larger social patterns and themes that can be discerned from the collective artifacts.

This activity was designed to create photographic artifacts that have the potential to evoke a strong emotional response, or epiphany, that will help to create an awareness of the complex influences of science and technology. van Manen (1997) describes 'epiphany' as a means to:

> bring about a transformative effect so that its deeper meaning makes an edifying appeal to the self of the [viewer]. Epiphany refers to the sudden perception or intuitive grasp of the life meaning of something. This experience is so strong or striking that it may stir us at the core of our being (p.364).

An epiphany is the moment that a student realizes there is more to their education than the acquisition of knowledge and invests themselves in the creation of a more personal awareness of STSE. Students were encouraged to make this journey, and potentially the process may provide the support and scaffolding necessary for them to become more engaged and reflective learners.

Participants were asked to create a photographic artifact, composed of a digital image and caption, which expressed an awareness of the influences of science and technology so that phenomenological reflection was possible (van Manen, 1997). The researcher looked for examples of how each artifact "brings to immediate presence, images and sensibilities that are so crisp and real that they in turn evoke reflective responses such as wondering, questioning, or understanding" (van Manen, 1997, p. 354). When all the artifacts were aggregated together, it

became a centrepiece where students could compare, reflect, discuss, and debate the direct and indirect messages of each student's photographic artifact. The journey of image construction and analysis represents an opportunity to evoke "particular images that call forth and bring into presence relevant aspects of the experience in which we are interested so that we can reflect on the meanings that inhere in them" (van Manen, 1997, p. 355). This open dialogue combined with the emotional, intellectual, and reflective growth of students was designed to surround their educational experiences with evocative moments that increase the sophistication of their awareness of the influences of scientific and technological understandings. The vividness of their photographic images lead to personal reflections about the meaning of how science and technology influences their lives on many different levels.

At the core of this phenomenological research was the opportunity for participants to deeply reflect on and express the unique and personal nature of their scientific and technological understandings in relation to social and environmental issues. This research is not about the acquisition of knowledge but the internal reflection of how scientific and technological understandings affect their lives. Participants were asked to create an image where the phenomena "is placed concretely in the lifeworld so that the [viewer] may experientially recognize it" (van Manen, 1997, p. 351). The goal for participants was to "find continuity between [their] concrete [images] and the particulars of [their] own lives" (van Manen, 1997, p. 353). This phenomenological activity concentrated on the expression of something that each participant found meaningful in his or her life. Throughout the design and implementation of phenomenological research it is important to include structural elements that can help to establish the trustworthiness of the data assessment, analysis and discussion chapters.

Trustworthiness

In order to build confidence in the analysis and discussion chapters of this phenomenological research, Lincoln and Guba's (1985) criteria for trustworthiness were operationalized. Multiple techniques were utilized in order to establish trustworthiness criteria such as credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). Specifically, the researcher applied Lincoln and Guba's (1985) credibility technique of Persistent Observation in order to "identify those characteristics and elements in the situation that are most relevant to the problem or issue being pursued and focusing on them in detail" (Lincoln & Guba, 1985, p. 304). The researcher "continuously engage[d] in tentative labeling of what [were] taken as salient factors and then explore them in detail … [until] the factors [were] understood in a nonsuperficial way" (Lincoln & Guba, 1985, p. 304). Triangulation, or the accumulation of "'multiple sources' [that] imply *multiple copies* of one *type* of source (such as interview respondents)", was also utilized to increase the credibility of the findings and interpretations (Lincoln & Guba, 1985, p. 305). Photographic images, written captions, and group interview material were triangulated in order to increase the "contextual validation … of a piece of evidence … by comparing it with other kinds of evidence at the same point" (Lincoln & Guba, 1985, p. 307). Referential adequacy was also maintained by digitally storing all photographic artifacts and interview video recordings (Lincoln & Guba, 1985). Transferability, confirmability, and dependability were also methodological design elements.

Lincoln and Guba (1985) define transferability as the "thick description necessary to enable someone interested in making a transfer to reach a conclusion about whether transfer can be contemplated as a possibility" (Lincoln & Guba, 1985, p. 316). This research was specifically designed in order to "provide [a] thick description [that] is grounded, is holistic and lifelike,

simplifies data to be considered by the reader, illuminates meanings, and can communicate tacit knowledge" (Merriam, 1998, p. 39). The dependability of this research was built through "inquiry audits" where a thesis advisor and committee member repeatedly examined the "process [and] product" of this research (Lincoln & Guba, 1985). Lincoln and Guba (1985) state that "in providing such an attestation the auditor certifies that both the process of accounting and the product – the account ledgers – fall within acceptable professional, legal, and ethical limits" (p. 318). Confirmability was built by creating an "audit trail" that included: raw data, data reduction and analysis products, data reconstruction and synthesis products, and materials relating to intentions and dispositions (Lincoln & Guba, 1985, p. 320). According to Lincoln and Guba (1985) "naturalistic inquiry operates in an *open* system; [and] no amount of member checking, triangulation, persistent observation, auditing, or whatever can ever compel; it can at best persuade" (p. 329). The preceding credibility, transferability, dependability, and confirmability techniques (Lincoln & Guba, 1985) were methodologically embedded in order to build and establish the trustworthiness of this research. Bracketing was another phenomenological strategy within this research that contributed to the analytic strategies utilized for data analysis.

Patton's (2002) procedures for bracketing were utilized in order to ensure critical and thorough interpretations of the participants' imaginative photographic artifacts. Bracketing involves the following steps:

> 1. Locate within the personal experience, or self-story, key phrases [images] and statements that speak directly to the phenomenon in question. 2. Interpret the meanings of these phrases, as an informed reader. 3. Obtain the subject's interpretations of these phrases, if possible. 4. Inspect these meanings for what they reveal about the essential, recurring features of the phenomenon being studied. 5. Offer a tentative statement, or

> definition, of the phenomenon in terms of the essential recurring features identified. (Denzin, 1989, p. 55-56)

This bracketing procedure allowed the researcher to organize the data into meaningful clusters that identified the invariant themes (Patton, 2002). The synthesis of these themes "points the way for new perspectives and meanings, a new vision of the experience. The fundamental richness of the experiencing participants is captured and communicated in a personal and creative way" (Patton, 2002, p. 487). The goal of this analysis was to provide an "ethical corrective [to] the technological and calculative modalities of contemporary life" (van Manen, 2007, p. 11). Within the context of my research, the hermeneutical interpretation of what science and technology means to students will provide evidence for the development of an awareness of postmodern understandings of environmental and social justice issues.

Methodological Limitations

There were a number of limitations to the methodological organization of this research. The research participants were secondary science students who, characteristically of this age group, were still developing emotionally and cognitively. According to Lincoln and Guba (1985) situated motives or "wanting to please the investigator, saying normatively appropriate things, or simply not being motivated to address the investigator's concern fully" (p. 302) may be problematic for teenage participants. The sophisticated and philosophical nature of this research may also result in the misconstruction of the researcher's instructions and interview questions due to a lack of vocabulary and/or philosophical familiarity (Lincoln & Guba, 1985). Bias on the part of the researcher could also constitute a methodological limitation.

Bias and subjectivity of the researcher can be a challenge from a methodological perspective. The impetus for this research stemmed from my experience over 35 years as a

science student and high school science teacher. Recognizing the importance of social justice and environmental sustainability within science education was a priority in my educational and professional experience. Awareness of this predisposition to affect positive social and environmental change without compromising my role as an unbiased researcher was a significant source of reflection and calibration throughout the research process. Through internal reflection and discussions with my thesis advisor, I attempted to expose, manage, and mitigate my personal biases by making efforts to separate my experiences from those of my research participants. Inclusion of Patton's (2002) bracketing strategy was purposeful in order to optimize critical interpretations of the participants' photographic artifacts. The postmodern nature of this research potentially helped to mitigate researcher bias because the goal was to stimulate open dialogue, and the personal and unique expression of how science and technology influenced participants, not to establish a priori objective and universal metanarratives.

Methodological limitations could also arise from attempting to elicit postmodern, imaginative, and artistic expressions of a traditionally modernist science discipline. From an ideological standpoint, research of this nature might be limited because science (as a modernist expression) and postmodernism may be philosophically antithetical and therefore may not be amenable for STSE analysis. There may also be philosophical obstacles to the implementation of a postmodern educational design within a society that has a significant modernist history. Participants, enculturated in a modernist discourse, may struggle to recognize and move beyond that discourse to develop an awareness of postmodern perspectives. Students and/or educators may struggle to recognize the potential benefits or disagree with the utilization of a phenomenological approach within science education.

Conclusion

Phenomenological research has the ability to "produce personal behavioural changes as well as deep social/collective transformations and political movements" (Fals Borda, 2001, p. 30). The self-reflection and analysis necessary to participate in phenomenological research creates opportunities for the relevant construction of learning. Imaginative and postmodern reflective activities may provide opportunities for education to change from its modernist origins into a system that promotes a:

> rising universal brotherhood of critical intellectuals - women and men - to construct open pluralist societies in which oppressive central powers, the economy of exploitation, monopolies and the unjust distribution of militarism and armamentism, the reign of terror, abuse of the natural environment, racism, and other plagues will be proscribed (Fals Borda, 2001, p. 34).

The end goal of this phenomenological research is to provide a description of science and technology that can elucidate insights "through raised awareness and collaborative action, [and] popular education practices [that] explore the learners' lived experiences in both their humanizing and oppressive dimension" (Conrad, 2004, p. 5). The benefits and risks of science and technology must be evaluated within the complex cultural discourses that propagate society. Gadamer (1998) states: "a culture based on science cannot survive unless rationalizing the apparatus of civilization is not an end in itself, but makes possible a life to which one can say 'yes'" (p. 35-36). This phenomenological methodology was chosen in order to provide students with an opportunity to create an awareness of postmodern understandings of how science and technology influences their lives.

Methods

Initially, and in collaboration with an academic thesis advisor and committee member, the abstract, introduction, literature review, and methodology chapters were developed and submitted for ethics approval. This research involved human subjects; therefore close attention was given to ensure that potential ethical consequences were considered closely. Ethics boards at Lakehead University and the school division approved the research design and implementation. Approved information letters and consent forms were read and signed by the principal, teacher, parents, and participants.

This research occurred at a high school in Alberta, Canada. The school housed approximately 1000 students in Grades 9 through 12. Twenty-one Grade 12 chemistry students from two separate classes volunteered to participate in this research. Throughout the duration of the research, students were supported with an informative and interactive Moodle site that outlined all the parameters of the research, online peer communication forums, links, and researcher contact information. The assignment lasted for approximately 10 days; beginning with a presentation by the researcher, a brief overview of the research topics, assignment expectations and criteria: STSE, photographic expression, Egan's (1997) Ironic Understanding, and McGinn's (1991) Foreground and Background Dimensions. After the presentation, the participants engaged in a collective discussion where research topics were considered and questions were asked regarding how they would approach their photographic STSE assignment. Every effort was made on the part of the researcher to explain the parameters of the assignment without guiding the participants to a specific answer or conclusion.

Participants were asked to create an autobiographical photographic artifact that expressed how science and technology influenced their lives. Participants were instructed to include the

following components in their photograph: 1) themselves; 2) science and technology; 3) visual expression of how science and technology has influenced their lives utilizing McGinn's (1991) Foreground and Background dimensions; 4) visual expression of Egan's (1997) Ironic Understanding connecting science and technology to social and environmental issues; and 5) caption briefly explaining the influence and meaning of science and technology in his or her life. Although the caption could be up to 2 or 3 sentences, the participants were instructed to compose their pictures so that they visually described the STSE influences. Once completed, the STSE artifacts were posted in the classroom for general reflection.

When all the photographic artifacts were completed, a recorded discussion occurred where students engaged in an interactive semi-structured, focus group interview and discussion regarding the different perspectives, themes, insights, and social commentary relative to the purpose of this research. The semi-structured interview questions are listed in Appendix A. The recorded interviews were designed to add depth and breadth to the data obtained from the STSE photographs. The completion of the assignment adhered to the following timeline: Day 1 - Moodle registration and explanation, introduction, and class discussion. Day 2 – researcher answered questions, and provided clarification for any students struggling to interpret the assignment criteria. Explanations of Egan (1997) and McGinn's (1991) constructs were provided but every effort was made to avoid guiding participants toward a specific conclusion, outcome, or specific photographic artifact design. Each participant was instructed to create a photographic artifact that was personal and unique to his or her experience with science and technology. Day 5 – online (Moodle) or physical submission of the first draft of STSE photographic artifacts. Day 6 – researcher returned artifacts to participants so they could further explore their ideas and improve different technical aspects of their photographic artifacts. Day 9

– date for the submission of the students' final visual artifact. These photographic artifacts were digitally aggregated in Appendix B after they were manipulated to maintain participant anonymity (e.g., faces were covered or obscured). The license plates in Olivia's photographic artifact were also covered in order to maintain participant anonymity. Day 10 - the final class discussions. Twenty of twenty-one students participated in two separate semi-structured, focus group interviews that were recorded and later transcribed into digital word documents.

Two participants did not directly own the technological equipment to carry out the assignment, therefore the researcher loaned them digital cameras from the school's media arts department. Students were cautioned that the creation of their photographic artifacts should not include any elements that were illegal, inappropriate (no nudity), and/or placed the student in any danger or exposed them to potential harm. Participants were also informed that if they experienced discomfort with respect to the self-reflection of scientific and technological influences in their lives then they were to discontinue the assignment and seek support from their parent(s)/guardian(s), teacher, and/or school counsellor. No students communicated any psychological trauma from completing their STSE photographic assignment. All completed artifacts (21 in total) were included in the phenomenological research and analysis. One participant completed a photographic artifact but, due to an absence, did not contribute to the interview material.

