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David Wong
Major Professor's Signature

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SUBLIME SCIENCE: TEACHING FOR SCIENTIFIC SUBLIME EXPERIENCES IN MIDDLE SCHOOL CLASSROOMS

By

Shane Cavanaugh

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ABSTRACT

SUBLIME SCIENCE: TEACHING FOR SCIENTIFIC SUBLIME EXPERIENCES IN MIDDLE SCHOOL CLASSROOMS

By

Shane Cavanaugh

Due to a historical separation of cognition and emotion, the affective aspects of learning are often seen as trivial in comparison to the more 'essential' cognitive qualities - particularly in the domain of science. As a result of this disconnect, feelings of awe, wonder, and astonishment as well as appreciation have been largely ignored in the working lives of scientists. In turn, I believe that science education has not accurately portrayed the world of science to our students. In an effort to bring the affective qualities of science into the science classroom, I have drawn on past research in the field of aesthetic science teaching and learning as well as works by, Burke, Kant, and Dewey to explore a new construct I have called the "scientific sublime".

Scientific sublime experiences represent a sophisticated treatment of the cognitive as well as affective qualities of science learning. The scientific sublime represents feelings of awe, wonder, and appreciation that come from a deep understanding. It is only through this understanding of a phenomenon that we can appreciate its true complexity and intricacies, and these understandings when mixed with the emotions of awe and reverence, are sublime. Scientific sublime experiences are an attempt at the re-integration of cognition and feeling.

The goal of this research was twofold: to create and teach a curriculum that fosters scientific sublime experiences in middle school science classes, and to better understand how these experiences are manifested in students. In order to create an

approach to teaching for scientific sublime experiences, it was first necessary for me to identify key characteristics of such an experience and a then to create a pedagogical approach, both of which are described in detail in the dissertation.

This research was conducted as two studies in two different middle schools. My pedagogical approach was used to create and teach two five-week 7th grade science units – one on weather (approximately 50 students participated) and the other on ecology (24 students participated). Both units proved to be a success in terms of the learning that resulted and in the positive experiences of the students and myself as the teacher.

In both cases, students were give a pre and post multiple-choice test that covered questions typical of those found on the state's achievement exam and the schools' regular tests covering weather and ecology. Both groups of students showed a significant increase in learning. In an attempt to gain an understanding of student experiences with this type of learning, surveys and interviews were administered. The units appear to have profoundly affected students' ideas of weather and ecology – many reporting to see these concepts in new, richer ways. The goal of teaching for scientific sublime experiences is not only content knowledge, but to transform students' understanding of the world. Based on student comments and observations of classroom discussions, I feel that I largely achieved my goal.

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There are many aspects of my doctoral education at MSU that I have benefited from, but above all I feel lucky to have found a group of people - David, Punya, Dick, Mark, John, Kevin, and Steve - who were also interested in exploring the seldom studied connections between science, learning, philosophy, and aesthetics. I am grateful that I was able to add my little take on these issues and look forward to continued collaboration with each of you.

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Introduction

Science is generally thought of as a discipline that seeks to objectively scrutinize the natural world in search of answers. Scientists are seen as people who view phenomena from a distance; who systematically, logically, and analytically explore the world around them. Science educators have been taught to look to the field of science and practicing scientists to guide them in their teaching of important ideas, processes, and approaches (NSE Standards, 1996). As a result, science pedagogy characteristically instructs students to step back from objects and events in order to dispassionately observe and analyze them. Recently, in an attempt to guide students towards thinking like scientists, the process of scientific inquiry has become popular in science education (NSE Standards, 1996) as well as the promotion of strong inductive reasoning skills (NSE Standards, 1996). While each of these efforts has enriched our understanding of science teaching and learning, if we are to more accurately depict the discipline as many scientists see and work in it we must connect these cognitive aspects with the equally important affective features of science.

A surprisingly large literature exists on the role emotion, creativity, beauty, and passion play in the working lives of scientists (Chandrasekhar, 1987; Dawkins, 1998; Dirac, 1963; McAllister, 1996; Poincare 1946; Root-Bernstein, 1989, 1997; Tauber, 1997; Wechsler, 1978). Unfortunately, the role of emotions and aesthetics in science has been largely overlooked in terms of science education. Recently, however, a few educational researchers have sought to include affect and aesthetics in science education by developing and testing theories of aesthetic scientific learning (Wong, 2000, Pugh,

2000, Pugh, 2002; Girod, 2001; Girod, Rau, & Schepige, 2003). This dissertation research builds on these previous studies of aesthetic science teaching and learning, but focuses on a particular branch of aesthetics, the sublime.

The sublime has been seen alternatively as a part of and as a contrast to the beautiful, but always associated with feelings of awe and exceptionality. It has captivated poets, philosophers, musicians, and artists for hundreds of years. I argue that scientists and naturalists should be added to this list and that we as science educators should strive to see and convey the sublime as well. An assortment of writings by scientists suggests that they in fact not only experience the sublime but also value it as part of their process of understanding. With these examples from science, and through research on the history of the sublime and its various characterizations, I have developed an approach for teaching that fosters sublime experiences in the science classroom.

This research is designed to a) develop a theory of sublime experiences had through learning science, b) create curriculum for teaching science that fosters sublime experiences, c) examine student experiences that result from this teaching, and d) investigate the efficacy of the teaching approach designed to foster experiences of this type.

Aesthetics, Affect, and Science

> Like the poet, the man of science also must always be able to put himself in thought in the place of Nature, to learn how she acts. . . the hypothesis is a kind of sublime romance, a scientific poem (Guyau, 1877, p.358).

Before I delve into the philosophy of the sublime, its connection to science, and my approach to teaching, I must first describe what I mean by aesthetics and where the sublime fits in. Aesthetics, a notoriously difficult concept to characterize, is nevertheless

defined by The American Heritage Dictionary (2004) as "of or concerning the appreciation of beauty or good taste". A more thorough definition is "An evaluation of some aspect of nature or human creation in terms of whether or not it is acceptable and satisfying within a given cultural and historical context" (Root-Bernstein, 1997 p. 25). This description of aesthetics describes beauty as a culturally based judgment; what is beautiful to one person may not be to another. To take the concept of aesthetics a step farther and closer to the ways in which I will use the term, Root-Bernstein (1997) offers another definition:

> It is the integration of thinking and feeling that characterizes the highest forms of aesthetic experience in both science and arts (p. 55).

In this definition, Root-Bernstein, a physiologist who also studies interactions and connections between science and the arts, emphasizes the importance of emotion in aesthetics. But he also pairs the emotional with the cognitive, claiming that aesthetic experiences are a combination of "thinking and feeling". This definition of aesthetics is also interesting because he explicitly mentions science as being capable of inducing such experiences. It is this version of aesthetics, a combination of cognitive and affective components, which I will refer to throughout this work and find particularly useful in terms of thinking about science education.

While Root-Bernstein's description of aesthetics includes science, this is not a particularly common view. In fact the worlds of science and the arts have at times been at odds with each other and partially as a result of this division we have experienced a historical separation of cognition and emotion. The affective aspects of science experiences have been seen as trivial in comparison to the more 'essential' cognitive qualities of learning. As a result of this disconnect the feelings of awe, wonder, and

astonishment as well as an appreciation of beauty have been largely ignored in the working lives of scientists. In turn, I believe that science education has not accurately portrayed the world of science to our students. As previously mentioned, in an effort to bring the affective qualities of science into the science classroom, I have begun an exploration of a particular branch of aesthetics – the sublime. I chose to investigate the sublime and how it can relate to science and science education because of two reasons: 1) It is a word often used to describe strong emotions inspired by nature, and science is ultimately the study of nature; and 2) The sublime represents the ultimate of emotions, what has been called, "the strongest of passions" (Burke, 1757, p.51).

The Sublime

> We call that sublime which is absolutely great (Kant, 1790, p. 106).
>
> Sublime: Characterized by nobility; majestic. 2a. Of high spiritual, moral, or intellectual worth. b. Not to be excelled; supreme. 3. Inspiring awe; impressive (American Heritage Dictionary, 2000).

The word sublime comes from the Latin word 'limen', meaning 'lintel' – the beam that forms an upper part of a door or window. Therefore, the metaphorical meaning behind the word sublime is to be lofty, or as high as a lintel. The word also has two interesting forms: sublimate and sublimation.

To sublimate, means to convert, transmute, or purify. Originally sublimate was a word used by alchemists to describe their work as they tried to convert sulfur into salt, salt into mercury, and finally mercury into gold. Sublimation, the process of sublimating, is today seen as the transformation of matter into purer substances as in changing from a solid to a gaseous state. Sublimation occurs when a step in the normal sequence of things (e.g. solid to liquid to vapor) is skipped as in the case of dry ice where solid water moves directly to water vapor. Quite understandably, these early chemists were confused and a bit taken aback by the seldom seen process of sublimation. Reportedly, alchemists believed that through sublimation they were witnessing matter dissolve into a higher spiritual form. In their own laboratories they were watching what seemed to be supernatural transformations of solid substances into escaping vapors. These experiences not only left the alchemists awe-struck but also convinced that they had witnessed a spirit or force that pervades all matter. Through these mystical encounters the early chemists attached feelings of fascination and reverence mingled with a sense of trepidation to the process of sublimation. Today the word sublime is often associated with these ideas of

perfection and transcendence that arose from the alchemists' belief that sublimation involved moving to a higher state.

As a subject of philosophy, sublime first dates back to the rhetorical writings of the essay, *On the Sublime,* by Longinus in 1st century Greece. Through emotion and language Longinus believed we are capable of transcendence; "the soul is raised by true sublimity, it gains a proud step upwards, it is filled with joy and exultation." Longinus used the sublime to describe excellence in writing that originated from five sources: reason, emotions, figurative language, noble diction, and elevated composition. Sublime writing, he believed, had the power to enthrall the reader through its imaginative and emotional depth (Klein, 2000). And so from the beginning, the sublime was associated with a sense of deep emotional transcendence.

The philosophical study of the sublime went largely untouched from the time of Longinus until the 1600's when an Englishmen, John Dennis, wrote write again of the emotions of the sublime. Dennis took Longinus' idea of the sublime as a deeply felt emotion, but he added something to it that would greatly influence future aesthetic philosophers. Dennis' delving into the sublime began as he described the sensations he felt during an expedition he made across the Alps. Like many before and after him, Dennis was awe-struck by the enormity of the mountains and the very real fear he felt trying to cross them. Before his actual journey Dennis had been enamored with his romantic imaginings of the mountains, but faced with the reality of the enormous snow-capped Alps, in 1693 he wrote:

> The sense of all this produc'd different emotions in me ... a delightful Horrour, a terrible Joy, and at the same time, that I was infinitely pleas'd, I trembled." (Wiener, 1973).