A rubric (see Figure 2) was utilized to provide self-assessment feedback with regard to the students' photographic artifacts. This rubric was designed to encourage depth and breadth of thought and self-analysis, and to facilitate artifact completion without influencing students toward a specific goal or product:

Assignment Criteria	Level 0	Level 1	Level 2	Level 3
Photo Quality – Clarity, Focus, etc.	Photo was generally of poor quality with significant clarity and focus issues	Photo was of reasonable quality with limited clarity and focus issues	Photo was of good quality with most aspects of clarity and focus being well addressed	Photo was of excellent quality with all aspects of clarity and focus being well addressed
Required Photograph Components	Photo did not include any of the required components	Photo included a limited number of the required components	Photo included most of the required components	Photo included all of the required components
Photographic Expression and Tone	Photographic artifact was of very poor quality with significant explanation needed for understanding	Photographic artifact was of limited quality with explanation needed for understanding	Photographic artifact was of good quality with most aspects of story clearly expressed	Photographic artifact was of excellent quality with all aspects of story clearly expressed
Influence of Science and Technology with McGinn's Foreground and Background Dimensions	Student does not express influence of science and technology with McGinn's Foreground and Background Dimensions	Student expresses a limited influence of science and technology with McGinn's Foreground and Background Dimensions	Student expresses influence of science and technology with McGinn's Foreground and Background Dimensions	Student expresses complex influence of science and technology with McGinn's Foreground and Background Dimensions
Ironic Understanding – connects Science and Technology with Social and Environmental Issues	Student does not express an Ironic Understanding of STSE	Student expresses a limited Ironic Understanding of STSE	Student expresses an Ironic Understanding of STSE	Student expresses sophisticated Ironic Understanding of STSE

Figure 2. Self-Assessment Rubric for Photographic Artifact Assignment

After all photographic artifacts were collected; the researcher transcribed the complete recordings for both semi-structured interviews. Throughout the transcription process, the researcher removed common language utterances (e.g., like, um, er, well, so, really, pauses, I guess) and repetitive statements; grammar has been corrected. These changes were made for clarity and accessibility of text but significant efforts were made to maintain the original meaning and intent. In the transcript, pseudonyms were utilized in order to maintain the confidentiality of the participants.

Photographs, captions, and interview material were closely analyzed for expressions and interpretations relating to McGinn's (1991) Foreground and Background Dimensions, and Egan's (1997) Ironic Understanding of STSE. Participant selections, gleaned from the photographic artifacts and interview transcripts, which were included in the analysis and discussion chapters of this research were selected through a specific process. Each photographic artifact and the entire transcript of the semi-structured interviews were extensively labelled and coded. Lincoln and Guba's (1985) techniques of persistent observation and triangulation, and Patton's (2002) procedures for bracketing were utilized in order to ensure only essential, relevant, recurring, and credible excerpts and references were included. Labels, codes, images, and quotes were then organized into themes and categories. The relevant material, organized into categories, then comprised the supporting evidence and specific headings for the analysis and discussion chapters. The following chapter will describe the results of the aggregated research data and participants' expressions and reflections of McGinn's Dimensions, modernist influences, imaginative and postmodern design elements, and Ironic Understanding of STSE.

Chapter 4: Analysis

The general atmosphere for this research was positive. Staff and students were open to the idea of participating in academic research. Twenty-one participants volunteered and consent forms were returned in a timely manner. During the introductory presentation, participants were initially reticent but most began to actively design and develop the concept behind their STSE photographic artifacts once they understood the activity parameters. Students expressed that they did not have any significant technological or logistical difficulties composing, capturing, posting, printing, and/or creating the caption on their photographic artifact.

Participant Reflections on McGinn's Foreground and Background Dimensions

One of the primary organizational characteristics of this research was to provide an STSE framework that would enable students to analyze the holistic, interconnected, multifaceted, and sophisticated scientific and technological influences in their lives. McGinn's (1991) Foreground and Background Dimensions provided a detailed socio-cultural analytical framework for participants to identify the numerous and pervasive influences of science and technology in their lives. Students identified technics that ranged from televisions, desktop computers, laptops, iPads, iPhones, calculators, Internet search engines, online information and communication websites, newspapers, LED lights, DVDs, combustion cars and trucks, hybrid cars, farming equipment, cooking appliances, sewing machines, consumer technologies, medical treatments, pharmaceutical drugs, as well as dance, music, and sports equipment. Students provided 45 descriptions of the different technics in their lives and then connected each of them with McGinn's (1991) Foreground and/or Background Dimensions.

Participants provided reflections for the majority of McGinn's (1991) Foreground and Background Dimensions. The Dimension that provided the largest number of responses was the

Personality-Behavioural Dimension where participants articulated numerous influences that have affected their behaviours. The Dimension that provided the least number of responses was the Practitioner Dimension that relates to factors that personally motivate the development of technologies, although Elizabeth extrapolated the Practitioner Dimension to the evolution of social perspectives toward science and technology when she stated that "the thing to think about when we talk about changing society is that it will be hard to get people to [change] without there being some sort of personal motive and insight for them to do it…some sort of incentive". A significant theme that emerged from the participants' photographic artifacts and interview material was recognition of the modernist influences in their lives.

Participant Reflections on Modernist Influences

A number of students made associations with modernist influences of science and technology such as environmental pollution, industrialization and the mass production of consumer goods, consumerism and economic competition, technological dependency, compartmentalised and reductionist learning, and academic engagement. One participant expressed the following sentiment:

> I don't really understand what we're leaning towards in our awareness of … or what we're trying to fix. I think that at this point everyone thinks about things in a certain way and I think that is just the way it is. Even if we fight it out and debate which is the better life, I think that people have known this for so long and have come to just rely on it. Even with the way things are marketed and sold to people and the way things are taught to people from a young age. I mean my little siblings have grown up with an iPad, so right? I think that it's just how it's going to be from now on. (Charlotte)

The negative influences of science and technology also expanded to the personal and familial experience of one participant in particular who expressed frustration that "[technology has] changed … how you interact with … people in your home. My family just watches movies all the time … People don't really go out and play a game of football with their family anymore. They sit and watch a game of football" (Amelia). Participants were keenly aware of the cultural inertia that often precludes positive scientific and technological change. Ben was concerned that "it takes generations … before social norms actually get changed. It isn't something that happens quickly. It happens over a long period of time". Participants also identified a number of specific themes that related to the negative influences of science and technology that could be attributed to modernist metanarratives, including industrialization, consumerism, technological dependency, and learning engagement.

Industrialization and consumerism. Aspects of this expressive photographic activity facilitated participants' expression of an awareness of the industrialization of society. Amanda revealed that participating in this research:

> made [her] realize how much industry is related to … all science and technology and how all these different [technologies] that benefit us have been so over industrialized. That's a huge issue [with] science and technology because it is with everything and it's causing a lot of problems.

Participants also made connections to industrialization with technics that require relatively less technological development than the more advanced technics such as computers, vehicles, appliances, and so on. Chloe, who constructed her photographic image and caption around the topic of ballet and the cultural influence of dance, connected the industrialization of consumer products with the environmental consequences of industrialization because she believed that

"everything went from being handmade to being made by machines. I have no doubt in my mind that uses up a lot of energy and uses fossil fuels too." Participants also identified and explored many of the negative aspects of the economic consumerism.

The modernist influences of consumerism were apparent in many of the participants' photographic artifacts. Many of their images and captions involved consumer technics such as computers, vehicles, televisions, sports and music equipment, as well as technics that mediate economic transactions such as point of sale cash registers and cultural traditions such as Christmas. Liam commented that the development of his photographic artifact helped him to analyze:

> the environmental impact because with new technology and especially equipment you have … new brands coming out every year. That produces a lot of waste because if you get a new pair of basketball shoes every year you are throwing out your old pair or a new bat or anything. It has a lot to do with consumerism because you [have] to constantly buy more and more product and produce more product [and] that harms the environment.

Another prevalent theme, expressed through the photographic artifacts and interview transcripts, was the dependency that participants felt relative to the utilization of science and technology in their lives.

Technological dependency. A number of participants articulated an overwhelming concern with the dependency that they perceived was developing due to scientific and technological applications in society. All participants agreed with an interaction between Jessica and the researcher when they stated, "Jessica - [this assignment] shows how dependent you are on technology. Without it we wouldn't be able to do anything. Robertson – Is that something you think is important [for students of] this age group to understand? All – Yes." Henry

expressed his concern, through his photographic artifact and interview responses, that science and technology are "slowly replacing human interaction … Robertson - Do you see that as a good or bad thing? Henry – Bad … oh, bad thing. Horrible thing." Ben ironically pointed out an essential metanarrative of recreational technologies when he stated, "but it's fun so you can't complain too much?" and participant Henry agreed "Yeah." The participants exhibited significant awareness of not only the negative influences of science and technology in society but also within their educational environment.

A number of participants reflected that this assignment provided an opportunity to consider technology's influence on how knowledge and information is researched and processed. Jessica specifically expressed a penchant for technology mediated assignment completion because she believed that "nobody uses their textbooks to research anymore. It's all on laptops or through their phones. Robertson – What would you say is the most common research [technology] that you use? All Participants – Google. Jessica - You can Google anything basically." Many participants centred their photographic artifacts on computer and Internet technologies. There were also a number of STSE images, captions, and interview responses that demonstrated the effects that science and technology have on the engagement of student learning.

Learning engagement. Educational engagement was a significant theme throughout the photographic artifacts and interview material. Liam was expressive when the subject of the personal nature of this research was broached:

> I think a lot of it is the mindset. When you are trying to learn something in a class that you are not particularly interested in or you don't have the motivation or it's not something you enjoy. You don't tend to pay attention or excel as well as something that

> you enjoy or you can expand on. You're motivated, you want to learn and it's just that mindset, it changes the whole project.

Olivia commented on the increased engagement that results when learning becomes holistic, authentic, and emotionally connected to humanistic, personalized, and experiential learning opportunities:

> I just think that if it is this personal you tend to put more effort into it because you are actually interested in what you are doing. Most of us are not really interested in a project where you have to graph how many apples Tom bought in one day.… Robertson – You found it more engaging, more interesting because it involves your own perspective? Olivia – Yeah.

Although the participants had a number of concerns with some of the negatively perceived influences of science and technology in society, the vast majority of photographic artifacts and interview responses positively correlated with the postmodern, imaginative, and constructivist elements of this STSE research assignment.

Participant Reflections on Imaginative Design Elements

Although, historically, scientific educational assignments often have reductionist design elements, participants gave positive feedback on the creative, imaginative, and self-reflective nature of this activity. Jessica believed that this activity "gave you more room to be creative … you didn't have to say this is what the teacher wants you to do, [or] this is what you have to do. You were given your own freedom and room to think about it." The theme of academic freedom was prevalent in the research data. Amanda "like[d] how there is more freedom in [this assignment] and it seemed more unlimited with what you could do where normally it is set in stone what you are supposed to do" and another participant felt she wasn't "restricted with what

you could do ... that [there] were so many different possibilities you could choose from…. The difference was that you could do anything" (Jessica). Participants connected with the personal and flexible design elements. Claire felt that she "liked how you could pick anything" and how this science and technology assignment "was really quite open-ended. It was less [about] this is how you do it. It [was] more [similar to] a language course, like English." This type of creative, divergent, and imaginative thinking produced a variety of unique photographs with a diverse expression of STSE perspectives.

During the group interviews the photographic artifacts were posted on the wall so participants could experience the variety and diversity of the photographic artifacts. Participants appreciated the uniqueness of the multiple perspectives expressed in the collection of STSE digital artifacts. Heather thought it was "cool to see how technology affects each individual differently" and Sophia expressed the following sentiment:

> With the photo[graphic artifact], it is something that everyone does differently. Everyone here had a different answer to the question and that's really cool because … you can't just Google the answer. You have to go out and come up with your ideas and you have to think about what other people are going to think when they see it and not just what you see and I thought that was really cool. It was interesting to see other people's perspectives on the same question.

The creative thinking and multiple perspectives exhibited in the participant's photographic artifacts and interview material also expressed a multicultural theme.

Global citizenship. Participants demonstrated a desire to utilize science and technology to explore and learn about different cultures around the world. Specifically, Claire's photographic artifact explicitly outlined the communication potential with news media that are

both paper based and digitally mediated. She felt that "the way we can learn about different cultures by clicking a mouse … is really interesting. Everything is accessible" and "I really want to go to places, go explore, go outside of North America and see places. I think that being able to connect with different cultures … I get a better sense of what I [could expect] if I was to go there" (Claire). When asked to make constructive observations on other participant's photographic artifacts, Jason gave the following reflection of Claire's digital photograph:

> The laptop and the newspaper [image is great] because it shows how much [the technologies have] developed and changed. Newspaper [was] a really vital way that information was spread back in history but now it is pretty remarkable that with the click of a button you can go through and find out new information on anything that is happening globally.

This type of peer reflection can be valuable to building the capacity of students as they become aware of multicultural and global concepts relative to the positive and negative influences of STSE.

Participant Reflections on Postmodern Design Elements

An important aspect of this research was to explore the participants' phenomenological expression of how the development and construction of photographic artifacts can help to create an awareness of postmodern understandings of science and technology. The aspect of postmodernism that was germane to this research was the participants' ability to express the influences of science and technology from a personal, individualized, social, cultural, contextual and/or subjective perspective. Due to the pervasive nature and sophisticated applications of technologies in our contemporary industrialized society and the educationally significant intellectual development that occurs in students at the high school level, it is important for

students to have opportunities to analyze the influences of STSE. A number of themes such as personal connections, affective connections, differentiated and relevant learning emerged from the participants' research data.

Personal connections. A main tenet of the postmodern philosophy, relevant to this research, is the personal subjectivity and expression of individual experience and perspective. Olivia thought that a positive aspect of this research was the opportunity to:

> make a personal connection because, for one, it's you. It's something that you chose. Out of everything, it is that one thing to express [and] to let other people know [about]. It's you in the picture. It's your thing, your very own. So, I think that presenting it that way lets them know that you care … if you take the time to put that effort into showing it.

This research also provided opportunities for all students, regardless of their personal experiences or interests, to connect with science and technology in a meaningful way. Chloe completed her photographic artifact because "with dance, I have done it since kindergarten. It has just been a part of my life for a long time," Liam expressed a personal connection to sports and how "sports run my life … if I am not in school, it's sports for me. So, because that takes up so much of my time then the technology side plays a really important aspect into how I play," and Ben's intense association with music was obvious when he revealed that "basically all I do is play guitar. I'll just go home and play guitar until my fingers are numb. That is basically most of my day if I'm not working or doing homework." Sophia wrote in her caption that her photographic artifact, which is visually composed of her watching television while at the same time connected to other individuals with similar interests through her computer, "expresses the connections between technologies, how in today's society you can love something and then go onto the Internet and find others all over the world, and connect with them through a story or

music." These personal connections to a variety of technologies help facilitate an awareness of scientific and technological understandings because "it's more personal … we have our pictures on [our photographic artifacts] so we had to put thought into [the image] and…how we want to portray it … for each technology. Robertson – Did that process help you to understand the STSE connection? Yeah" (Ben). Participant interview responses also confirmed a strong emotional and affective link to this learning opportunity.

Affective connections. Many of the participants indicated that this assignment successfully created affective connections to the influences of science and technology. Teri thought that the STSE photography assignment was very gratifying because it "was actually connected to something that I enjoyed. It was a lot easier to understand the concepts … the science behind it. Thinking about [science and technology] in a way I like instead" and she felt that it was "easier to connect to something that you are emotionally attached to because then you have previous knowledge of it already. You just have to expand a little more." Amanda gave the following account of her experience participating in this research:

> [When] I'm done my homework [I'm] like 'thank god' I'm done. I don't ever want to think about this again. All – Yeah. Amanda – With this you are wow! This is really interesting. You actually keep thinking about it and [want] to know more and think about it when you are doing whatever it is about. (Amanda).

This response gave important feedback on the affective associations that are necessary to potentially inspire lifelong learning. A number of participants referenced how 'passionate' they were about the scientific and technological subject of their photographic artifact including Claire who made the following statement during the interview process:

> You are way less passionate about a titration than you are about the things you do in your normal life. You get all this homework and you have to go home and do it even though you work until ten o'clock or you're doing something. It is nice to have this personal connection to what you are actually doing at school.

Another participant, whose photographic artifact explored the influence of digital story telling, expressed her affective attachment to the digital medium of television programming:

> I really did [my photographic artifact] on something that I am really passionate about. I love TV and the way that it is created, the stories that it shows, and how people and the world connect to these different stories. (Sophia)

As well as these participant reflections regarding the construction of personal and affective connections, there were also participant reflections that indicated that aspects of this research exhibited characteristics of a differentiated and relevant educational experience.

Differentiated and relevant learning. A number of STSE images and captions, as well as multiple interview responses concentrated on the benefit of technology within educational environments. Sara indicated that this activity is more representative of "real life and it is more relatable because normally we are just doing calculations or memorizing terms. [This assignment] actually lets you use that knowledge [and] apply it to real life and it makes it … easier to connect to science." Although, as discussed previously, a few of the participant responses indicated a concern with regard to dependency on online reference software such as Google, which is commonly utilized to complete homework assignments, Samantha, who completed her photographic artifact on technologies that facilitate her academic responsibilities, gave the following reflection on the utilization of educational technologies:

> I'd say that technology really helps me pass school … it really does, especially if you have a question for a friend that you are in a group with. You can stay connected anywhere and work through the project. You don't even need to hang out. You can do it over the phone, you can do it on the computer. You can email each other.… Robertson – Do you find that is a benefit to your education? Samantha – Yes, it's a benefit.

Another participant also understood the metacognitive benefit of technology mediated learning opportunities, like this STSE research, for different types of learners. Samantha expressed that not everyone "can learn by just reading, just being told, and taking notes off a board. Sometimes you need that visual picture to understand. I am a visual learner. I need to see a visual picture and that helps me [learn]." Claire expressed a connection between the STSE artifact assignment and understanding her life at school:

> I think that a picture is one of the biggest ways to portray a message these days. I read *National Geographic* [and] the pictures are very, very important [to] the whole magazine … the issues around the world impact life outside of school and that helps to understand the things inside of school.

Amanda indicated that the design of this research also had an educational benefit when she explained that taking "a picture just makes you have to do a real thing. Whatever it is, you actually have to think about it legitimately not just theoretically." Olivia, who composed her photo with a conventional combustion car and a hybrid car, talked about her interest to continue her studies in STSE after high school:

> For university, I want to go into the environmental sciences. That is what I am interested in … so having a hybrid car [is] obviously big. It's a big thing for me. I would be helping out … that's how I plan to do it.

The participants' research materials exhibited evidence of the benefits of technology mediated individualized learning and important personal connections to science and technology that helped contribute to a differentiated and relevant learning experience.

Participant Reflections on Ironic Understanding

Artistic constructivism. Participants expressed numerous reflections on the artistic, creative, and imaginative aspects of this assignment. A characteristic of Egan's (1997) Ironic Understanding is the utilization of artistic constructivism that is fundamental to the expression, interpretation, and development of an awareness of the complexities of our understandings. Elizabeth compared the interpretative components of the STSE photographic artifacts to that of other artistic creations:

> When you see a picture and a paragraph before it … the first thing you do is look at the picture rather than reading the words and you come up with your own impression of it. Then you read and see how they felt and how it went. When you go to an art museum and it is just pictures there [are] no words. It's your own interpretation.

An important aspect of the analysis of the STSE photography examples was not lost on the participants. Specifically, Chloe thought that presenting their ideas in the form of a picture was valuable because they "have to think about the reasons behind all these technologies instead of just accepting that they [are] a big part of your life. You have to try and to convey your point to other people through the picture." Moving beyond their dependency on technological mediated completion of schoolwork, Jessica understood that by designing and composing the picture:

> it made us think for a change because we couldn't just Google the answer to it. You have to interpret in your own way and take the time to think. What does this picture actually

> mean? What was it trying to tell me? So I looked at it from a different perspective for once.

Charlotte also recognized the value of the artistic aspects of this research because the image in each photographic artifact:

> lets people infer what they want. It doesn't tell people how to think. It lets them decide what they pull from the image. Robertson – Why is that important? Charlotte – Because it makes people think about things. It's not just written to them in black and white. It makes them make a little sense.

Ben created a photographic artifact that attempted to demonstrate the artistic expression of an Ironic Understanding. The participant's caption explained his perception of the juxtaposition between mass produced guitars and the personal expression of music. The photographic artifact articulated, though the utilization of light and shading, the loss of individuality that may result from mass-produced musical instruments (see Appendix B, Ben's Photographic Artifact). Charlotte visually conveyed the disconnect that can occur with technology by having her family all sit on the couch but instead of talking to each other they are all texting and Henry also expressed a similar theme in his photographic artifact by visually portraying a family member sitting immediately across from him but instead of talking they are communicating through their computers. The combination of artistic constructivism with its inherently expressive and interpretative elements with scientific and technological influences produced an environment where evidence of Ironic Understanding of STSE could emerge.

Awareness of STSE. There were a number of qualitative indicators that demonstrated evidence of different aspects of an emerging Ironic Understanding of STSE. A number of participants thought this was a very unique assignment and a novel approach that brought more

attention to the negative aspects of science and technology. Sara specifically expressed the following sentiment:

> I think what I found new was definitely the negative effects. What was most [important] for me was the [emphasis on the] negative effects of technology … definitely. Robertson – That came more to the forefront with an activity like this? Sara – Yeah, it was something I hadn't thought about before. I really realized after this project. Robertson – Do you think that your regular science education, over the last ten years, has been more [about] the positive or the negative [aspects of science]? Sara – I'd say more positive. A little bit of negative but more the positive. [Other participants on camera nodded in agreement]. Robertson – An assignment like this helps to bring out more of the Ironic [Understanding], the other end of the spectrum, and a balance? Sara – I do, yeah.

Tanya thought "it would be really hard to change [their behaviours] because [these] are all [technologies] that affect us daily and a lot of them are things we love to do [and] we have never seen the negative side of it. So I think change would be hard for a lot of us." Reflections, such as this example, were less frequently expressed in the interview transcripts than realizations that developing an awareness of the influences of science and technology is important when considering STSE topics.

Many Participants felt it was important to take the time to analyze the influences of science and technology in their lives. Sara, who created the photographic artifact expressing the influences of her sewing machine in her life, stated:

> I really liked how it forced me to look more [deeply] at how technology influences life because I know it helps us [perform] jobs but it [also allowed me] to see how it changes

> society too and how society works. I was able to connect it to something and see how it actually affects my life.

Henry commented that awareness is just the beginning and it is "the least we can do ... Robertson – Do you feel that this assignment or assignments like this [can help] to create that awareness? Yes (response was from an unknown participant who was off camera)." Generally, participants felt that an increased awareness gave them a greater appreciation for the benefits and disadvantages of STSE. Sara mentioned that it was "nice to see how [many tasks are] easier with science and technology. How much [technology] really helps us out. We kind of take advantage of it because we don't realize how much more difficult it would be without it" and Claire recognized that we "rely on [technology] so much that if it's gone we wouldn't be able to protect or sustain ourselves." This increased awareness also facilitated an appreciation for STSE, as demonstrated by one participant who "[realized] how science and technology is literally related to everything and everything" (Amanda).

The qualitative data exhibited evidence that the increased awareness of the influences of science and technology extended beyond their own photographic artifacts. Liam made the following comment with regard to Tanya's photographic artifact, which was based on her interest in cooking.

> I think it helps broaden your perspective. You don't really realize how much you use [technology] in your life. Even if you don't necessarily bake, you still have food that you consume which, some of it does have to be made in an oven. You see all the different aspects that people have personalized and [even though] you may not make a personal connection with them specifically … they still influence you.

Participants, through this research, uncovered new connections to STSE. Jason realized that "the photo did change the … learning experience of the project in general. We learned more about technology than we would have just writing stuff down." Another participant extrapolated that this assignment might help them to realize that, "science and technology [are] related to other things too and not just the specific [subject] I studied. I'll probably look at different [technologies] and realize all the different effects of that technology" (Sara). Extending from the multitude of influences was evidence that this assignment generated an awareness of STSE. Another theme that emerged from the data was an awareness of modernist influences in the lives of the participants.

Awareness of modernist influences. A postmodern awareness of science and technology incorporates the capacity to recognize modernist metanarratives. Henry, whose photographic artifact explored the potentially dehumanizing nature of communication technologies, expanded on his social analysis during the first interview session:

> My personal connection is [similar to] what she [Charlotte] said about being too dependent on [technology]. It is very hard because everyone around is using it. That is something I sometimes talk about, how in society there is … no individual, there is just a collective and if you step out of line then you get laughed at … technology is feeding this collective.

Olivia also identified a key economic obstacle to the positive technological changes that might benefit society:

> Between the hybrid car and the car normal people use, obviously there is a lot of science and technology put into the hybrid car and creating that change. The only thing that is wrong is that they are way more expensive than cars that don't use electricity, which

> makes people not want to buy them. The effect on the environment is that we are still polluting and still contaminating.

From this recognition of the modernist influences of science and technology, emerged awareness relative to critical thinking. Amanda thought that this assignment gave her "a whole new perspective on all these different issues which could make you think more critically about these [technologies] if you have a better understanding. That could help generally." Recognition and analysis of these metanarratives could, over time, contribute to the development of the critical thinking necessary to reveal potential solutions to the social and environmental issues facing society. Liam stated, "I had never thought of the environmental impact before. I just always thought [about] how I [can] improve my game and perform [better] rather than [think about] what affects it actually [has] on the environment." Another participant also connected this research with the environmental aspects that inherently comprise STSE issues:

> With Christmas lights you just plug them into the wall and that's it right? But you never really take the time to think [about] what goes on behind it. What does it take to power these [technologies]? It's something as simple as how you never really take the time to think about how you go to that or the steps it takes to light them. (Jessica)

Jessica also extended on this theme in her written caption on her STSE artifact, which expressed her perception of the causality that produced these behaviours:

> At first these lights and decorations were simply associated with Christmas and seen as a way of celebrating and getting into that 'holiday spirit' but now we use these lights and Christmas decorations as a way to compete with one another and 'outshine' each other. (Jessica)

The research data also revealed that participants acknowledged an awareness of the importance of resisting modernist impacts relative to technological dependency, economic consumerism, and behavioural influences of science and technology.

Awareness of the importance of resisting modernist influences. An important theme that emerged from the data was participant concern for the negative aspects of science and technology and their awareness of the importance of resisting these destructive influences. Through this research process, Emma recognized "how much we rely on technology. The amount of dependency shouldn't be happening so I should try [to] limit it" while Charlotte stated that she would rather emulate:

> [Henry] and not use a phone and not feel like I have to rely on things so much because, when you think about it, our parents … wouldn't have [been] able to Google [information] to figure [problems] out they would have had to think about it. I think that is something that we really take for granted.

There was also evidence for the recognition of the importance of resisting consumerism. In particular, Henry expressed frustration with the continuous technological upgrades designed to maintain constant consumerism. He defined these persistent consumers, who demonstrate a need to always have the newest technology models, as 'trendies': "I hate trendies. People are [always stating that they] need the latest phone. I'm like 'oh my god', your phone works just fine. It doesn't matter if it's five years old" (Henry). Another student, who earlier expressed her frustration at the vast amounts of time her family spends watching television, also displayed an awareness for the need to manage the negative influences in her life through her desire to change the social interactions within her family: "I just wish that my family would just not watch movies. Lets just go for a walk … but not just watch these people walking on the TV" (Amelia).

Sophia extended her awareness of STSE to the potential to not only resist modernist metanarratives but also to eventually create solutions to STSE issues:

> If people were more aware of actually what is going on then we could come up with better solutions then just pushing this aside. Until we did this [assignment] we didn't understand the kind of affect it had and if more people in the world understood that then we could probably work together and come up with better solutions.

This research gave participants an opportunity to reflect on and express the nature of the influences of science and technology in their lives. The preceding themes, relative to an awareness of STSE, emerged from the photographic artifacts and interview material, and provide the evidence for the following discussion chapter.