By writing of this experience Dennis developed an aesthetic theory which became one of the first distinctions between the beautiful and the sublime, two contrasting concepts of aesthetics most commonly associated with Edmund Burke (1757) and Immanuel Kant (1764, 1790). Dennis' description captured the essence of how Burke and Kant would later characterize the sublime – as an enthralling combination of fear and delight.

While it was philosophers, and later poets, who labored to describe and analyze the sublime, it is important to remember that the word and its feelings were first associated with the work of early scientists – the alchemists. The relations between science, scientists and the sublime will be further explored and connected to ideas of science education later in this dissertation. But for now I will explore the sublime in works of prose and poems in hopes of making connections between the worlds of science, philosophy, and literature and to classify the various types of sublime. Philosophers and poets have taken a variety of stances on the sublime, but out of these writings two very different forms emerge, what I call the extreme and the connective sublime.

The Extreme Sublime

> The passion caused by the great and sublime in nature, when those causes operate most powerfully, is Astonishment; and astonishment is the state of the soul, in which all its motions are suspended, with some degree of horror (Burke, 1757, p. 57).

The first type of sublime that I have identified, what I have come to call the extreme, is associated with words such as: astonishment, enthralling, fear, horror, delight, awe-inspiring, and humbling. I found that this type of sublime first emerged from Dennis' 1693 description of his feelings associated with a dangerous crossing of the Alps. Inspired by nature, his account included the seemingly contradictory feelings of

"delightful Horrour" and "terrible Joy". Over 60 years later, Dennis' treatment of the sublime greatly influenced the two philosophers most associated with it, Edmund Burke (1757), and Immanuel Kant (1764, 1790). Both writers expressed feelings of reverence towards the power of nature in events like hurricanes or in the vastness of space. These authors, mainly writing about the sublime as a contrast to the beautiful, described the feelings of being awe struck, amazed, and astonished by the sublime in nature. To contrast the sublime with the beautiful, Kant (1764) wrote:

> Tall oaks and lonely shadows in a sacred grove are sublime, - flower beds, low hedges and trees trimmed in figures are beautiful. Night is sublime, day is beautiful…The sublime moves, the beautiful charms (p. 27).

While Kant considers the beautiful as a matter of taste and culture, the sublime is attributed with a deeper, overwhelming and undeniable presence. Kant valued the sublime over the beautiful often portraying the beautiful as trivial while the sublime is seen as powerful and moving. The sublime is found in 'sacred' places and is cast with a solemn tone – being associated with the 'lonely' and with the 'night'. In contrast, beauty is linked with more tamed and cultivated aspects of nature like 'flower beds' and 'trees trimmed in figures'. Here Kant (1764) describes the sublime as intensely emotional and stirring while beauty is seen as static and superficial:

> For just as we charge with want of *taste* the man who is indifferent when passing judgment upon an object of nature that we regard as beautiful; so we say of him who remains unmoved in the presence of that which we judge to be sublime, he has no *feeling* (p. 131).

Notice also the emotions associated with the sublime in contrast to those that come with beauty. We can "regard" or view something as beautiful, but we are moved and stirred by the sublime. One who does not recognize beauty has no "taste" – clearly a subjective term, but those not affected by the sublime have "no feeling".

Kant's sublime as portrayed in "Observations on the Feeling of the Beautiful and Sublime" (1764) and "Critique of Judgment" (1790) is squarely that of the extreme. In Kant's works the extreme sublime is provoked by the huge, by dizzying heights, and terrifying depths, always including a sense of fear mingled with captivation. Kant (1764) writes of the sublime as "the description of a raging storm … arouse[ing] enjoyment but with horror" (p.26). When trying to imagine the extreme sublime, consider the person who despite the wails of sirens cannot tear herself away from staring at an approaching tornado. With this type of sublime we are overwhelmed by what our senses and imagination cannot fully comprehend. Regardless of the sense of danger the viewer simply cannot turn away, since mingled with the terrifying, is something even more enthralling. Kant (1790) describes this mix of fear and enthrallment when he writes,

> The mind feels itself *moved* in the representation of the Sublime in nature … quickly alternating attraction towards, and repulsion from, the same Object (p. 120).

The extreme sublime lures us into ignoring our fears in order to feed our fascination.

Like Kant, Burke focuses on the terror in the sublime and explores our attraction to it. In his 1757 book "A Philosophical Enquiry into the Origin of Our Ideas of the Sublime and Beautiful", Burke (1757) describes our fascination with frightening, at times dangerous, events as arising from our natural feelings of self-preservation. He explains:

> The passions which belong to self-preservation, turn on pain and danger; they are simply painful when their causes immediately affect us; they are delightful when we have an idea of pain and danger, without being actually in such circumstances … Whatever excites this delight, I call *sublime*. The passions belonging to self-preservation are the strongest of all the passions (p. 51).

Our instinctual feelings of self-preservation allow us to recognize situations that are potentially dangerous and to find delight in these moments. Similarly, Burke writes:

> When danger or pain press too nearly, they are incapable of giving any delight, and are simply terrible; but at certain distances, and with certain modifications, they may be, and they are delightful (p. 40).

The delight arises when we realize we are not in immediate danger but instead in a position to watch with awe and respect. Kant (1790) also describes the sublime in this way, "… the sight of them is the more attractive, the more fearful it is; provided only that we are in security…" (p. 125). Burke argues that our feelings of self –preservation explain our fascination with the sublime, explaining why, from a safe distance, we like to watch dangerous animals or why we enjoy peering over the edge of the Grand Canyon. The drop of our stomachs, the raised hairs on the back of our necks, and the basic urge to flee often accompany our experiences with the most extreme sublime.

Based on his notion of the sublime resulting from feelings of self-preservation, Burke breaks up the sublime into several categories. Some of his categories include:

1. **Terror**: "terror is in all cases whatsoever, either more openly or latently the ruling principle of the sublime" (p. 57).
2. **Obscurity**: "To make any thing very terrible, obscurity seems in general to be necessary. When we know the full extent of any danger, when we can accustom our eyes to it, a great deal of the apprehension vanishes" (p. 58).
3. **Power**: "I know of nothing sublime which is not some modification of power" (p. 64).
4. **Vastness**: "Greatness of dimension, is a powerful cause of the sublime" (p. 72).
5. **Infinity**: "Infinity has a tendency to fill the mind with that sort of delightful horror, which is the most genuine effect, and truest test of the sublime" (p. 73).
6. **Magnificence**: "A great profusion of things which are splendid or valuable in themselves, is magnificent. The starry heaven, though it occurs so very frequently to our view, never fails to excite an idea of grandeur" (p.78).

Today our fascination with the types of sublime experiences that Burke and Kant wrote of has permeated into popular culture. No longer are these rare occurrences where the observer comes into actual contact with the natural sublime. The sublime is now enthralling people everyday through television programs that focus on such topics as

violent storms, dangerous animals, or on nature's extremes and oddities. The extreme sublime is everywhere and our students are watching. In fact, "The Most Extreme" is currently a popular show on the channel "Animal Planet" where they "countdown the most extreme animals on the planet" such as the deadliest, most venomous, and overall scariest creatures. Of course watching the sublime on TV is not the same as experiencing it oneself; viewing a documentary on sharks cannot compare to the horror of seeing an actual dorsal fin slide through the water. Still, we must feel some of the delight that Burke mentioned from the sublime that we experience vicariously. Perhaps some of the fear is removed, but we are nevertheless fascinated.

While the extreme sublime begins as horror mingled with fascination, according to Kant it finishes with a humbling sense of knowing one's place in the world. When looking into the clear night sky at the endless pinpricks of light, we cannot help but feel that we are just a glint of life in the vastness of the universe. There is something both beguiling and frightening in the infiniteness of space that ultimately leaves the viewer with a sense of being definitively small. This is the sublime of Kant, the sublime that leaves people conscious of their own destinies and gives them a sense of their human worth. Kant's view has a distinct Christian tone in that the person is left with a feeling of being small and insignificant in relation to larger, more powerful forces. "When we are confronted with the overwhelmingly powerful, the weakness of our empirical selves makes us aware of our worth as moral beings" (1790, p. 232). This extreme sublime serves to distance the observer from nature and from God. Kant's (1790) following lines describing the sublime perhaps best sum up the extreme sublime:

> Bold, overhanging, and as it were threatening rocks; clouds piled up in the sky, moving with lighting flashes and thunder peals; volcanoes in all their violence of

destruction; hurricanes with their track of devastation; the boundless ocean in a state of tumult; the lofty waterfall of a might river...these exhibit our faculty of resistance as insignificantly small in comparison with their might. But the sight of them is the more attractive, the more fearful it is; provided only that we are in security..." (p. 125).

These lines capture all the essences of the extreme sublime, the frightening power and enormity found in nature and the resulting feeling of our own insignificance that we are left with upon viewing these awesome things.

The Connective Sublime

A sense sublime of something far more deeply interfused,
Whose dwelling is the light of setting suns,
And the round ocean and the living air
And the blue sky, and in the mind of man,
- A motion and a spirit, that impels
All thinking things, all objects of all thought,
And rolls through all things.
- Wordsworth (1798), from Lines Completed a Few Miles Above Tintern Abbey.

Hence arises a pleasure mixed with awe ...a …degree of the sublime is felt (Emerson, 1836).

The second type of sublime that I have identified is found in the Romantic poetry of Wordsworth and Coleridge and the American Transcendental philosophy of Emerson, Whitman, and Thoreau. These writers emphasize different aspects of the sublime than found in the extreme, and I call this second perspective the connective sublime. In both views, there is initially a sense of uncomprehending and even sometimes fear, but while the distanced, extreme sublime ends with humility, the connective sublime results in a connection between the person and nature. Rather than feeling one's insignificance and separation from the world through an experience, in the connective sublime the observer is left with a feeling of connection to and intimacy with the world. The connective sublime highlights feelings of unity with nature along with the mixture of fear,

fascination, and awe. The following quote by Ralph Waldo Emerson (1836) captures the feeling of the connective sublime as he describes a winter walk:

> Crossing a bare common, in snow puddles, at twilight, under a clouded sky, without having in my thoughts any occurrence of special good fortune, I have enjoyed a perfect exhilaration. Almost I fear to think how glad I am … Standing on the bare ground, - my head bathed by the blithe air, and uplifted into infinite space, - all mean egotism vanishes … I am nothing. I see all. The currents of the Universal Being circulate through me; I am part or particle of God.