Chapter 5: Discussion

This research found limited support for whether the development and construction of imaginative photographic artifacts can be utilized to create an awareness of postmodern understandings of how science and technology influences secondary science students. In this discussion chapter, the results presented in the analysis chapter were linked to the material in the literature review in order to provide evidence and support for the following conclusions. The examination, interpretation, and qualification of the results provided the basis for the evaluation of the research question (American Psychological Association, 2001). This process provided opportunities for the author to draw inferences, emphasize theoretical consequences, and validate the conclusions stated in this discussion chapter (APA, 2001). The discussion was organized according to McGinn's dimensions, modernism, imagination, postmodernism, ironic understanding, phenomenological expression, limitations, new literature, implications for teaching and learning, recommendations for future research, and the conclusion.

McGinn's Dimensions

McGinn's (1991) definition of technics helped students to identify a variety of diverse scientific and technological items. Approximately forty-five technics were represented in the photographic artifacts of the participants with electronic devices and recreational equipment comprising the majority of items. Very few students utilized McGinn's (1991) definitions to identify technologies that could be described as "the complex of knowledge, methods, materials, [and/or] constituent parts used in the making of a certain kind of technic" (p.14). The utilization of McGinn's (1991) Foreground and Background Dimensions aided participants in the identification of a variety of Behavioural, Economic, Material, Cultural, and Environmental influences that resulted from the application of science and technology in their lives. There was

a paucity of reflections that related to the Practitioner, Political, Technical, Societal, and Ideational Dimensions. The utilization of McGinn's (1991) Dimensional framework elicited a diverse expression of recreational and learning technics but was limited in its ability to expand participants' awareness to the more complex and subtle influences of science and technology. Specifically, participants did not articulate the significant influences of political and/or military policies; Ideational or cognitive phenomena, such as worldviews, recognized bodies of knowledge, core beliefs, and central values; and Societal Dimensions such as institutions, communities, movements, organizations, classes, and rituals (McGinn, 1991). Although this research exhibited a limited ability to expand the participants' awareness of the influences of science and technology, it did elicit a number of reflections with regard to the modernist influences in their lives.

Modernism

This research created an environment where students could personally analyze, express, and build their awareness of the negative influences of modernism such as environmental pollution, industrialization, consumerism, reductionist learning, and technological dependency. This awareness of contemporary modernist influences contributes to the participants' critical understanding of why "master narratives and traditions of knowledge grounded in first principles are spurned" (Giroux, 1995, xiv). Specifically, participants produced multiple pictures, captions, and interview responses that indicated that this research helped develop students' awareness of the negative aspects of the industrialization of mass-produced consumer goods and consumerism. This finding is indicative of Hodson's (2003) statement that:

> disturbing social changes and deep ethical concerns arising from scientific and technological innovations have caused science to be viewed by many as a potential threat

> to familiar and comfortable ways of life; the increasing commercialization, [and] industrialization … of science have shown once and for all that science is not value-free and disinterested. The merger of science and technology into technoscience … and the usurping of the scientific and technological endeavour for the goal of ever-increasing levels of material consumption, have profoundly changed the sociopolitical and moral-ethical contexts of scientific and technological practice. (p. 649)

Students were also critical of the perceived dependency that is developing with regard to their education. Concern for their reliance on internet resources (e.g., Google) to complete and check the accuracy of educational assignments may undermine the potential of "students, including future scientists, to be educated to be critical consumers of scientific knowledge" (Osborne & Dillon, 2008, p. 8). Students repeatedly indicated that they are more connected, engaged, and motivated with learning that is from a personal and subjective perspective, interdisciplinary, and grounded in relevant experiences. This indicator substantiates Littledyke's (2008) concern that student engagement is low because science education has become a sterile, compartmentalized, and abstract representation of modernist science goals that are emotionally and ethically detached from students' interests and experiences. The opportunity for participants to identify modernist influences was balanced with the imaginative and creative expression of the influences of STSE.

Imagination

This research produced personal and unique photographic artifacts. Each artifact was constructed from the subjective interests of participants in order to develop personal and affective connections, and a greater awareness of the influences of science and technology in their lives. These results represent opportunities to develop individual narratives of science and

technology that support Giroux's (1995) description that "the fixed and unified identity of the humanist subject has been replaced by a call for narrative space that is pluralized and fluid" (p. xiv). Participants repeatedly expressed positive feedback for the imaginative and self-reflective nature of this research. The students' appreciation for the intellectual freedom to personally connect and imaginatively express their perception of the influences of science and technology in their lives, and individualized their artifacts juxtaposes Blades' (1997) concern for the ubiquitous penetration of modernist themes lead[ing] inexorably toward establishing 'metanarratives,' that unify thoughts and reduce the diversity of individual expression. The imaginative expression and interpretation of the participants' artifacts helped facilitate the postmodern research design elements.

Postmodernism

The utilization of McGinn's (1991) Socio-Cultural-Environmental System and Egan's (1997) postmodern design elements produced photographic artifacts that personally and affectively connected participants to the positive and negative influences of science and technology in their lives. These results correspond with Olssen et al.'s (2004) expression of "*epistemic relativism* which claims that all beliefs or knowledge are socially constructed, so that knowledge is contingent, neither the truth values nor criteria of rationality exist outside of historical time" (p. 21). By situating students' awareness of science and technology within their personal, social, cultural, and experiential perception, learning has an opportunity to include a "critical understanding of one's deep, perhaps contradictory and inconsistent, personal knowledge structures and beliefs, recognition of personal assumptions, predispositions and biases, cultural blinders, and ideological boundaries" (Hart, 2002, p. 1248). This postmodern learning activity created an environment where participants, through their critical interpretation

of modernist influences, expressed a skepticism toward "all-encompassing, single worldviews ... [such as] the modernist faith in rationality, [and] science" (Giroux, 1995, p. xiv) by incorporating a more comprehensive awareness of the positive and negative aspects of STSE. Students' photographic artifacts (Appendix B) also demonstrated a capacity to link their scientific and technological knowledge to social justice and environmental issues through their personal experiences.

The postmodern design element of this research faciliated many personal connections to science and technology relative to the social and environmental consequences. These connections were facilitated through a "non-reductive, holistic, analysis of social life" (Olssen et al., 2004, p. 51) that created a more individualized, and subjective awareness of STSE that was demonstrated through the participants' unique and personal artifacts. Postmodernism embraces the individuality and personal connection of knowledge to its social and cultural context as opposed to the conformist nature of modernist universal metanarratives. Affective connections to STSE were established through emotional connections to science and technology and a social and environmental value-based science learning strategy (Pedretti & Nazir, 2011). Personal and affective connections produced a learning experience that increased the engagement and motivation of students toward an Ironic Understanding of STSE.

Ironic Understanding

The artistic nature of this research facilitated a variety of expressions of STSE, represented by the participants' photographic artifacts, and created discussions and a variety of interpretations, represented by the interview transcripts, around the influences of science and technology relative to society and the environment which substantiates Egan's (1997) postulate that "irony, combining artistic imagination and scientific rationality, can enable us to make our

way, using our artistic creations as stepping stones, beyond the chaos of this world" (p. 147). Participants reflected that this research brought an increased awareness to the negative side of science and technology, to the positive and negative duality of STSE, and to STSE issues perceived to be outside of their lives which constitutes a "more insightful and socially powerful outlook on the world in which they live" (Gaskell, 2001, p. 390). A number of participants indicated an awareness of the necessity to resist the negative modernist influences in their lives which could potentially represent an important step toward facilitating solutions that are designed to improve social justice and environmental sustainability issues because STSE education has a "crucial role to play in teaching [students] how to exercise the enormous power of technology responsibly, carefully and compassionately, and in the interests of all living creatures" (Hodson, 2003, p.663). Educational learning strategies that are contextualized from a socially and culturally derived perspective encourage discussions regarding the ethos of a community and its influence on individuals.

Phenomenological Expression

The collected photographic artifacts and interview material expressed van Manen's (1997) Mantic Meaning through a phenomenological essence that was characterized by students who demonstrated a limited capacity to express an awareness of postmodern understandings of STSE. The photographic artifacts created by the participants expressed a wide variety of recreational technics and insights relative to the behavioural influences of science and technology. Phenomenologically, participants expressed 'epiphanies' (van Manen, 1997) with respect to their awareness of the negative modernist influences in their lives, increased affective and personal connections, differentiated and relevant learning experience, and greater awareness of the influences of STSE in the participants' lives. This research helped to facilitate the

participants' expression and awareness of many of the negative influences of modernism, which represents the start of "a critical consciousness [that] allow[s participants] to question the nature of their historical and social situation" (Conrad, 2004, p. 5). The photographic artifacts produced by this research are exemplars of the diverse experiences that "enrich our perceptiveness and … contribute to our reflective understandings of the possible meaning and significance of everyday experiences" (van Manen, 1997, p. 350) and comprise the participants' awareness of their understandings relative to how science and technology relate to society and the environment through their personal experiences. Phenomenologically, this research provided opportunities for participants to consider the complex interplay of STSE through their own experiences and to express that awareness from an interdisciplinary perspective. This research produced limited results due to a number of significant limitations relative to participants' attempts to create an awareness of postmodern understandings of how science and technology influences students.

Limitations of Results

There were a number of methodological, ideological, and pragmatic limitations to this research. One limitation was that a single reflective activity did not elicit the sophisticated awareness that could potentially result from repeated STSE activities or a curriculum that is constructed from a postmodern design philosophy. Social, cultural, economic, and political structures are complex and often affect individuals indirectly. The analysis of multifaceted, interdisciplinary, and interconnected STSE influences may present too many layers of abstraction for a cogent awareness, understanding, and/or expression of STSE. Students sometimes focus only on recreational technics and neglect the larger social and environmental analysis that is the focus of this research. Aside from these general limitations, there were also a

number of limitations that resulted from the utilization of McGinn's (1991) Social-Cultural-Environmental System as an analytical tool.

The outcomes of this research were defined in terms of a postmodern awareness of STSE but participant reflections concentrated on the analysis of McGinn's (1991) Behavioural, Economic, Material, Cultural, and Environmental Dimensions and they rarely extended their analysis to the Practitioner, Political, Technical, Societal, and Ideational Dimensions (McGinn, 1991). Students only demonstrated a rudimentary awareness of STSE. Awareness, in itself, does not necessarily result in personal advocacy and/or social change toward a more just society and environmental sustainability. The evidence produced in this research does not support Fals Borda's (2001) idea that participants experienced "personal behavioural changes [nor] deep social/collective transformations and political movements" (p. 30). It is evident that active resistance to modernism, and postmodern behavioural and/or social changes are beyond the scope of the results of this research. There were also limitations relative to the nature of teaching STSE through an integrative and interdisciplinary approach.

A postmodern awareness of STSE produced a minority of feedback that suggested a potential decrease in student confidence with regard to science and science education as a positive social influence. Participants also reflected that the analysis of the negative effects of the scientific and technological influences that play a significant role in their lives might eventually decrease their affective connection to the technics. Another limitation was the concern that this research may undermine the benefits of science and technology without effectively addressing the social justice and/or environmental sustainability issues that are inherent to STSE. There were also a number of pragmatic and methodological limitations that were evident from the results of this research.

With a larger time frame and economic support it would be advantageous to include longitudinal evidence gleaned from multiple samples taken from numerous activities organized over the span of a participant's education. Postmodern, imaginative, and constructivist studies could be completed in science classes at each grade level of a student's primary and secondary education. Multiple iterations would provide participants the opportunity to develop photographic skills such as composition, focus, lighting, depth of field, and so on, that could contribute to the expression of their photographic artifacts. Multiple iterations would also create the potential for participants to increase the depth and breadth of their analysis. Further familiarity with McGinn's (1991) Socio-Cultural-Environmental framework and Egan's (1997) Ironic Understanding should allow participants to increase the sophistication of the analysis and expression of their STSE awareness. The inclusion of a control sample may also provide insights relative to whether results were a product of the research assignment or another aspect of the participants' education. The design, outcomes, and results of this research have comparisons to other research found in published academic journals.

Similarities to Other Research

Although the nature of my research is derived from source material developed by McGinn (1991) and Egan (1997), and premised on the epistemological foundation of postmodern imaginative constructivism and STSE Ironic Understandings, there are similarities to SocioScientific Issue (SSI) oriented science education. According to Zeidler, Sadler, Applebaum, and Callahan (2009) the SSI movement:

> seeks to engage students in decision making regarding current social issues with moral implications embedded in scientific contexts … These issues provide students with a

> context that encourages active reflection and examination of relevant connections among science, their own lives and the quality of life in their community. (p. 74)

Although there are similarities between SSI and this research in terms of outcomes, the two approaches have significantly disparate methodologies. SSI concentrates on the inclusion and development of the moral implications of contemporary scientific concepts where the locus of this research is the development of a subjective awareness of the influences of science and technology in the lives of students. SSI studies have confirmed research outcomes such as the benefit of reflective judgment (Zeidler et al., 2009), the improved understanding of the nature of science (Eastwood et al., 2012), the promotion of moral sensitivity (Fowler, Zeidler, & Sadler, 2009), increased engagement and higher order thinking skills (Lenz & Willcox, 2012), and the promotion of character and values for global citizens (Lee et al., 2013). There are also design parallels between my research and the research that has supported the inclusion and implementation of STSE curricular outcomes in science education.

The findings of this research have similarities to STSE research such as Hollenbeck's (2006) study that substantiates the necessity to combine STSE and constructivism so that scientific learning is taught in the context of the human experience and understanding, and Solbes and Vilches (1996) study that the inclusion of STSE within science education builds engagement. Yager's (2007), and Yager and Yager's (2006) comparative studies demonstrate an increase in creative thinking skills, the development of a more positive attitude, and an improved understanding of the nature of science through the inclusion of STSE. My research was also designed and implemented in an attempt to build on the socially just application and utilization of STSE and there are a number of potential research opportunities that could result.

Recommendations for Future Research

There are a number of recommendations that could potentially extend from this research. Researchers could explore alternate postmodern STSE activities that are based on student interests. Although the researcher choose photographic construction and expression as the artistic medium of this research, there are innumerable artistic mediums that could also be explored. All constructivist activities could be applied to McGinn's (1997) and Egan's (1991) frameworks and 'epiphanies' (van Manen, 1997) could emerge from assignments where participants create websites, presentations, blogs, journals, wikis, paintings, sculptures, songs, poems, short stories, and so on, that express an Ironic Understanding of science and technology. Longitudinal studies could provide evidence of long-term phenomenological expressions of Ironic Understanding. Extending the methodology of this research to include quantitative measures of STSE awareness, engagement, and personal and affective connections would be difficult but might provide additional research evidence. Creating individual studies to analyze the specific aspects of the phenomenological experience identified by the participants in this research would allow potential researchers to further delve into the scientific and technological awareness of students and to extrapolate socially beneficial teaching and learning opportunities.

Significance of Research

The significance of research of this nature is that it has the potential to provide teachers with a heuristic that reveals the holistic understandings of the influences of STSE held by the students. One significant goal of this activity was for students and teachers to develop an STSE typology to inform their "theoretical understandings, choices, and practices in the context of STSE education" (Pedretti & Nazir, 2011, p. 619). Postmodern reflective activities provide students with opportunities to potentially understand science from a subjective, relativistic,

contextual, cultural, and personal point of view that values individual perspectives. This research incorporated affective dimensions by actively exploring the emotional, aesthetic, cultural, and experiential domains of learning. This method of applying and contextualizing scientific understandings is humanizing and emphasizes the importance of delving into the experiences and perspectives of students to find areas of educational interest and even misconceptions that can inform pedagogical practices.

This research was also significant because it created opportunities for participants to become engaged in the development of an awareness of holistic understandings that result when students augment their scientific knowledge with an artistically constructivist journey that fosters a learning community that shares, inquires, and creates (Booth, 2013). Contextualizing scientific knowledge and logic skills with a self-reflective and postmodern awareness of STSE may facilitate an authentic connection between educational learning outcomes and comprehension of social and environmental consequences of science and technology in their lives.

Implications for Teaching and Learning

This research has some ideological, epistemological, and pragmatic implications for teaching and learning. This research demonstrates that postmodern and imaginative constructivist activities can provide a heuristic for teachers to analyze the nature of their students' awareness of scientific and technological understandings. This assignment could represent an introductory activity for many science courses where the teacher would like to contextualize the curriculum from the students' perspective and develop an atmosphere where STSE learning outcomes are relevant and meaningfully balanced with knowledge and logic objectives. This activity also creates important opportunities for students to emotionally and personally connect with their educational journey and awareness of STSE. The posted

photographic artifacts create an environment where authentic, personal, and contextualized discussions around student viewpoints of science and technology are encouraged and should provide educational insights for curricular applications and lesson plan design. The increased awareness of modernist influences should provide opportunities to critically and constructively evaluate the potential of scientific and technological applications from a balanced perspective.

Conclusion

Participants' photographic artifacts and interview material exhibited a limited Ironic Understanding of STSE; a critical awareness of modernist influences such as industrialization, consumerism, technological dependency, and lower engagement relative to reductionist learning strategies; increased personal and affective connections to science and technology within a differentiated and relevant learning experience; and an awareness of the duality of STSE. The phenomenological expression of the aggregated photographic artifacts can inform teaching and learning strategies in order to purposefully craft curricular implementation and lesson plan design for contextualized and engaged learning opportunities that incorporate students' awareness of STSE. This research has produced evidence that a postmodern, imaginative, and constructivist learning experience, where students have the opportunity to analyze and communicate the complex and interdisciplinary nature of science and technology as they relate to society and the environment, can create a limited awareness of postmodern understandings of STSE.

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Appendix A – Semi-structured Interview Questions

Photographic Artifact Assignment Questions:

1. What insights emerged regarding the influence of science and technology in your lives?
2. What connections between science and technology, and the social and environmental issues did you explore?
3. What connections did you make between your scientific and technological curricular knowledge and the influence of science and technology?
4. What social and environmental issues did you explore through this assignment?
5. What new STSE perspectives emerged from completing this assignment?
6. What personal connections did you make with regard to the influences of science and technology?

Photographic Artifact Compilation Questions:

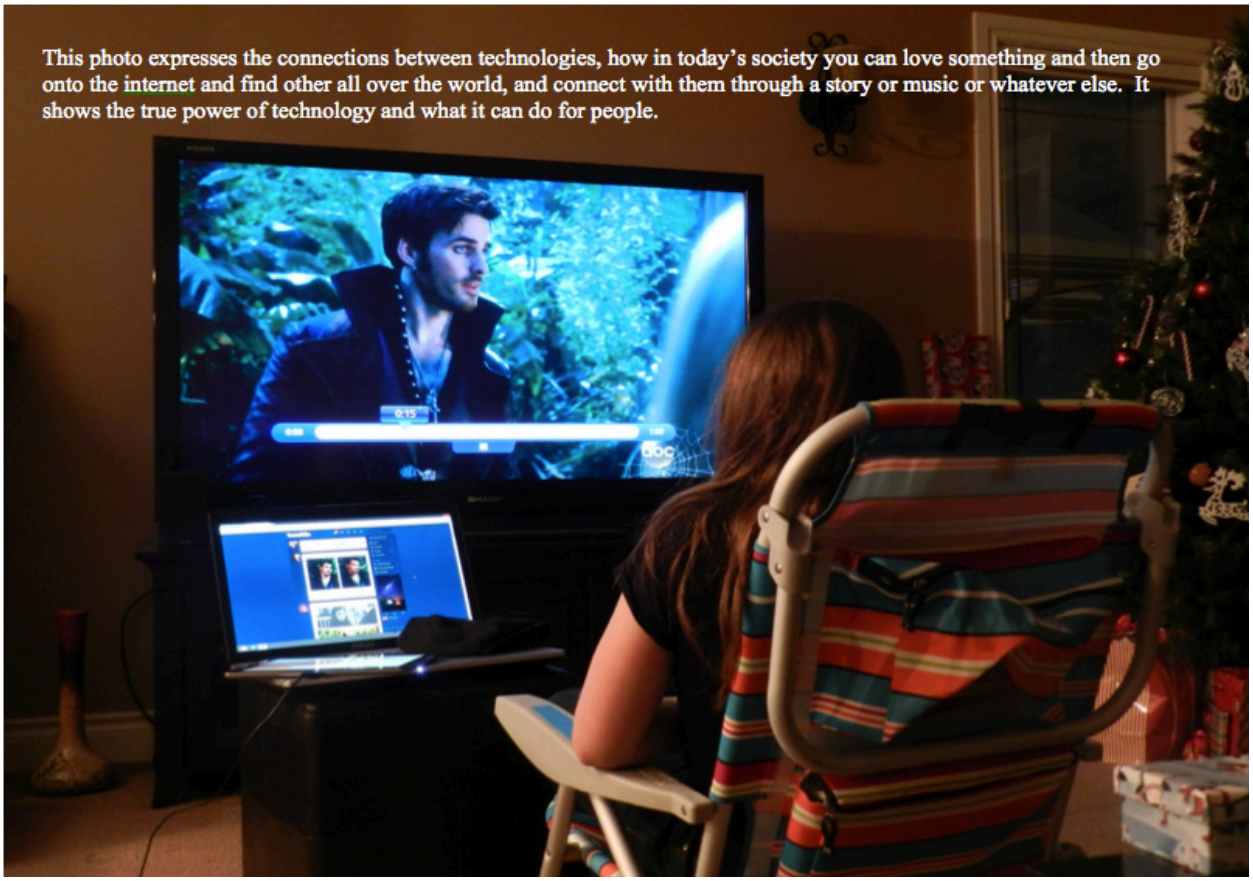
1. What common themes were revealed when all the photo narratives were posted together in the classroom?
2. What images best reflect a personal connection between science and technology and social and environmental issues?
3. What new STSE perspectives emerged from the compilation of photographic artifacts?

Summary Questions:

1. How can the development and construction of imaginative photographic artifacts be utilized to create postmodern understandings of how science and technology influences secondary science students?
2. What changes would you make to your photographic artifact if you had to complete a second photographic artifact?
3. What understandings of STSE influences were revealed through this assignment?
4. How could this reflective assignment help to reveal potential solutions to the social and environmental issues facing modern society?
5. What aspects of the intricate balance between the benefits and risks of STSE did you explore?
6. How did the inclusion of a personalized, individualized, empathic, ethical, and imaginative STSE assignment change your understanding of science and technology?

Appendix B – STSE Photographic Artifacts

Sophia's Photographic Artifact



Jessica's Photographic Artifact

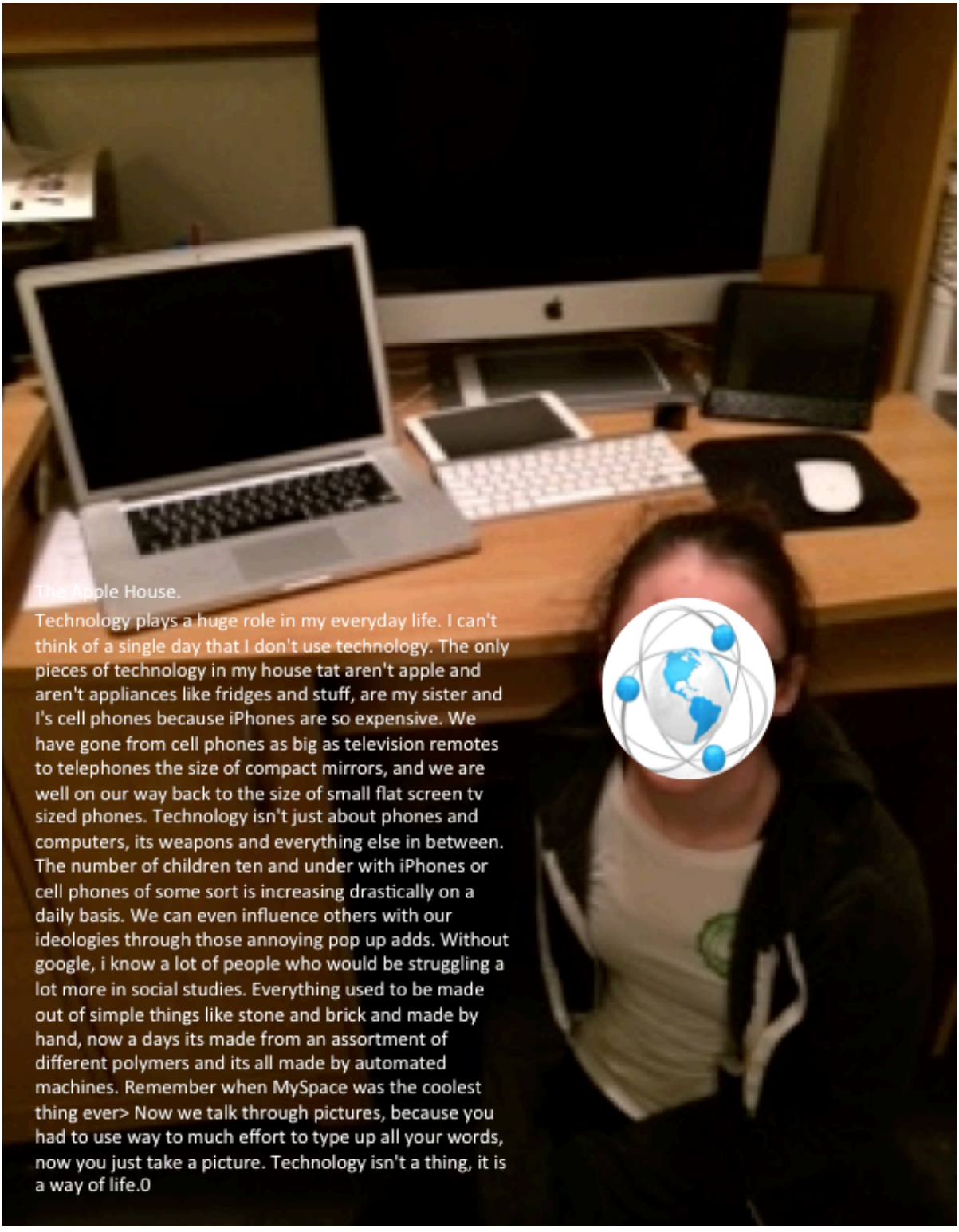
Amelia's Photographic Artifact

The revolution of technology has given rise to new ways of entertainment and social interaction. Many people now a days enjoy sitting down and watching TV or a movie, whether it be with friends, with family, or on their own. While this technology is a great pastime as well as an educational source, it develops into an issue when people become so absorbed in it that they begin to put aside responsibilities. One responsibility in particular would the responsibility to yourself to maintain your health. Technology today has become a large distraction from physical activity as it has developed more effortless ways of living.