The sublime experience described by Emerson is similar to that described by the extreme sublime in some ways, but in other ways differs greatly. Unlike the sublime described by Kant, Emerson is not left with a feeling of humbleness and modesty, but instead is elated by his connection to the universe. He has tapped into the energy coursing through nature and experiences "exhilaration". This universal current is the same mentioned earlier in regards to Emerson, an important idea for the transcendentalists representing one's connection to the world. When Emerson writes that he "is nothing" it may sound Kantian in character, but he follows this line with "I see all" and moves into a description of being a "part or particle of God". While Kant writes that God's presence is also revealed in the sublime, he would not claim that the viewer becomes a part of God or nature through this experience. For Kant, the sublime occurs when we recognize some aspects of our separation and autonomy from nature rather than the unity expressed by Emerson.

Another important distinction between Emerson's experience and that of the sublime described by Kant and Burke is that Emerson's experience happened with the ordinary. Kant (1764) saw the sublime in displays of great natural forces like hurricanes and tornados, or in objects of great height or depth, writing, "The sublime is always great" (p. 125). In contrast, Emerson felt the sublime on an ordinary winter walk through

New England woods. Emerson's lines do not describe anything unusually large or great, yet the poet still felt that he tapped into the "currents" of nature and allowed "the Universal Being to circulate through" him. Another example from Emerson (1844) illuminates both the writer's feeling of connection to nature and his ability to find the sublime in the small and commonplace as he describes his feelings upon gaining insight into the workings of an ant:

> The instincts of the ant are very unimportant, considered as the ant's; but the moment a ray of relation is seen to extend from it to man, and the little drudge is seen to be a monitor, a little body with a mighty heart, than all its habits … becomes sublime.

It is unlikely that either Kant or Burke would have found any sort of sublimity in a mere ant, but here Emerson highlights several important parts of the connective sublime. There is sublimity found in a connection to nature when "the ray of relation" is realized, when the onlooker sees how similar he is to an outwardly simple insect. For Emerson the sublime represents a universal connection and happens the moment we realize this unity. Similarly, Emerson (1844) wrote of the ultimate connection to nature:

> A life in harmony with nature, the love of truth and of virtue, will purge the eyes to understand her text. By degrees we may come to know the primitive sense of the permanent objects of nature, so that the world shall be to us an open book, and every form significant of its hidden life and final cause.

In these lines Emerson writes that in order to reach sublime understanding we must lead "A life in harmony with nature" and come to know the true ways of the world like an "open book". This sense of harmony with nature is an important aspect of the connective sublime and has interesting implications for thinking about science education since it implicitly addresses how the world becomes more intelligible as a result of the experience.

Along the same line, in "Art as Experience", John Dewey (1934) writes of the integration of the viewer and the object as an essential quality of aesthetic experiences.

> For the uniquely distinguishing feature of esthetic experience is exactly the fact that no such distinction of self and object exists in it, since it is esthetic in the degree in which organism and environment cooperate to institute an experience in which the two are so fully integrated that each disappears (p. 249).

Similarly, Wordsworth in his famous poem *Lines Completed a Few Miles Above Tintern Abbey* described this moment or feeling as "A sense sublime of something far more deeply interfused", "A motion and a spirit, that impels" and "rolls through all things". Here Wordsworth is describing an idea common to many transcendental writers that within everything is an underlying, unifying force and to Emerson and Wordsworth, this force is sublime. Both Emerson and Wordsworth devoted much of their writing to this idea of a union with nature and the sublime represented the ultimate emotion of awe and unity.

The Sublime, Science, and Science Education

At this point it is important to address the question, "Why use the sublime in science education?" To answer this, it is important to again mention the historic separation of cognition and emotion in science. I see the sublime as a lens through which to examine nature as a way to call attention to the affective qualities in science and to help foster compelling, moving experiences in the science classroom.

One reason the sublime lends itself well to science is simply that in both the connective and extreme philosophies of the sublime, the word has been used to describe the most awe-inspiring aspects of nature. A central goal of science learning is to make sense of the natural world and the sublime provides a lens through which to do this. The extreme and connective sublimes capture different yet equally compelling aspects of

nature and can be used to create deeply affecting learning experiences in the science classroom. The extreme sublime of Kant and Burke represents our universal fascination with terror, obscurity, power, and vastness. The feelings evoked by these experiences - astonishment, horror, and awe mingled with delight can serve as a motivating force for students. These feelings are described as arising from self-preservation and Burke called them "the strongest of all passions". The sublime is more than an intense emotional reaction; it is the ultimate, the most compelling of all feelings. An understanding of what makes up the extreme sublime allows teachers to create experiences in the science classroom that tap into these strongest of all feelings. In teaching, by presenting science content that astonishes our students - that alternately repulses and attracts them - we are tapping into the sublime.

Some cognitive theorists see our motivation to learn as a way to achieve goals, to solve problems, to reduce cognitive dissonance, or to maintain equilibrium (Piaget & Inhelder, 1969; Gardner, 1985, Greeno et al., 1996, Posner et al., 1982). For other theorists, understanding is not most commonly driven by practical or instrumental reasons. Instead, the drive to learn is to seek connections – to nature, the universe, ideas, or others. This view of understanding does not see the sense of connectedness as only being at the cognitive level; instead it is a merger of emotions and understanding (Dewey,1934; Prawat, 1993) and this is where the connective sublime comes in.

While the extreme sublime astonishes and often bewilders, the connective sublime works more subtly to convey a largely different set of emotions. The connective sublime and its associated feelings of connection, harmony, respect, and unity are particularly relevant to science and science education. According to the National

Science Education Standards (1996), "Certain attitudes such as wonder, curiosity, and respect for nature are vital parts of the science learning community." Understanding and promoting the connective sublime in science classrooms is one way to reach these vital aspects of science learning. We want science students to be moved and engaged by these feelings of connection and can strive for them to reach the ultimate feelings of unity that Emerson, Wordsworth, and Dewey speak of. In terms of education, the connective sublime is particularly important to pair with the extreme sublime since it provides a way of finding wonder and awe in even the ordinary. While the two types of sublime that I have identified, the extreme and the connective, represent two different takes on the sublime, they both provide an interesting lens through which to examine the often ignored emotional side of science.

The Scientific Sublime

While the extreme and connective sublime both represent exhilarating emotional experiences, they are based on the instinctual rather than the intellectual. Both Kant and Burke claim that the sublime defies reasoning and logic. On this point, Burke (1757) writes,

> .. the mind is so entirely filled with its object, that it cannot entertain any other, nor by consequence reason on that object which employs it (p.52).

Similarly Kant (1790) writes:

> ...if we are to call the sight of the ocean sublime, we must not *think* of it as we ordinarily do, as implying all kinds of knowledge (that are not contained in immediate intuition). For example, we sometimes think of the ocean as a vast kingdom of aquatic creatures; or as the great source of those vapours that fill the air with clouds for the benefit of the land; or again as an element which, though dividing continents from each other, yet promotes the greatest communication between them: but these furnish merely teleological judgments. To call the ocean sublime we must regard it as poets do, merely by what strikes the eye (p. 138).

While, many would take issue with Kant's final sentiment that poets only consider the world "merely by what strikes the eye", his lines do make it clear that the extreme sublime is not about understanding the phenomenon, but about its powerful presence.

The connective sublime is also about the emotions associated with an experience with nature. Wordsworth describes the sublime as a "sense" that "impels" and "rolls through all things". Similarly, Emerson writes of being "exhilarated" and "uplifted" when a "ray of connection" is recognized between the viewer and the natural world. These are certainly overwhelming feelings, but as in the extreme sublime, they do not necessarily involve an understanding of the object. While I see value in fostering these two types of sublime in the science classroom, I also see potential to take the aesthetic ideas of the sublime further. I have been inspired by the powerful emotional aspects of both the extreme and connective sublime, but want to add to them to create a sublime that can be applied to science learning. Unlike the two previously discussed types of sublime, in this new sublime scientific knowledge is at the center of the experience.

The Instinctual Aspects of the Extreme and Connective Sublime

It is not just poets and philosophers who have written about the sublime, scientists have also written about experiences in language that conveys feelings of the sublime. I argue that it is often the sublime aspects of science that initially attract people to the study of science and sustains their interest in the field. While the initial level of the sublime may at first impress and pique their interest, I think that scientists are continually compelled to pursue scientific study as a result of deeper sublime understandings. What I am describing is another, secondary type of sublime, the scientific sublime that results from a combination of cognition and emotion. The scientific sublime may incorporate

aspects of the extreme and connective sublime, but most importantly it represents feelings of awe and wonder that come from a deep understanding of a phenomenon. This sublime differs from that experienced by poets, philosophers or casual observers in that it arises from knowledge of the phenomenon. This is in stark contrast to Kant (1790) who writes that the sublime does not include what we know about an object or event and that instead things are judged sublime "merely by what strikes the eye" (p. 138).

With this type of sublime the feelings of awe and astonishment are based on scientific understandings of the object's inner workings. It is only through a deep understanding of a phenomenon that we can appreciate its true complexity and intricacies, and these understandings when mixed with the emotions of awe and reverence, are sublime. Although Kant describes the initial impressions felt upon the sight of an ocean as sublime, I argue that so too is the experience that comes with understanding the oceans. Truly knowing and appreciating that the oceans are "a vast kingdom of aquatic creatures" can be just as great and inspiring as appreciating the ocean's powerful presence.

Scientists and the Sublime – The Scientific Sublime

While the actual word "sublime" may not be used, the feelings behind the sublime of philosophers and poets are apparent in the writings of many scientists. In the following quotes, each of the previously mentioned qualities of the scientific sublime are evident on some level. For example, an emotional response brought on by scientific understanding is evident in Werner Heisenberg's (1925) writing about developing a new atomic physics:

> At first I was deeply alarmed. I had the feeling that through the surface of atomic phenomena, I was looking at a strangely beautiful interior, and felt almost giddy

> at the thought that I now had to probe this wealth of mathematical structures nature had so generously spread out before me (Miller, 1996, p.23)

Much of Heisenberg's description of physics echoes Kant and Burke's depiction of the extreme sublime. Heisenberg feels "deeply alarmed" and yet is fascinated and "giddy" upon looking into the structures of atomic phenomena found in nature. True to the extreme sublime, for Heisenberg there is something terrifying about peering into the inner workings of the universe. But it is also clear that these feelings of sublime came about only through his deep understanding of atomic physics. His brush with the sublime is not something that a casual observer could experience, instead only someone who truly understands atomic physics could be moved by its "beautiful interior". This awe and wonder that comes from scientific knowledge is also apparent in the following lines Heisenberg wrote to Einstein:

> You must have felt this too: the almost frightening simplicity and wholeness of the relationships which nature suddenly spreads out before us and for which none of us was in the least prepared (Heisenberg as quoted in Chandrasekhar, 1990, p. 53)

This second passage by Heisenberg again conveys feelings of the extreme sublime where Heisenberg is in awe of the "frightening simplicity" associated with the relationships he has suddenly understood. Heisenberg also highlights another important aspect of the scientific sublime, that through understanding, one can see the unity or interconnectedness in nature. He describes this unity as seeing the "wholeness of the relationships" which had so unexpectedly become evident.

This insight into physics was also a very emotional experience for Heisenberg, a necessary ingredient in the scientific sublime. For example, the passage to Einstein begins with "You must have felt this too"; Heisenberg uses the word "felt" rather than

words like "seen", "discovered", or even "realized", making it clear that he is describing n emotion. In both of Heisenberg's passages his language is not the objective, neutral words that are ordinarily associated with scientists. Instead they are brimming with excitement and anticipation, embodying the sublime. His passages unmistakably show an emotional response to something great, powerful, and perfect that comes about through scientific understanding. From his writings, it appears that Heisenberg is also actively engaged with the ideas behind physics and that his world has changed as a result of his understanding.

Another example of the scientific sublime can be found in the writing of Nobel laureate physicist Richard Feynman. Where Heisenberg's writing showed an emotional response similar to Burke and Kant, Feynman's (Sykes, 1995) writing more closely resembles the connective sublime of the romantic poets:

> Poets say science takes away from the beauty of the stars – mere globs of gas atoms. Nothing is "mere". I too can see the stars on a desert night, and feel them. But do I see less or more? The vastness of the heavens stretches my imagination – stuck on this carousel my little eye can catch one-million-year-old light... (p. 17).

In this passage, Feynman disagrees with those who would argue that understanding the science behind a phenomenon reduces its aesthetic and romantic appeal, its sense of the sublime. He reports that he not only sees the stars for what they are scientifically, but he feels their presence as well. Feynman's lines are reminiscent of those of Emerson who was exhilarated by his feelings of a strong connection to nature. The sublime is apparent in Feynman's emotional connection to the stars, his amazement at the "vastness of space", and in the understanding that he can glimpse "one-million-year-old light". Feynman makes it clear that his understandings of the working of nature have not taken away from his enjoyment and appreciation of it, but instead have added to it. While poets

can marvel at the stars' appearance, through an understanding of the stars, a scientist can also marvel at and be moved by their amazing complexity. In this case and in the examples from Heisenberg's writing, it is apparent that scientists have a different understanding of the sublime than poets and philosophers. These scientists can feel the awe, admiration, and connection of the sublime when interacting with nature on an initial level, but they also experience these feelings as a result of a deep understanding of nature.

Another example of elements of the connective sublime is apparent when Einstein wrote, "I am a little piece of Nature" (Holton, 1973, pp. 366-374). At first glance, his comment may not seem particularly enlightening, but considered in the context of the feelings aroused by the connective sublime, the simple statement becomes more. Root-Bernstein (1997) elaborates on this same idea,

> That which is true is what satisfies me after I have struggled with it, interrogated it, and pondered the meanings of its answers in light of my experience, my existence myself. I become what I study, and when the I and It merge, understanding has been achieved (p. 69).

Here Root-Bernstein emphasizes the importance of the connection between himself and his object of study in forming true understanding. With Root-Bernstein's statement in mind, Einstein's words become more meaningful and more sublime. Einstein's statement is reminiscent of Emerson's words in the "Crossing a bare common" passage where Emerson claims that through his experience he has become a "part or particle of God." These feelings of supreme unity with nature or an object of study are at the heart of the connective aspects of the scientific sublime. Another example of a scientist who has expressed feelings of connection with aspects of nature and her objects of study is animal scientist Temple Grandin. Grandin's connection with the animals she studies is described

by Oliver Sacks (1995), "...her sense of animals' moods and feelings is so strong that these almost take possession of her, overwhelm her at times" (p. 267).

A final example of a scientist clearly expressing the emotional as well as cognitive aspects of the scientific sublime is apparent in an interview on National Public Radio with astrophysicist Janna Levin:

> ... fact has turned out to be stranger than fiction and not only stranger but somehow more moving, more amazing, blows your mind away more than any fantasy that you could hear about more than any mythology that you've learned about. The facts that we've uncovered scientifically are absolutely moving, staggering, overwhelming, difficult to believe and yet you can believe them because they follow logically from the first step to the last and that to me is incredibly exciting and powerful." (Jan 30, 2004)

Notice the sheer number of classic sublime words and terms Levin uses in these few lines: "moving", "amazing", "blows your mind away", "staggering", "overwhelming", "exciting", and "powerful". Levin's statement is charged with emotional enthusiasm. It is also important to point out that Levin uses these emotional words in conjunction with more conventional scientific ways of thinking. Her feelings of the sublime are "uncovered scientifically" and "follow logically from the first step to the last". Levin's quote epitomizes the scientific sublime where strong emotional responses are coupled with deep scientific understanding.

Scientific Sublime as Compelling Experiences

The combination of the cognitive and affective found in the scientific sublime do not come about by memorizing concepts, but arise from understanding ideas. Scientific sublime experiences result from stirring ideas and become compelling experiences.

Dewey referred to ideas as encompassing every part of an educative experience, except those that are stagnant and retreating. Ideas instigate action and lead to *an*

experience as they are tested out either physically or in one's imagination (Wong & Pugh, in press). Dewey's notion of *an* experience, alternatively called aesthetic experience or educative experience, differs from everyday experiences in that it is a dramatic, compelling event with a history or plot that is full of emotion. Just as in a good novel where the reader cannot help but read on while anticipating what will come next, in a Deweyan experience the learner is driven forward by anticipation. This anticipation not only leads to a sense of drama or excitement, but is also a natural motivation for learning. Through anticipation "learners get a sense of what might be and are inspired to move forward. Thus, learning not only results in understanding, it is also compelled by it." (Girod & Wong, 2002, p. 204)

I have drawn on Dewey's explanations of educative experiences to think about scientific sublime experiences. Both are filled with emotion and involve the learner being overwhelmed and engulfed by the experience. "The child is simply absorbed in what he is doing; the occupation in which he is engaged lays complete hold upon him." (Dewey,1900, p. 145) As a result of these experiences, the learner begins to see and be in the world differently. Just as someone who has witnessed the awesome power and destruction of a hurricane can never look again at the ocean in the same way, sublime and educative experiences transform the way we see the world. And while Dewey recognized that aesthetic experiences and their vital appreciations apply to science, an exploration of the scientific sublime can shed much needed light onto the area of science teaching and learning.

Why Sublime Science Education?

The goal of my dissertation research is to meaningfully connect these ideas of the scientific sublime with science education. I have identified three main rationales for pursing this purpose: 1) To provide students with a more accurate view of science, 2) To help foster an appreciation for science and the natural world, and 3) To provide experiences that allow students to see and be in the world differently.

Provide students with a More Accurate View of Science:

The previous examples of scientists experiencing the sublime in their work show a side of science that is rarely seen. Because science educators look to the field of science to determine the content, processes, and mind-sets that should be taught, it is problematic that the affective side of science is rarely mentioned. Unfortunately, students are most often given an image of scientists as unemotional and objective, distant and painstakingly rational. Recent science education has focused on cognitive aspects of science such as conceptual change (Posner et. al, 1982), scientific inquiry (NSE Standards, 1996) working and talking as scientists (Lemke, 1990), and strong inductive reasoning skills (NSE Standards, 1996) Each of these efforts has enriched our understanding of science teaching and learning, but the affective aspects of science are missing. As a result, our students are receiving an inaccurate view of the domain. In contrast to the widely taught view of science, scientists like Levin, Heisenberg, and Feynman have more recently shown us that science is full of emotion, excitement, and wonder. The following words by Shirley Tilghman a molecular biologist and president of Princeton represent a new approach to incorporate some of the affective qualities of science into science education:

> I'd like to see us teaching more than a canon, a collection of facts, but why this is exciting, why is the exploration of nature one of the most wonderful ways to spend one's life (New York Times, July 8, 2003).

While it is important that students have a strong conceptual understanding of the material, ask important questions, feel enough a part of the scientific community to talk like scientists, and develop reasoning skills, I want more for my students. I want them to be fully engaged with science ideas, to be impressed, awe-struck, and moved by what they are learning. I want my students to encounter the sublime in science and be inspired and stirred by what they study. Aspects of sublime experiences compliment these other endeavors in teaching and learning science by helping to explain why students would want to engage in science learning. These other approaches only emphasize the cognitive aspects of science and for the most part leave out the affect. Scientific sublime experiences represent a more sophisticated treatment of the affective qualities of learning. The affective aspects of experiences are typically seen as separate and even superfluous to the more 'central' cognitive qualities of learning. However, this account cannot explain the learner's motivation, the awe and exhilaration experienced in the act of learning that sustains the often difficult process. We are motivated to learn not simply to make sense of and adapt to the world, but also to have experiences in which we feel the exhilaration of learning. Scientific sublime experiences are an attempt at the re-integration of cognition and feeling.

It seems that at the core of all these approaches to science education is a desire to change the way students understand the world in light of what they have learned. In order for learning to have a lasting effect on students' perceptions of the world, they must connect with it in some way. Science is potentially an exciting field of study that helps

explain the natural world, but it is usually taught in ways that do not highlight its inherent interesting qualities or even worse destroy any natural curiosities students have. It seems essential to highlight the dramatic, compelling aspects of science in order to promote science learning. Of course it is not enough to pique student interests through the extreme and connective sublimes, instead sublime experiences that are coupled with understanding must be the goal.

As is evident from the writings of many scientists, the emotional and aesthetic aspects of science are an important part of discovering, creating, and understanding science. The previous quotes by Feynman, Heisenberg, and Levin make it clear that aspects of the sublime underlie their understandings of science. When these dramatic, emotional, and aesthetic aspects of science are not allowed to surface in the classroom, students may find it difficult to relate to science and form negative opinions of the subject. Along this same line, feminist theory has criticized the common way science is portrayed as being an objective and dispassionate domain (Harding, 1991;Duran, 1998). Students are encouraged to emulate scientists who are represented as detached and removed from their objects of study. This depiction of science, while largely false, surely has a negative effect on some students and may discourage them from pursuing science. Perhaps by teaching science with the explicit goal of fostering sublime experiences for students, students will gain a more accurate view of and appreciation for science.