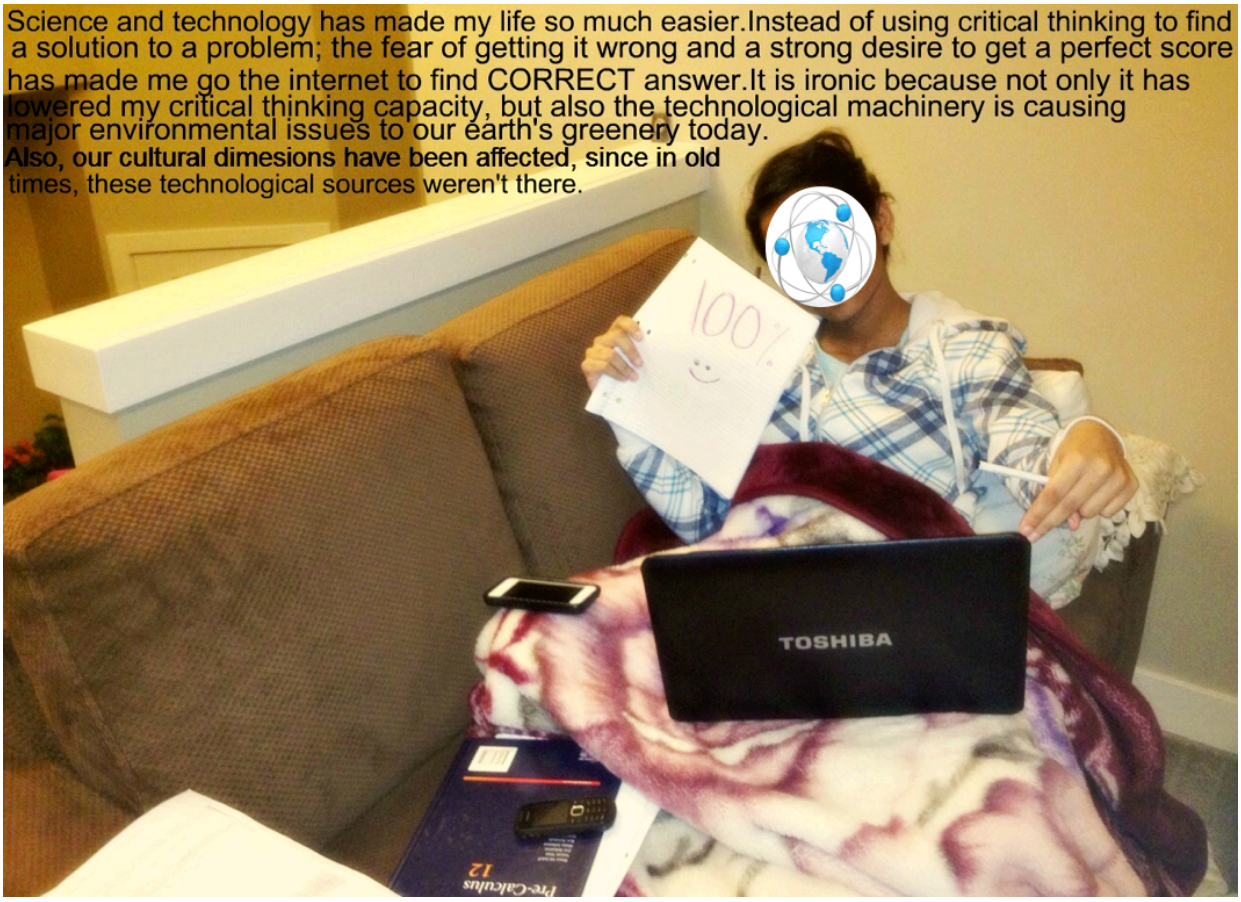
It is because of improvised technology that society has seen an increase in pollution as well as corruption. Technology is affecting our near future so it becomes our responsibility to streamline it in the right direction.

Chloe's Photographic Artifact

Elizabeth's Photographic Artifact



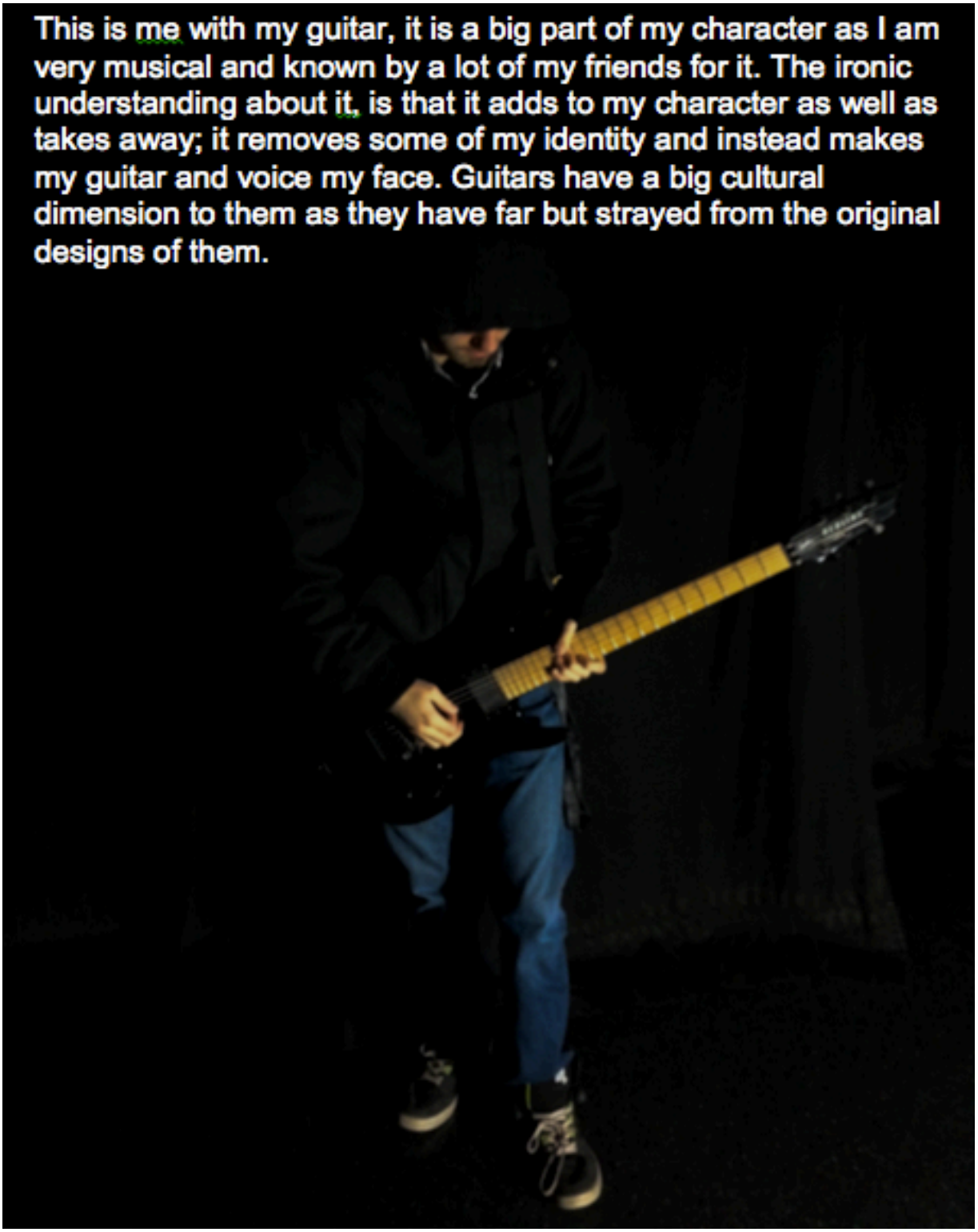
Emma's Photographic Artifact



Claire's Photographic Artifact

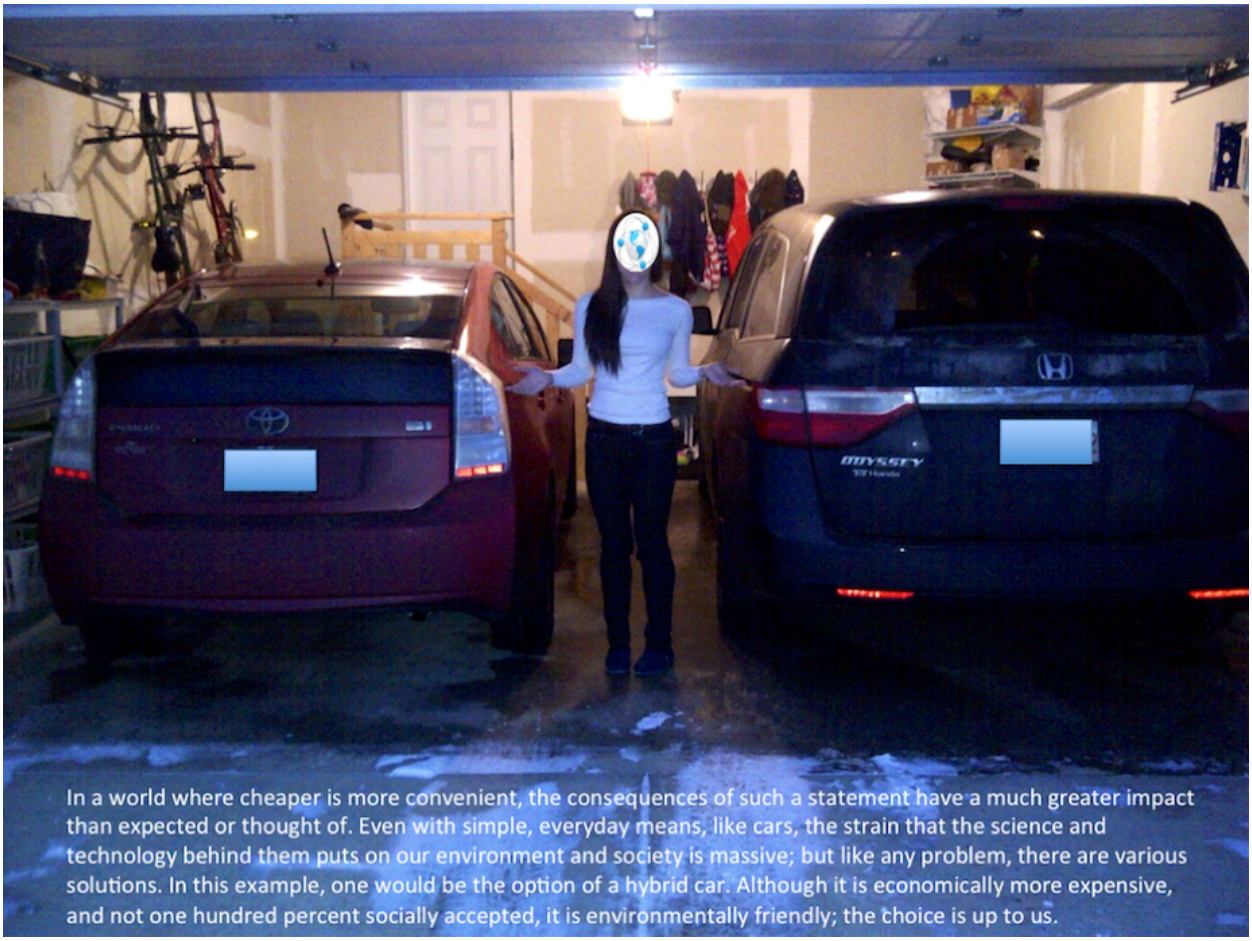
For me, Science and Technology allows me to connect with events and issues all over the world(The Political-Economic Dimension). Without access to a news paper, the internet, or a television, I would not have known about Nelson Mandela or his legacy. Communications Technology allows us to see different perspectives, learn about different cultures and traditions, and be enlightened about what it truly means to be human. (The Cultural &The Ideational Dimensions). However the Ironic Perspective, knowing about world issues, societies, and cultures in other areas of the world could make what is happening here and now less captivating or somehow less important.