Appreciation for Science and the Natural World

Reform in science education has consistently recommended that students should have an appreciation for the natural world, positive attitudes towards science, and general enthusiasm for learning. Unfortunately, typical science education rarely works towards

fostering this. In contrast, appreciation is an important component of a sublime experience and entails not only respect and understanding, but also a sense of rousing engagement. Using Dewey's work I will elaborate on what is meant by appreciation and its centrality not just to sublime experiences, but also to science education as a whole.

There are aspects of the sublime in what Dewey (1933) called "vital appreciations", something he defines as "ideas involving emotional response and imaginative projection" (p. 341). For Dewey, appreciation is a special kind of experience not a state of possessing a certain set of knowledge or facts. In terms of education, appreciation is a word usually only applied to art or music appreciation class. In these classes students are expected to gain more than an understanding of how a piece and its artist fit into a period or a general sense of the quality of the work, they are also expected to form feelings of admiration and regard. Students should be able to do more than rattle off aspects of the work; they should come to respect and appreciate it through interacting with it. Students can gain new insights when they incorporate what they have learned about the background of a piece along with time spent studying and puzzling over the actual piece. Works of art and music are meant to elicit emotional responses and through interactions with them it is expected that students will respond emotionally and be in some way moved.

Dewey believed that these appreciations were not limited to the arts. Vital appreciations "are ultimately as necessary in history, mathematics, scientific fields, in all so-called 'informational' and 'intellectual' subjects, as they are in literature and the fine arts" (Dewey, 1933 p. 341). In regards to science education, appreciation is certainly one of the most important things we can work to convey to our students. To get at this

appreciation, science class should be taught more like a good art or music appreciation class. Students should be expected to learn concepts and ask questions, but just as importantly they should be moved by what they study. In order for students to be affected by science, science teachers should take a cue from good art and music appreciation teachers. Art appreciation classes point out remarkable and exemplary works and help students understand what makes them so, likewise science teachers should highlight the amazing and awe-inspiring in their field.

Art teachers also call attention to the interesting aspects of a work of art that may otherwise seem ordinary or chaotic to the inexperienced student. This should also be a goal of science teachers - to show students the sublime in not just the extraordinary but also in seemingly ordinary experiences. This line of thinking again comes from Dewey's concept of appreciation, he saw it as an "...enhancement of the qualities which make any ordinary experience appealing, appropriate – capable of full assimilation – and enjoyable."(Dewey, mw.9.246) It is through the scientific sublime, a combination of the cognitive and affective, that students can gain an appreciation for things that may have once seemed ordinary.

Seeing and Being in the World Differently

I am certain that most science teachers hope their teaching causes students to see and understand the world differently. Often this results in students who can name and describe objects and events in the scientific or natural world. These students can identify and categorize various flora and fauna or describe the steps involved in a process like photosynthesis, but the world has not necessarily changed for these students. Teaching

for sublime experiences goes farther than this, where the result of such experiences is an impossibility for the learner to see the world in the same way.

Sublime experiences are more than a state of knowing, but are emotional events or interactions between the observer and the content. As in the examples from Heisenberg and Feynman, out of a scientific understanding arise feelings of awe, insight, and connection that forever changed the way they saw the world. To briefly return to art appreciation, Jackson (1998) discusses Dewey's ideas of appreciation in ways that emphasize the resulting change in the way learners see and live in the world:

> The true appreciator of an art object, for Dewey, is not the casual listener or viewer. Rather, he is someone who has spent time with a work, has found it engaging, stimulating, puzzling, perhaps even troubling, and as a result of his sustained exploration of it, has undergone a significant change of some kind. His encounter with the object of performance forces him to modify his former habits, his old ways of looking at things. The new and the old become integrated. They form a new pattern, a new way of perceiving.

This passage highlights several crucial factors not only in appreciating art, but also in experiencing the sublime. Just as in the scientific sublime, a true appreciator is not a casual viewer, but is someone who has spent some time with an object. An accidental observer can easily see the extreme sublime in the power of tornadoes, but only someone who has spent time studying them is moved by the surprising delicacy of such a storm. These sublime experiences "inspire moments of heightened awareness; once one sees a tornado, vast pattern of limitless energy, he never quite sees nature the same way again." (Wilson, p. 74, 1998) As Jackson points out, the viewer undergoes a "significant change" and is forced to forever alter the way in which he sees the world. After experiencing the scientific sublime, the world becomes a richer, more interesting place for the learner.

Chapter 2: A Pedagogical Approach to the Scientific Sublime

Introduction

The goal of this research was twofold: to create and teach a curriculum that fosters scientific sublime experiences in middle school science classes, and to better understand how these experiences are manifested in students. In order to create an approach to teaching for scientific sublime experiences, it was first necessary for me to identify key characteristics of such an experience. Based on previous work by Prawat (1991, 1993) Wong (2001), Girod (2001, 2003), and Pugh (2000, 2002) in the field of science teaching and learning, and drawing heavily from Kant and Burkes' aesthetic philosophies of the sublime, as well as the poetry of the Romantic and Existential poets, and finally from the writings of scientists, I have developed a set of qualities that make up a scientific sublime experience.

Qualities of a Scientific Sublime Experience

I define a scientific sublime experience as one which combines the cognitive with the affective; an experience where the learner is inspired, awed, and moved by a deep understanding of scientific ideas or processes. I have determined three main qualities of the scientific sublime experience that I hoped to foster in my students. They are:

1. Being awed by how science ideas reveal the world
2. Developing insight through engagement with the ideas
3. Seeing and being in the world differently

The first and second qualities, being awed by how science ideas reveal the world and developing insight through engagement with the ideas, represent understanding in the scientific sublime. These experiences do not exist only as an instinctual emotional

reaction to the sublime; instead, the scientific content is at the center of the intense emotional experiences. This first quality focuses on emotion in the scientific sublime while the second focuses on the insight and understandings that arise. Rather than concepts, which are simple forms of knowledge, ideas provide different, richer ways of understanding and being in the world (Wong et al, 2000). In the scientific sublime, when ideas are realized, they create a compelling, awe-inspiring experience for the student.

Dewey wrote of the power of ideas to transform our perceptions of the world and felt that art could play a special role in these transformations (Jackson, 1998). Based on this notion, Pugh (2000, 2001) focused on using carefully crafted science ideas to expand student perceptions in similar ways. He called these experiences *transformative* and defined them as actively using the scientific concept, an expansion of perceptions, and an expansion of value. In scientific sublime experiences, I build on Dewey's notion of the power of ideas and on Pugh's work with science learning. Like Pugh's transformative experiences, the second quality of scientific sublime experiences involve engagement with the science ideas, resulting in insight.

According to the American Heritage Dictionary (2004), insight means, "The act or outcome of grasping the inward or hidden nature of things or of perceiving in an intuitive manner." The second quality of the scientific sublime involves the learner reaching a level of insight in which occurs a growing awareness and realization of connections and patterns within a phenomenon and nature. An important part of the scientific sublime is the realization of the coherence between various parts of the phenomenon and the connection to other aspects of nature. Just as physicists search for the grand unifying theory, in a scientific sublime experience the learner seeks to find

unity between and within objects or events. It is only through an insight into the phenomenon that one can recognize these connections. This insight must come from a deep, imaginative engagement with the scientific ideas and results in feelings of awe, excitement, and exhilaration. These are the sentiments expressed by astrophysicist Janna Levin as mentioned in chapter 1:

> The facts that we've uncovered scientifically are absolutely moving, staggering, overwhelming, difficult to believe and yet you can believe them (The Next Big Thing, NPR, Jan 30, 2004)

The last essential quality of a scientific sublime experience is seeing and being in the world differently as the result of the experience. This different way of being in the world does not result simply from scientific understandings, but comes from the total experience with the scientific sublime where sublime emotions arise in connection with content understanding. Just as Jackson (1998) emphasized that a true appreciator of art undergoes some type of change, so too must an appreciator of science. Dewey (1934) writes of the transactional nature of educative experiences where the resulting disposition of the learner is one in which we live, see, and act differently in the world. Based on Dewey's notions of transaction, Girod's (2001, 2003) work on aesthetic learning stressed the importance of students being able to "re-see" the world as a result of their experiences. In "re-seeing", Girod hoped his students would come to see the world anew, to look upon familiar objects in the light of their new aesthetic science understanding and to see them differently. Similarly, after a scientific sublime experience students have gained new cognitive understandings merged with the overwhelming feelings of the sublime and are forced to see the world in a new way. For example, once hurricanes are understood through a scientific sublime lens, the Atlantic will can longer be just an

ocean, but instead a vast energy reserve capable of unleashing horrendous storms. Because of an experience with the scientific sublime, the world has forever changed and one cannot help but see the world in a richer, more interesting way.

Teaching to Foster the Scientific Sublime: A Pedagogical Approach

Since the goal of this research is to foster sublime experiences in the process of teaching and learning science, it is important to describe my pedagogical approach. Again, based on work in aesthetic science education by Pugh (2000, 2002), Wong (2001), and Girod (2001, 2003) and by building on my own experiences as a science learner and teacher, I have identified six aspects of teaching to foster scientific sublime experiences:

1. An emphasis on the content's big ideas
2. The use of metaphor
3. An emphasis on visualization
4. Highlighting the sublime
5. Encouraging imaginative exploration of scientific ideas
6. Modeling a sublime sensibility

Based on the aforementioned aspects of teaching for sublime experiences, I developed and taught two 7th grade science units – weather and ecology. Each unit was based on content typically taught in middle school science classes and teachers at both sites allotted approximately five weeks teaching time for the particular units I taught. For this research, I incorporated each of these pedagogical elements into my teaching, worked to monitor and study their efficacy, and to understand how students responded to them. Each of these aspects of teaching to foster scientific sublime understandings and briefly how they were represented in the two units I taught will be elaborated on in this section.

A more thorough discussion of how each of these teaching techniques were employed and their efficacy is found in Chapter 5.

An Emphasis on the Content's Big Ideas

The first aspect of teaching for scientific sublime experiences is to identify and emphasize the content's "big ideas". Often in science education, facts are over emphasized and the more important, unifying ideas are left out. Prawat (1991, 1993, 1998) has written of the importance of focusing on essential ideas developed by content experts within the various disciplines. This view works on the assumption that some ideas are inherently more valuable than others and should be given greater emphasis in teaching. "The true test of an idea is thought to lie in its ability to open up new aspects of the world, in a cognitive-perceptual sense, for the inquirer" (Prawat, 1998). Identifying and emphasizing the essential concepts around the science encourages the type of conceptual understanding necessary for scientific sublime experiences. Through this understanding, students can gain a perspective that allows them to begin to acquire insight.