Ben's Photographic Artifact



Charlotte's Photographic Artifact

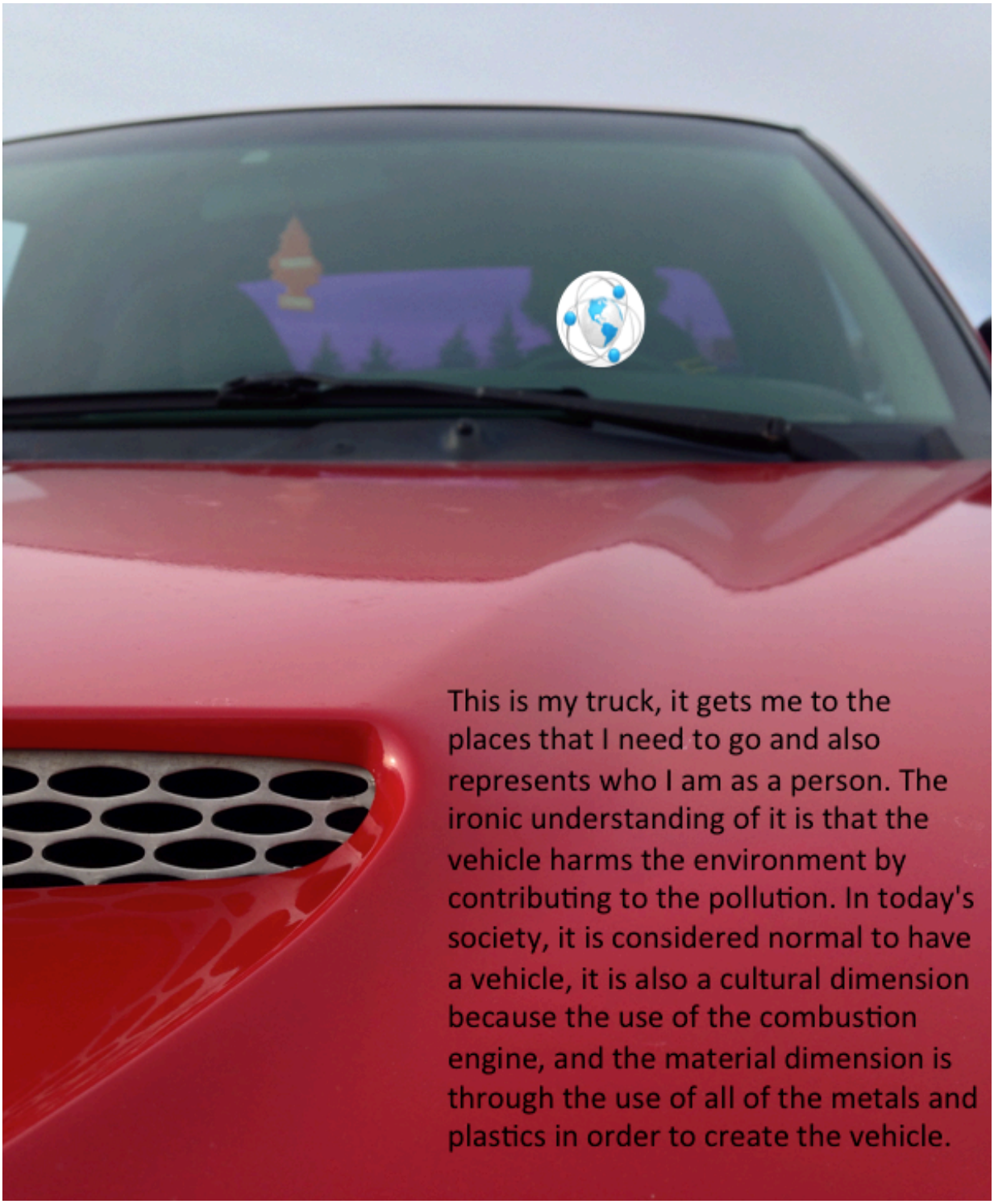
Olivia's Photographic Artifact



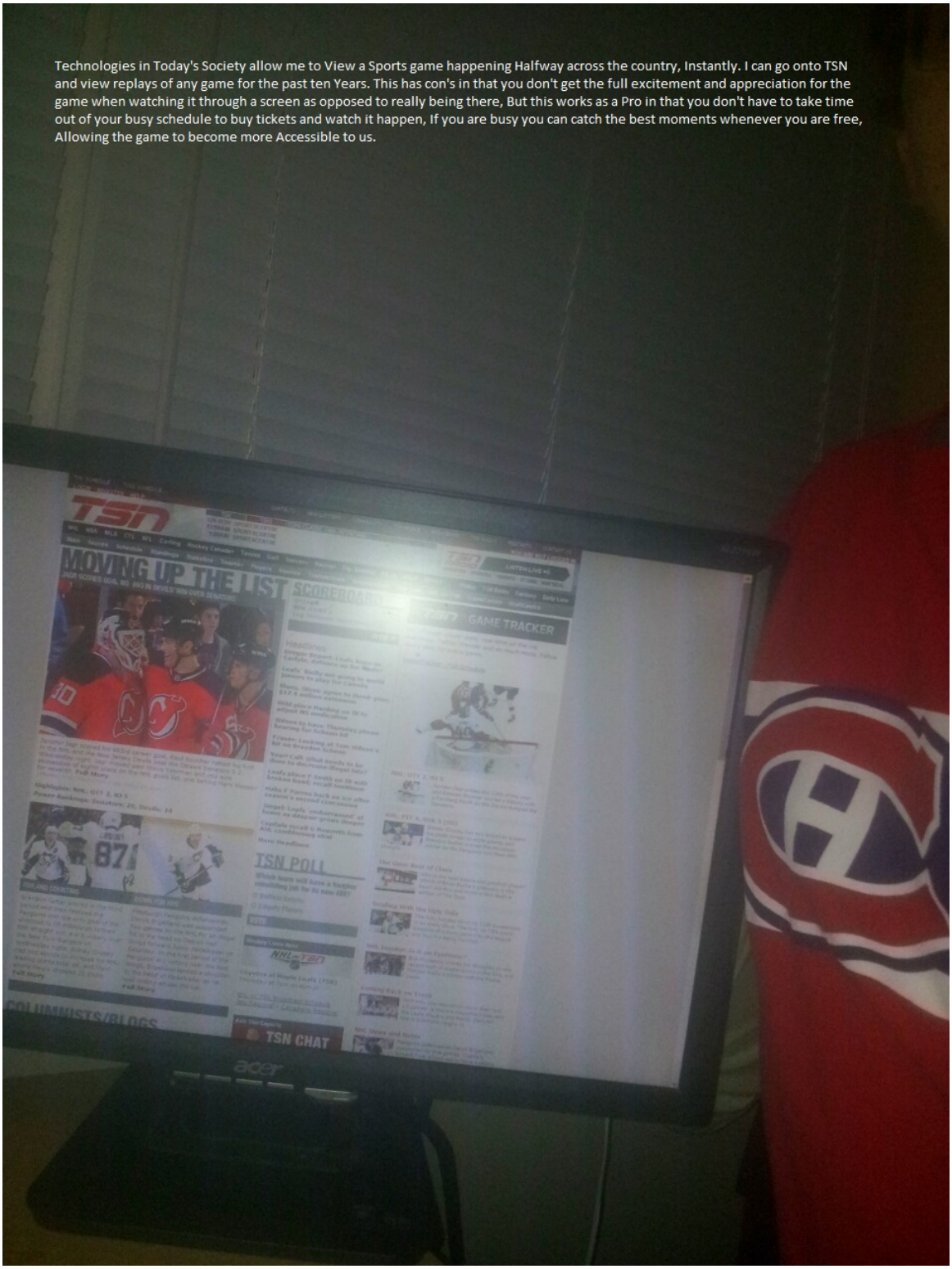
Henry's Photographic Artifact

William's Photographic Artifact

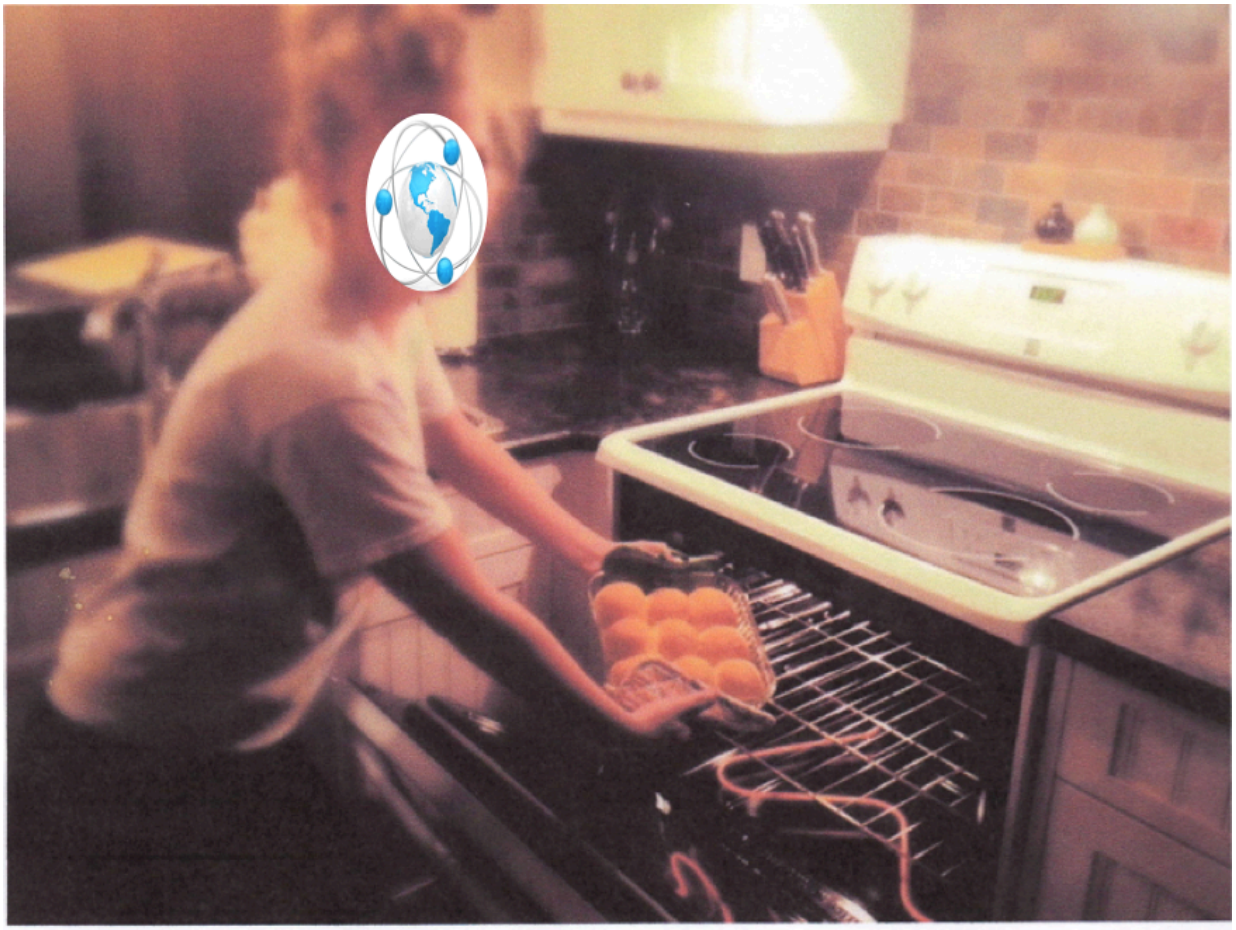
Andrew's Photographic Artifact



Jason’s Photographic Artifact

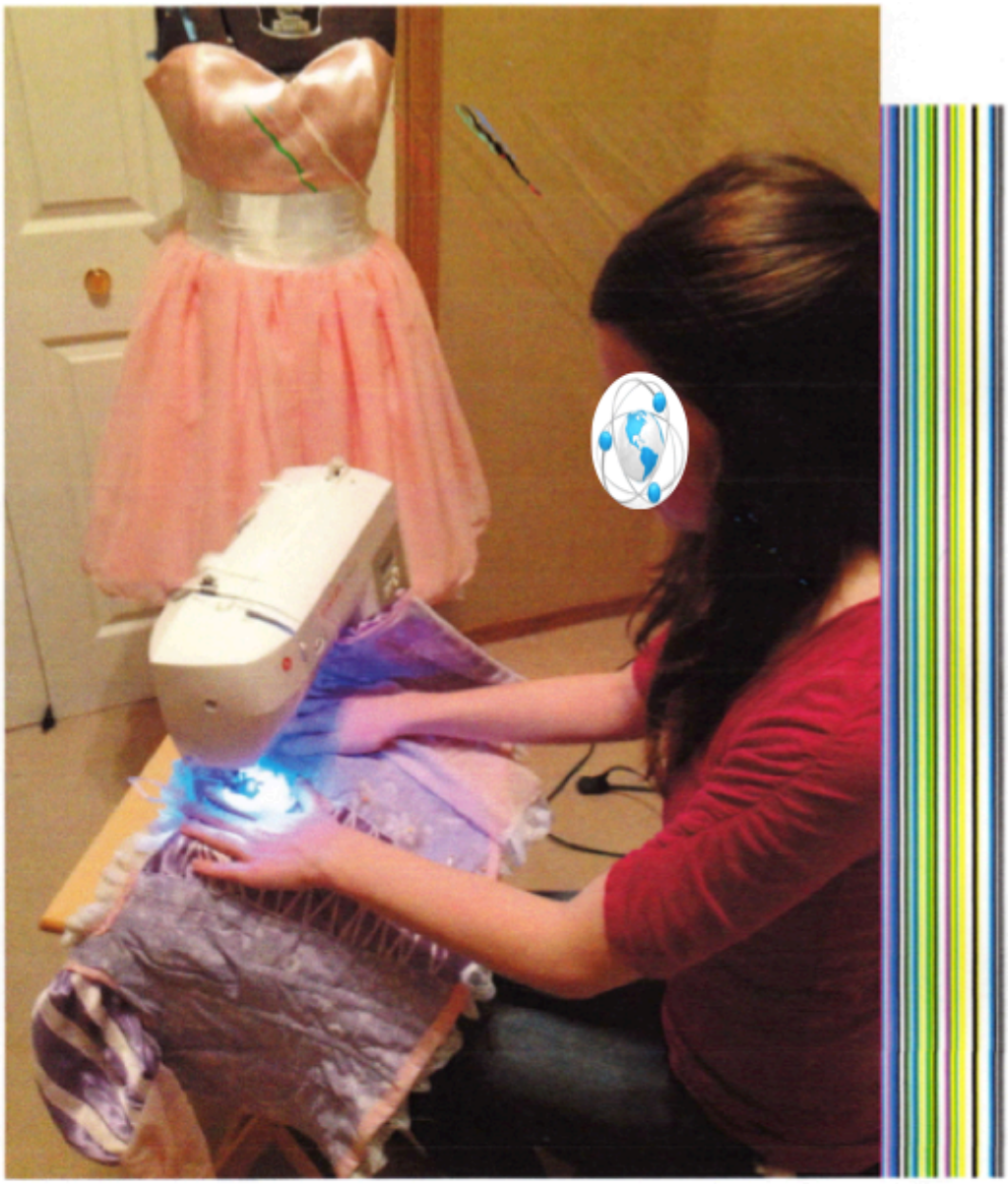


Tanya's Photographic Artifact



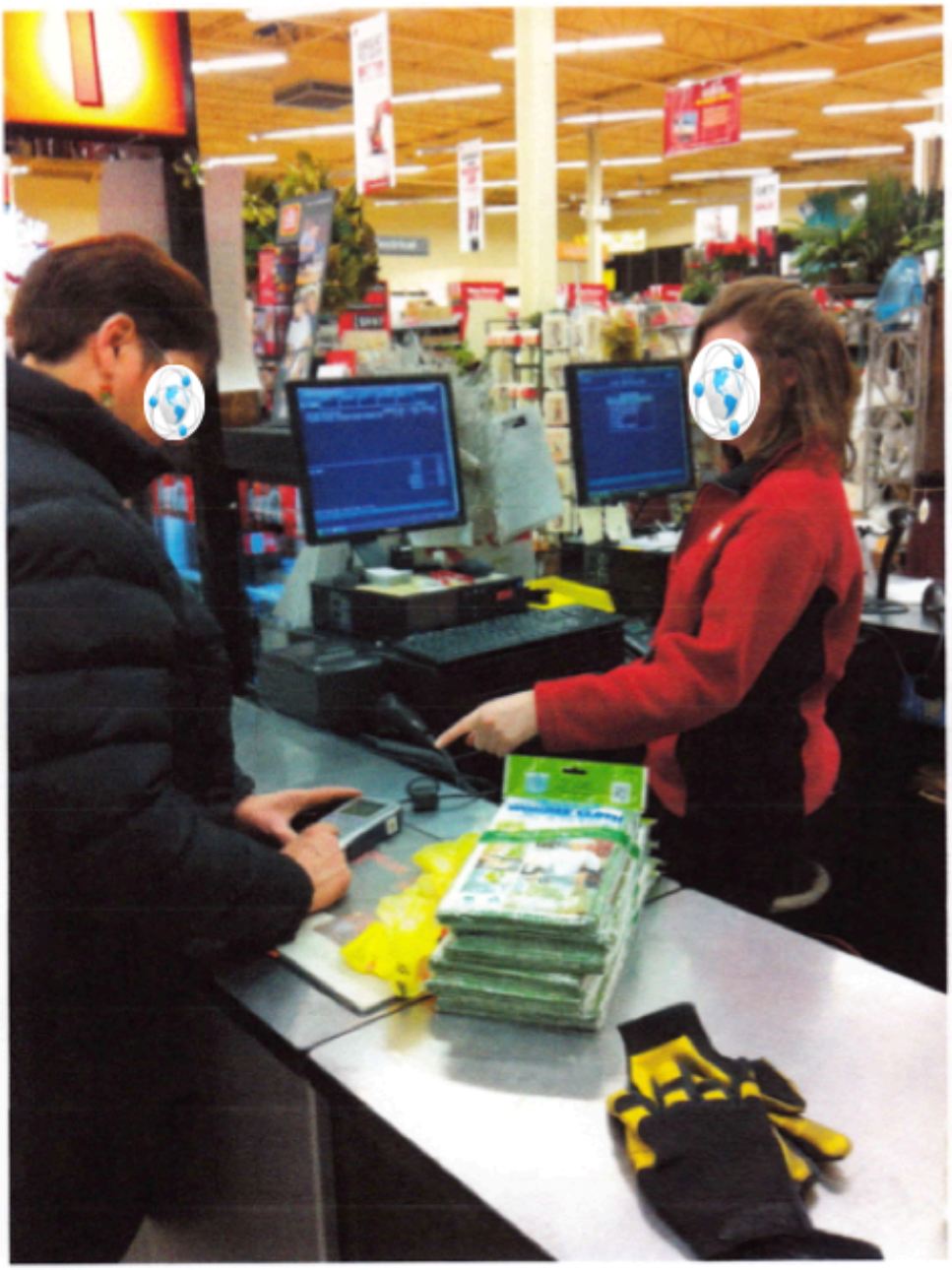
I enjoy baking and am able to do that with an oven instead of having to build a fire every time I want to bake buns. Materials, such as ovens, allow me to express my personality through baking. The down side to the use of ovens is that they require electricity which is produced by burning fossil fuels thus having a negative effect on the environment.

Sara's Photographic Artifact



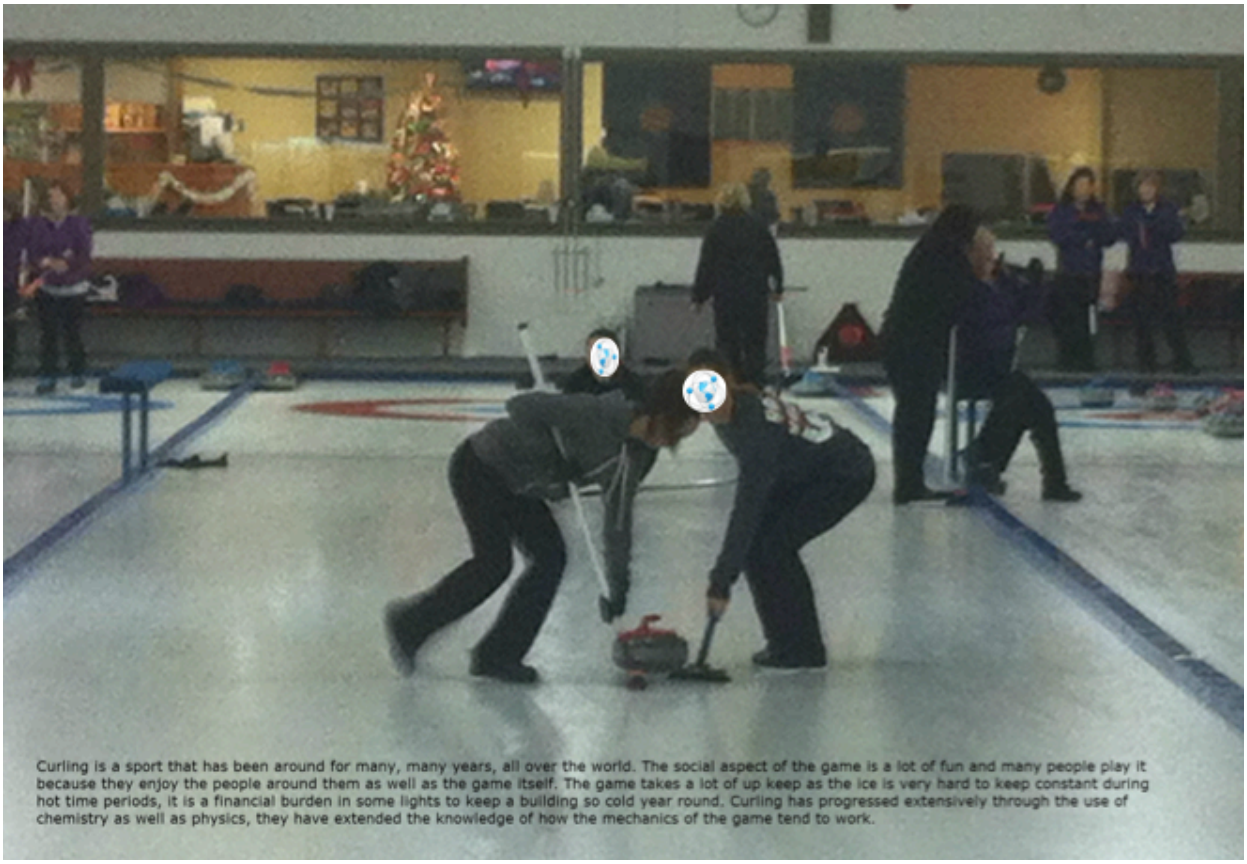
The study of science and technology has changed the way clothing is made through the introduction and innovation of sewing machines. With the use of sewing machines, clothing can be produced much quicker, easier, and cheaper, but unfortunately because of sewing machines and the mass production that they contribute to, there is now less of a connection to the clothing that people wear, and there is less of an appreciation for the amount of effort and time that goes into making a unique, well-made garment.

Heather Photographic Artifact



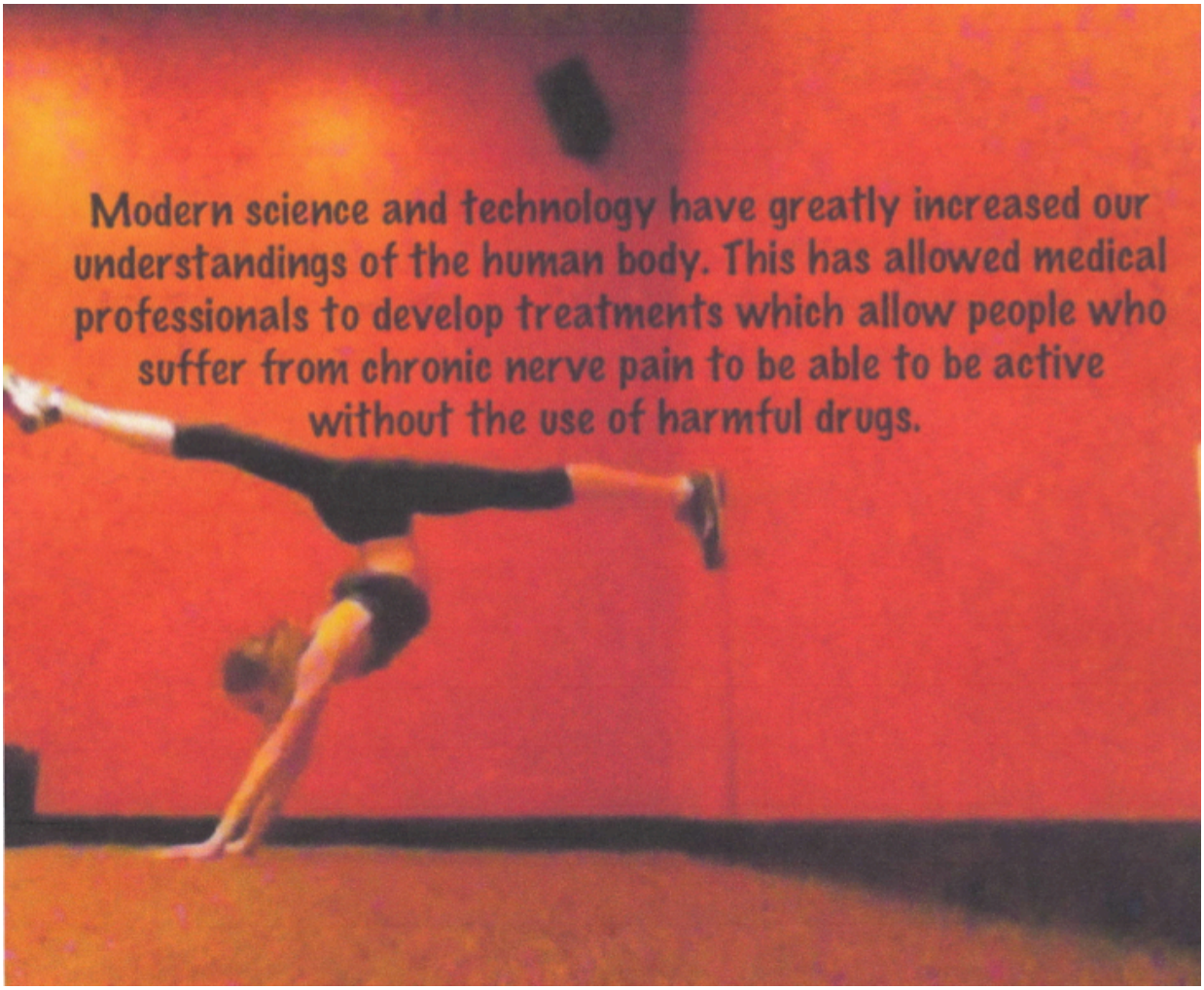
With the knowledge of science and technology, society has created new ways to purchase items without using cash. The creation of debit and credit cards has influenced the economic dimensions and the behavioral dimensions of society. Although this invention has been very useful and encouraged the purchase of more items, it is now easier to steal ones identity and people are becoming more impatient.

Teri's Photographic Artifact

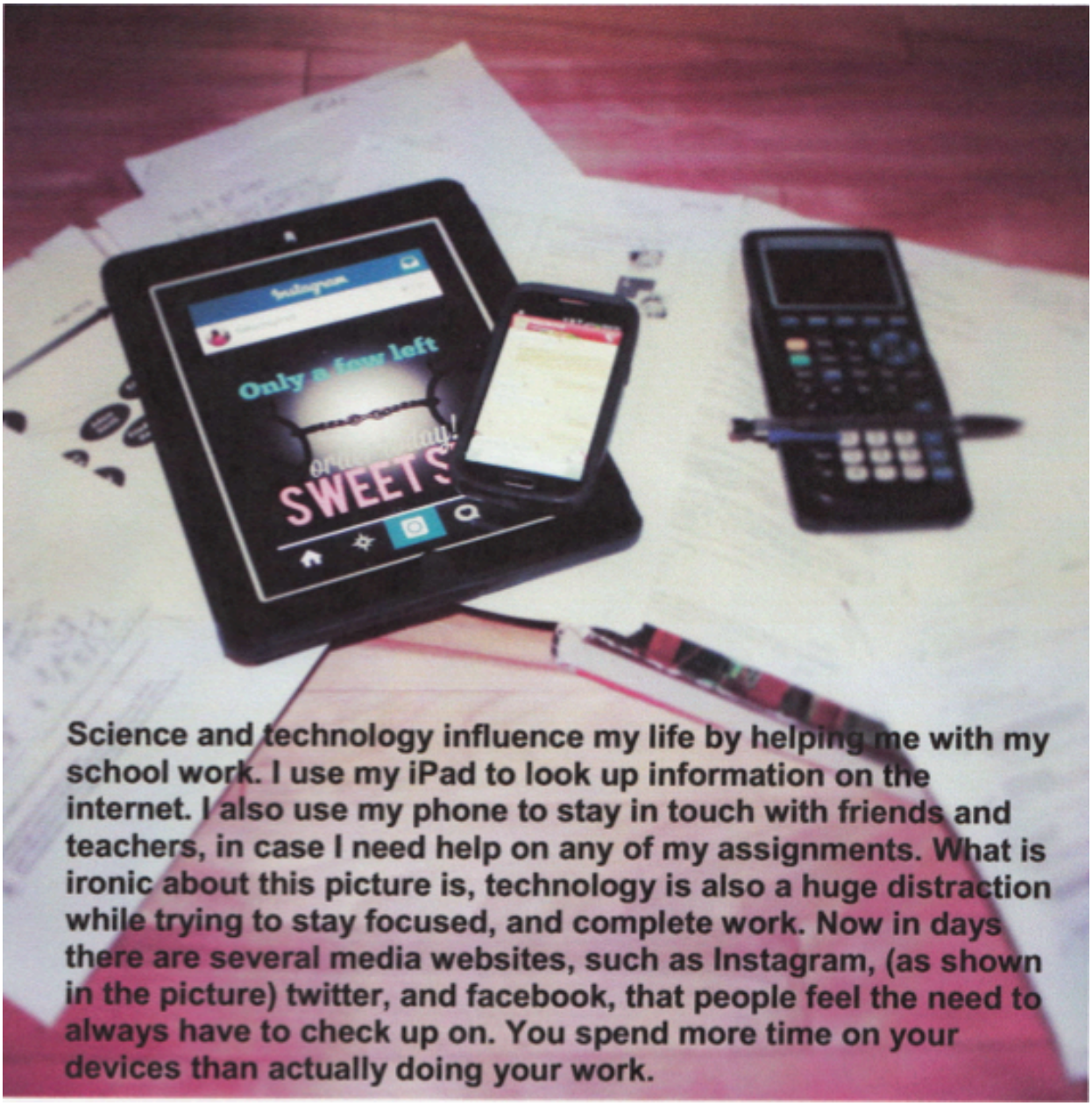


Curling is a sport that has been around for many, many years, all over the world. The social aspect of the game is a lot of fun and many people play it because they enjoy the people around them as well as the game itself. The game takes a lot of up keep as the ice is very hard to keep constant during hot time periods, it is a financial burden in some lights to keep a building so cold year round. Curling has progressed extensively through the use of chemistry as well as physics, they have extended the knowledge of how the mechanics of the game tend to work.

Amanda's Photographic Artifact



Samantha's Photographic Artifact



Liam's Photographic Artifact