In addition, big ideas should be identified as ideas that not only explain the content, but are also compelling in the Deweyan sense – inspiring possibilities to be explored (Prawat, 1993). Rather than teaching a series of small, often disjointed concepts, in teaching with big ideas, the ideas drive the curriculum. For example, the weather unit's big idea is that "weather is the movement of energy". This idea is akin to the way meteorologists think of weather, but is not typically taught in middle school weather units. The idea is powerful because it provides an overview for truly understanding weather, what it is and why it exists. The text book used by the middle school I worked

with on the weather unit did not contain any mention of weather as being driven by energy. Instead, the book built a weather unit on particulars, i.e., various types of precipitation, pressure systems, and fronts. This typical reliance on specifics gives students understandings of what weather consists of, but not what weather *is*. Pugh (2000) used a Deweyan aesthetic approach to teaching science that focused not only on working to create experiences that foster conceptual development, but also in engaging students in content that fosters enriched experiences. Similarly, big ideas should be more than just stagnant concepts to memorize, but should provide unifying understandings that create interesting ideas for students. A big idea should also help be broad enough as to connect other important ideas in science. When such an idea succinctly explains a scientific object or process and when this idea is realized, it can be a powerful and moving experience. It can be astonishing for students to look at a phenomenon like weather, something that most of them felt simply could not be understood or explained, and to realize that the whole process can be summed-up in one sentence.

Big Ideas: The Weather Unit

The weather unit that I taught and researched was developed with a team of university educational researchers as part of a large funded project to develop technology-rich middle school science curriculum. This development team included me as well as two university professors (Prawat and Bell) and another doctoral student (Wojcikiewicz) who met weekly to discuss theoretical foundations as well as our pedagogical goals and sequencing for the weather unit. While this input from the team was invaluable, I was ultimately the one who wrote, revised, and taught the lessons. The group began by deciding on a big idea for the unit. After conferring with a university

meteorologist, we determined that the essential understanding for the unit would be: 'weather is the movement of energy'. In more detail, 'weather is the movement of energy in response to the disequilibrium of the sun's energy on earth'. The second part of this, disequilibrium, is also an important idea seen throughout almost every branch of science. Nature is full of examples of disequilibriums and harmonious processes that work to maintain and restore balance and to a system. An understanding of disequilibrium is not only useful in learning weather, but in many other areas of science as well. In fact with the weather unit we tended to think of it as being about two big ideas; the movement of energy and disequilibrium. The big idea behind weather proved so compelling for a science teacher that we later worked with on the project that for the upcoming school year he has decided to structure his entire 7th grade science course around the unifying idea of the movement of energy.

In addition to being an important and unifying scientific idea, the weather unit's big idea is also potentially ripe for fostering scientific sublime understandings. As previously mentioned, most students came to the weather unit with some knowledge of the component pieces of weather, but did not understand why weather happened. In a survey question that asked students if their understandings of weather had changed as a result of the unit, one student, Jimmy wrote, "Yes, because I didn't know that weather was like that, like weather has energy, that's something I didn't know". Another student, Kyle, found weather, and storms in particular, "interesting because they are made of energy moving."

By giving students a simple explanation as to what weather actually is, there is the potential for scientific sublime experiences based on elements of the connective as well

as the extreme sublime. In terms of the connective sublime, the big idea can help students understand through forming connections within nature and science. By understanding a previously unexplainable prevailing natural process, the world becomes more understandable, more harmonious. Alternatively, in terms of the big idea fitting into the extreme sublime, the understanding that throughout the world, our atmosphere is in a constant state of instability – where energy builds up to a point that it must be moved, often violently – can be an overwhelming idea. In this case, the learner can be left with the Kantian sense of feeling small and insignificant in the universe. Of course, the learner may experience both of these feelings connected with the sublime, alternating between feelings of connection and feelings of astonishment.

Big Ideas: The Ecology Unit

For the ecology unit, I developed curriculum to teach for sublime experiences based largely on the usual ecology lessons taught at this school. Unlike the weather unit, which was in many ways dramatically different in terms of the content covered in a typical weather unit, the ecology unit dealt with more representative ecology subject matter. However, like the weather unit, I picked two related big ideas to emphasize throughout the unit. The unit's related big ideas were: 'all living things are connected' and 'adaptation' - in regards to an animal's unique set of traits or behaviors that allow it to thrive in its environment. As in the weather unit, these big ideas represent themes that are important throughout other realms of science. Understanding that nature is full of delicate balances actually connects with the weather unit's big idea of disequilibrium as the driving force behind weather. Obviously by focusing the big idea on connections within ecosystems, the ecology unit's big ideas fit into the realm of the connective

sublime. Like the weather unit, understanding this idea can create a sense of harmonious understanding of nature and in this particular unit, our personal relationship with nature.

Understanding adaptation can also be a sublime experience. When adaptation is first grasped, it can be an amazing idea that provides a new, interesting way for students to look at animals. For some, animals will no longer be just 'cute' or 'pretty'; the learner now sees them through the lens of adaptation and wonders how survival in a particular environment has helped determine the animal's shape, size, and markings and what role the animal plays in the lives of other animals in its ecosystem. These realizations can be dramatic and compelling, transforming the way the learner sees nature. Adaptation allowed my students to find coherence in nature, to see the world and its creatures differently.

The Use of Metaphor

Metaphors are also an important part of teaching for scientific sublime experiences. Like big ideas, metaphors promote deep understanding by providing a lens through which students can make sense of the world. The use of metaphors has long been supported by cognitive scientists as a powerful way to connect concepts to objects and events in the physical world (Johnson, 1990; Ortony, 1979). They give students a way to grasp scientific complexity by engaging them in ideas. Dewey encouraged the use of powerful metaphors and analogies that allow the learner to see patterns in nature and to see "familiar objects in a new light" (Dewey, 1933, p. 278). Prawat (1999) discusses how metaphors like plants as "food factories" or the heart as "pump" are a natural part of idea acquisition. In addition, scientists also utilize metaphors to aid creative thinking, understanding, and discovery (Root-Bernstein & Root-Bernstein, 1999).

In science teaching, metaphors can highlight connections and patterns within and between phenomena that would be hard to imagine without them. The process of mapping a metaphor onto a phenomenon requires us to focus on a level of detail that may otherwise go unnoticed (Pugh, 2000). This level of focus then results in an expansion of perceptions. Girod (2001) used metaphors as an integral part of his approach in teaching for aesthetic understanding and found students. In the Girod study, students began to see the world around them quite differently after he gave them the metaphor "erosion is a war between earth and water". A common element found in the use of such metaphors was that eventually the details of the metaphor recede into the background and the scientific ideas and new ways of seeing the world are brought to the forefront. Also important, as literary devices, metaphors stir the imagination and encourage the having of aesthetic or sublime experiences.

Metaphor: The Weather Unit

A critical element in the weather unit was the frequent use of metaphor. Early in my teaching I introduced an intricate 'team' metaphor as a way for students to make sense of weather. Throughout the unit, the metaphor became more developed and was applied to different weather events to aid in student understanding and to highlight weather patterns. The basics of the metaphor are as follows: Weather is made up of a 'team' of three 'players' –air, water, and land – that interact with each other in predictable ways. The goal of this team is to combat disequilibrium and redistribute energy on earth. Each type of weather event or storm happens in a specific 'season' and a particular storm can be thought of as a 'game'. Each weather game is made up of three 'plays' – the formation, strengthening, and landfall. Once students became familiar with

the framework that this metaphor provided, they were able to apply it to new weather events. No longer were storms an unexplainable phenomenon, instead students understood enough about the patterns and regularities in weather to make some sense of them. Other, smaller metaphors were used throughout the unit such as seeing the atmosphere as an "ocean of air".

In terms of fostering sublime experiences, the metaphor highlights connections within and between various weather events – an aspect of the connective sublime. Also, in terms of the extreme sublime, the metaphor builds on the big idea: showing a global team of natural elements battling out an epic fight over energy, often resulting in monstrous displays of energy relocation – storms. This metaphor paints a vivid, compelling, and awe-inspiring picture of weather and the nature.

Metaphor: The Ecology Unit

Like the weather unit, there was one main metaphor that was used throughout the ecology unit – that of "the web of life". This visual metaphor was useful in terms of helping students understanding the big idea of 'all living things are connected' and stressed the importance of all forms of life within an ecosystem. Again, this metaphor brings to the forefront the idea of the connective sublime.

Throughout the unit, other metaphors were used to explain aspects of the content. For example, a particularly powerful metaphor showed the process of primary succession as a war between human made objects and nature. Through this metaphor, students saw this war happening all around them – a scraggly weed poking through a patch of asphalt or ivy climbing over and often enveloping old brick buildings. This metaphor was used

to evoke feelings of the extreme sublime in students as students realized there was an epic battle between us and nature, and it appears that nature may ultimately win.

An Emphasis on Visualization

The third aspect of teaching for scientific sublime experiences is an emphasis on visualization. Before I began teaching for this dissertation research, I knew that using pictures and other images would be important both for scientific understanding and to rouse emotion. However, it was not until my first few days of teaching in the weather unit that I began to fully realize the power of pictures and video to evoke sublime experiences. As my teaching progressed it became clear to me how moving a carefully chosen picture can be. Since the sublime is a type of aesthetic experience, and since aesthetic experiences arise from one or more of our senses, it is only fitting that 'seeing' should be so critical to sublime experiences. Just as metaphors foster a creative or artistic way of thinking about science, so too can pictures. Historically, the sublime has long been a part of the world of art and artists. The work of Burke, Kant and others around the emotions of the sublime influenced a group of artists who formed America's first school of art, the Hudson River school. Much of the work of these artists today is called, "The American Sublime". Wilton and Barringe (2003) describe this school of painting as "...an imaginative response to natural phenomena involving a 'delightful horror' prompted by potential danger or the unknown." Within this group, painters depicted different subjects - from landscapes, to storms, to religious themes - with the same desire to capture and convey intense, overwhelming emotion (Klein, 2000).

Much like these early American painters, science teacher can use pictures - photographs, video, or paintings – to evoke similar feelings of the sublime. Such affective

pictures can either illustrate a unique or unfamiliar object, or show a familiar one in a new light. Some of these pictures will instantly convey feelings of the connective, or more likely, the extreme sublime. Other pictures need to be looked at more carefully and analyzed through scientific understandings for their meanings to surface. With all types of pictures, for students to experience the scientific sublime, they need to interact with the image in some way - through personal or social sense making. In teaching to foster these types of experiences, the teacher needs to model and scaffold the process of using ideas to help evoke feelings of astonishment or harmony through the pictures. This can most readily be done through a whole-class discussion of what students as well as the teacher see, feel, think, predict, or wonder about based on the pictures.

Visualization: The Weather Unit

Pictures and video were used extensively throughout the weather unit, particularly of storms and their aftermath. These types of images were used to convey the extreme sublime and just as Kant and Burke would have predicted, produced feelings of astonishing, horror, and awe mixed with a large degree of delight. Students were fascinated by pictures of storms, but they did not simply look at them, they talked about them. Students seemed compelled to talk about what they noticed, what they imagined to happen next, what they wondered about, what they saw deep inside the picture, and how these storms came into being. Another way in which visualization was used in the weather unit was through online simulations called "weather makers" where students used their understandings of weather patterns to create virtual hurricanes, lake effect snowstorms, and tornadoes. The weather makers were a different type of visualization that was engaging and fun for students, but also allowed them to form and then test their

weather understanding. This form of visualization offered potential for scientific sublime experiences – by allowing students to 'see through' a storm into its inner workings and realize the similarities and connections between each storm.

Visualization: The Ecology Unit

The ecology unit used images in much the same way as the weather unit. Throughout the unit students and I looked at and discussed pictures of animals as well as ecosystems in terms of the scientific ideas. The extreme scientific sublime was often provoked, to the delight of my students, by looking at and later examining nature's more dangerous animals like lions, cheetahs, wolves, or snakes. The big idea of adaptation was frequently the focus of much of our investigation while looking at pictures. Students would look at an animal and see it through their understandings of adaptation, recognizing certain characteristics that enabled the animal to live in particular environment and questioning other characteristics that may not seem to belong.

Highlighting the Sublime

Highlighting the sublime is the fourth aspect of fostering sublime experiences. This includes calling attention to what is astonishing, terrifying, unifying, or harmonious about the content. Aspects of the extreme sublime are often dramatic and compelling and easily pique the interest of students. The most important part of highlighting the sublime is what Pugh (2000) calls, "crafting the content" where "The teachers' task is to craft ordinary (and uninspiring) concepts into powerful ideas that have the potential to instigate action, transform perception, and expand value" (p. 61). In terms of teaching for the scientific sublime, this means teachers will have to examine the content and create curriculum that either emphasizes the most potentially sublime ideas or emphasizes the

sublime in otherwise 'regular' ideas. Both the ecology and weather unit make use of this crafting of the content as will be discussed in the following sections.

Other examples of highlighting the sublime are to read first-hand accounts that emphasize the emotional impact of the content - for example reading stories of hurricane survivors, and sharing statistics that emphasize qualities like massive or minute size, power, extreme speed, etc. To highlight the sublime, the science teacher needs to have spent time with the content and been moved by its ideas, objects, and processes; and be able to use her experience with the content to seek out various tools that will most emphasize the scientific sublime for her students.

Highlighting the Sublime: The Weather Unit

To highlight the extreme sublime throughout the curriculum, the weather content was "crafted" around storms. Beginning with a study of hurricanes, followed by lake effect snowstorms, and ending with tornado outbreaks students learned the basic processes, concepts, and vocabulary behind weather through the context of storms. Each of these storms was chosen because of the massive destruction they can cause, which never ceased to delight the students in a Kant and Burke sense, and because they well illustrate the unit's big idea. Specifically, it is easy to see the enormous amounts of swirling energy that are moved in hurricanes and tornado outbreaks. Lake effect snowstorms, though less obviously, are also driven by an energy surplus found in the relatively warm lake waters. This storm, common in Michigan and unique to the great lakes region, was chosen in an effort to connect the curriculum with typical student experiences. Having grown up hearing the term lake effect snow, but never understanding what it was or how it formed made the topic particularly interesting for my

students. This is a case where a more common phenomenon became more sublime through scientific understanding. This crafting of the unit resulted in a very different weather curriculum than is normally taught in middle school weather. The text-book used in this classroom laid out a weather unit that taught vocabulary and concepts - like precipitation, condensation, and evaporation and patterns like low pressure systems and warm fronts, but only mentioned storms in the final two pages of the unit. The way my weather unit was structured, where students learned the concepts and processes in the context of storms seems much more likely to evoke scientific sublime experiences.

Highlighting the Sublime: the Ecology Unit

The ecology unit was also "crafted" around potentially sublime aspects of the content. I knew that most students are interested in animals and learning about them, so the main focus of the unit was on animals, particularly dangerous animals. In order to create the potential for sublime, rather than just interesting experiences, I worked to show students different, captivating understanding of animals based on science - as in adaptation, and also to expose students to new or particularly astonishing or terrifying creatures. In addition, I frequently attempted to bewilder students with statistics like the fastest, the largest, the slowest, the smallest, or the most ferocious animal.

Encouraging Imaginative Exploration of Scientific Ideas

The fourth aspect of fostering sublime experiences is to encourage imaginative exploration of scientific ideas. This can most readily be done in class discussions where students interact with and try out the scientific ideas. Wong (2001) suggests that educative ideas in the Deweyan sense "...are something that seize students and transform them" and that "The goal of ideas-based teaching is to help students to be taken by an

idea and live with it, to be with it in their world" (p.15). Therefore, an important role for the teacher is to create a classroom norm where students are encouraged to 'play' with the ideas by asking questions, and posing hypothetical situations and outcomes. These discussions should encourage imaginative speculation based on students' understandings of scientific ideas. When ideas are explored and applied to new settings, they have the potential to awe and astonish. The following sections give examples from the unit where ideas were explored.

Imaginative Exploration of Ideas: The Weather Unit

The students in the weather unit frequently used tested and explored their understandings of weather in our class discussions. For example, during the weather unit students posed and pondered such student generated questions as, "Could we have a hurricane on Lake Michigan" and "If the president made a giant ice cube and dropped it on a hurricane, would it kill it?" In response to the first question, students worked with their understandings of what it takes to form a hurricane to form an answer that had personal meaning and importance to them. Students were awed and astounded by the idea of a possible hurricane on Lake Michigan; it represented a new degree of danger that had not previously considered. The second question showed great imagination and became a compelling and continuing thought process. Students used what they knew about hurricanes to try to develop hypothetical ways to break one apart before it could do any damage. While engaging in this type of thought process, students' understandings of the world were being transformed. These two examples typify the type of imaginative "playing" with scientific ideas that can lead to sublime experiences.

Imaginative Exploration of Ideas: The Ecology Unit

Students in the ecology unit also participated in working with and trying out scientific ideas during class discussions. A favorite idea these students liked to entertain was 'what makes an animal a top predator?' and what made one predator better than another. In discussions when we were analyzing a picture of an animal, it was common for students to try to use adaptation as a lens for deciding how strong of a hunter the animal would be. For instance, students may point out that a male lion has huge, sharp claws and long, pointed teeth to tear apart its prey, that its color acts as camouflage and its padded paws help it sneak up on an unsuspecting animal. Also, students use their understandings of adaptation to look at an animal and imagine what type of ecosystem it lives in based on its traits and behaviors. In these types of activity, students try out and refine their understandings and begin to adopt them as a new way of seeing the world. These discussions can also illuminate aspects of animals that they had not seen or realized before, resulting in new found feelings of awe and respect for the animal.

Modeling a Sublime Sensibility

The final aspect important in fostering scientific sublime experiences in the classroom is for the teacher to model her own ways of seeing and being in the world – specifically for being moved, appreciative, and inspired by aspects of the sublime in science. There is a large theoretical background supporting the importance of modeling when trying to influence students' perceptions. The situative learning perspective, which places emphasis on participation in a sociocultural activity, views learning as part of a process of enculturation (Brown, Collins & Duguid, 1989; Greeno, Collins, & Resnick, 1996). As individuals participate more fully in the sociocultural activity, they begin to

adopt the culture's values, knowledge, and behaviors (Lave & Wanger, 1991). From this line of reasoning, apprentice type models of teaching emphasize the necessity of scaffolding and modeling to bring learners into a culture's way of thinking and knowing (Brown, Collins & Duguid, 1989; Collins, Brown & Newman, 1989, Palincsar & Brown, 1984). Pugh (2000) and (Pugh & Girod 2002) have focused on this apprenticeship model of teaching in their work with transformative and aesthetic experiences since they see a strong social component to these experiences. They worked to create a classroom community of learners that valued an artistic appreciation of scientific ideas. This was done by modeling their own ways-of-being in the world and by helping students participate in these experiences through scaffolding.

In regards to scientific sublime experiences, the desired classroom community is one where members are free to be moved and inspired by the content, and where scientific ideas are appreciated for the astounding or unifying qualities they can bring to elements in nature. The teacher's task in creating this community is to model her own sublime sensibility and eagerness to be 'swept-up' in the experience. To be truly captivated by the experience is what Wong (2000) calls the "the opposite of control" based on elements of Dewey's educative experiences:

> One must let go – as much as possible - one's long held ways of seeing, doing, understanding, and feeling. The degree that one undergoes, the degree that one can truly experience, is the degree that one be open to the true nature of an outside influence (p. 321).

By releasing control and letting go of our former ways of seeing, feeling, and understanding, we are truly open to a new experience and can take in the effects of the sublime – be they astonishment, horror, harmony, or unity. Through modeling this type of learning experience, a teacher can work to enculturate her students to the scientific

sublime. The teacher should create such a compelling vision of the content that students are eager to become a part of it. Part of modeling a sublime sensibility is to guide students as they practice seeing the powerful, moving ideas in the content.

Modeling a Sublime Sensibility: The Weather Unit

Many of the ideas and images in the weather unit are compelling all in their own right in terms of the extreme sublime and little modeling on my part was needed. The delight experienced in the midst of horror and astonishment that Burke and Kant wrote of is immediately evident to most everyone when looking at violent storms. However, modeling the scientific sublime and its feelings of the sublime accompanied by understanding is often necessary for students to have such experiences. Letting students see how my understanding of the science behind such storms enhances my feelings of awe and amazement, encourages them to want to understand these same scientific processes.

Modeling a Sublime Sensibility: The Ecology Unit

Modeling of my own scientific sublime experiences was equally important in the ecology unit. Like the weather unit, elements of the extreme sublime often immediately arise from pictures and videos of dangerous animals, but experiencing the scientific sublime required some modeling and scaffolding. Using my understandings of adaptation, I was able to show students how to look at animals through the eyes of a scientist and be moved by what I saw. Animals became more intriguing, fascinating, and even terrifying when I helped students use their new understandings of science to look at these animals. Throughout the unit, we practiced seeing animals in terms of adaptations to gain a sense of admiration and respect for the animal's design. While I was able to take

the feelings of the extreme sublime and motivate students to experience the scientific sublime, it was more difficult to instill feelings of the connective sublime. By telling stories of my own feelings of sublime connection to animals and nature I hoped to inspire my students, but as well be discussed later in this dissertation, I had great difficulty in doing this.

Chapter 3: Setting and Methods

Introduction

This research was conducted as two studies in two different middle schools. In order to test my theory of sublime understanding and the efficacy of my developed curriculum and teaching methods, I acted as the science teacher in both studies. Both studies took place in 7th grade science classrooms where I taught for approximately five weeks. While there was a great deal of similarity in my teaching methods at both sites, the schools and students themselves were quite different.

Settings and Participants

Study 1: Semi-Rural Middle School

The first study was set in a small, semi-rural middle school where I taught two sections of 7th grade science – third and fourth hour. The classes were in two different classrooms and regularly taught by two different science teachers, Mr. Platt and Ms. Kelsey. These science teachers' classrooms were connected by an office where they both worked together on developing content and aligning their classes' progression through the course. I taught a total of 46 students, 25 were in Ms. Kelsey's 3rd hour and 21 in Mr. Platt's 4th hour. The composition of the students in the two classes was very different in terms of school success. At this particular school, students were placed into science classes based on their math placement. As a result of this tracking, my 3rd hour science students were typically in algebra 1 while my 4th hour students were in a remedial math class. The regular science teachers commented on what they saw as the differences between the students in the two classes. 3rd hour students were considered overachievers while 4th hour students were thought of as low-achievers. Teacher perceptions did not

stop at academic ability, Ms. Kelsey's 3rd hour students were also considered well behaved and a 'perfect' class for me to work with while Mr. Platt's 4th hour students were reported as not being so well behaved. I was told that these 4th hour students were explicitly placed with Mr. Platt because he was known to be a strict disciplinarian and best capable of controlling such students. This teacher was concerned that I would not be able to mange his students and I was warned that the students would 'not able to handle a child-centered teaching approach'. Student characteristics for the two classes appear in Table 3.1.

Table 3.1: Student characteristics of site 1

Class	Female	Male	Total
3rd hour	10	14	24
4th hour	11	10	21

In both classes, I taught the same unit on weather every day for approximately five weeks. The weather curriculum as discussed in Chapter 2 was a cohesive unit that relied on a definite sequence to develop and strengthen understanding of the important ideas. For this reason, I acted as the primary teacher with both classes. The regular teachers, Mr. Platt and Ms. Kelsey, agreed to give me control as to the material I covered and the manner in which I conducted class. As can be expected there was some uncertainty in the beginning as to handing over their classes and both teachers would often sit in the back of the room to watch while I taught. As a sense of trust developed, it became common for the teachers to not be present during some or all of my teaching. The transition for students to begin thinking of me as their teacher was relatively quick and

uncomplicated. I am sure part of this was because of the large number of student-teaching interns and other pre-service education students from the university at this school. In fact, Mr. Platt had a student teacher who was present throughout the time I was at the school. There were some very noticeable differences in the way the two classes responded to the curriculum and my teaching, but I will leave that for a later discussion.

Site 2: Large, Urban Middle School

The second study took place approximately 10 months later in a large, urban middle school where I taught one section of Mrs. Marcella's 7th grade science class. At this site I also identified a control class of similar students with which to compare learning outcomes. Both groups of students were regularly taught by Mrs. Marcella and she considered both groups of students to represent typical 7th grade classes at this particular school. The treatment class was made up of 16 regularly attending students while the control class had 12 regularly attending students. Unlike the first site where all students were white, there was a great deal of ethnic diversity in this second school. Student characteristics for both class the treatment and control class appear in Table 3.2.

Table 3.2: Student characteristics at site 2

Class	Treatment Class				Control Class				Total
Ethnicity*	A	AA	C	H	A	AA	C	H	
Females	1	6	1	1	0	4	1	0	14
Males	0	5	2	0	0	5	2	0	14
Total	16				12				28

*A: Asian
AA: African American
C: Caucasian
H: Hispanic

The two classes each progressed through a unit on ecology for approximately five weeks. Both the control and treatment class largely covered the same material, but I taught my class (treatment class) using the approach for fostering sublime experiences as outlined in Chapter 2. In contrast to the weather unit taught at the first site, I did not develop a complex, cohesive unit where it was critical that the lessons and ideas be taught in a specific order. Instead, I worked to develop lessons using my framework for sublime understanding to teach within the district's existing ecology unit. The main reason I took this approach was to provide a different type of test of my approach to teaching for sublime experiences. Rather than teach a unit that was conceptualized and planned in a university setting as part of a larger project as was the case with the weather unit, I wanted to work with more typical school curriculum for the next study. In the ecology unit I took the district's and state's learning objectives for ecology to identify the ideas I found most important and compelling. From there I created and constantly updated lessons that would promote sublime understanding of ecology.

This also meant that I would not be required to be the sole primary teacher, but rather to act as an additional teacher. The teacher at this site was reluctant to completely give up her class for the five weeks since she wanted the option of taking one day a week to teach. The days in which she taught were usually to practice reading comprehension skills that were a part of the school-wide seventh grade curriculum or certain activities that she particularly enjoyed teaching. On average I taught four days a week at this school and acted as the regular teacher while I taught. At times Mrs. Marcella was in the room doing work while I taught, but other times she would use the break to run errands and other administrative duties. As in site 1, students at this school were accustomed to

having multiple adults in the room taking a turn at teaching. In fact, Mrs. Marcella's classes had one student-teaching intern, one pre-intern university student there to observe, and one university student there to help tutor for class credit. The students I taught easily accepted me as another teacher.

Research Design

Given this setting, the research questions were:

1. Will students experience the sublime as a result of my teaching?
    - What types of sublime will they experience – the extreme, connective, or scientific?
        - Will students feel a combination of awe, horror, and delight?
        - Will students experience feelings of connection, unit, and harmony?
        - Will students be awed by how science ideas reveal the world?, Develop insight through engagement with the ideas?, See and be in the world differently?
2. To what extent did the various aspects of my teaching help to foster students' sublime experiences?
    - An emphasis on the unit's 'big ideas' and the use of metaphors
    - An emphasis on visualization
    - Highlighting the sublime
    - Encouraging imaginative exploration of scientific ideas
    - Modeling a sublime sensibility
3. To what extent will students learn science content when taught in ways that promote a sublime experiences?

In an effort to investigate these questions I developed a four-stage design that involved developing an instructional unit, collecting various pre-instructional data, teaching an instructional unit while gathering data, and gathering post-instructional data. This four-stage design was similar for each site the difference being that at Site 1 for the weather unit, students were given a written survey about their experiences with the unit and at Site 2 for the ecology unit, students were interviewed at various points throughout the unit to learn of their experiences.

The overall scope of research at site 1 for the weather unit appears as Table 3.3 and Table 3.4 followed by further explanation of each stage.

Table 3.3: Sequence of Research at Site 1 – Weather Unit

$Time_1$ – Development Phase	• Development of curriculum based on school and state standards, but designed to create sublime science experiences for students
$Time_2$ – Before teaching	• Classroom observation to gain a sense of classroom environment and to familiarize students with my presence • Pre-test of content understanding
$Time_3$ – Teaching	• Teaching the developed unit for approximately five weeks • Video and audio tapes of classes • Teacher journal observations
$Time_4$ – After Teaching	• Student experience surveys • Post-test of content understanding

Table 3.4: Sequence of Research at Site 2 – Ecology Unit

$Time_1$ – Development Phase	• Development of curriculum based on school and state standards, but designed to create sublime science experiences for students
$Time_2$ – Before teaching	• Classroom observation to gain a sense of classroom environment and to familiarize students with my presence • Pre-test of content understanding

Table 3.4, continued

$Time_3$ – Teaching	• Teaching the developed unit for approximately five weeks • Video and audio tapes of classes • Teacher journal observations • Student interviews
$Time_4$ – After Teaching	• Post-test of content understanding

In both units, $Time_1$ was an important and time consuming part of the study in which I developed the units I would later teach. Starting with each school's objectives for the specific unit and working from the state's standards and benchmarks, I worked to create the units following the guidelines that I outlined in chapter 2 for developing curriculum to invoke sublime experiences. The specifics of each unit will be discussed at length in the following section.

During $Time_2$, I visited the classroom(s) where I would be teaching at least three times a week two weeks before I began teaching. This was done for two main reasons. First, I wanted to see the classroom's environment and norms, the current teaching methods, and to get a sense for the students themselves. I was interested in observing the regular classroom teachers' teaching styles and to understand to what extent if any they were already teaching towards evoking sublime experiences. As is to be expected, the three teachers whose classrooms I would later teach in had different teaching styles, but none of them showed signs of explicitly teaching towards sublime experiences for their students.

The second reason I spent time in each classroom before my teaching began was to allow the teachers and students to become familiar with my presence. Each of the teachers had volunteered to allow me to work with their classes and I felt an overall sense

of trust from each teacher largely because they were all connected in some way to the university that I was coming from. The teachers introduced me to their students as someone from the university who was going to do a special project with their class.

In two of the three classrooms (Mr. Platt and Mrs. Marcella) there was a university intern who spent everyday in the classroom, had taught earlier lessons or units, and was teaching in the classroom teacher's other sections. In Mrs. Marcella's classroom at Site 2 there were also at times two pre-service university students who were there to observe and assist in helping students in a one-on-one basis. All of the students I worked with had at least one university student present in at least one of their classes. The presence of these university students in the science classrooms, as well as throughout the schools in other classes, made it very easy for me to fit in. Because of the consistent university presence, students and teachers did not see my presence as unusual or particularly intrusive. In fact, for the most part, students thought of me as just another student teacher.

Also in $Time_2$ students were given a multiple-choice pre-test of the content covered in the unit I would teach. In developing the pre-test for the second site I used the district wide standard ecology test as the model for my pre and post test. The test I created used the same multiple choice and matching format and covered the same type of content.

During $Time_3$ I studied my own teaching of the lessons developed to foster sublime experiences and observed the control classroom at Site 2. Most lessons were either audio or videotaped and everyday I wrote down my impressions and reactions to

each lesson in a teaching journal. I also interviewed the ecology students about their experiences at Site 2 throughout $Time_3$.

During $Time_4$, after teaching, all students at both sites were given the appropriate post-test. Weather students at Site 1 were also given the student experiences survey.

Measures

Weather Unit

In the weather unit, there were two sources of information used to look for evidence of sublime experiences in students. The first was my recorded observations from the perspective as the teacher. The second source, and the main way in which I collected information on student sublime experiences was through a written survey. Students were also given the same multiple choice test for the pre and post test. The test was developed based on state standards and on questions that I felt were important to understanding relevant topics such as energy and disequilibrium. The Weather pre/post test is attached as Appendix 1.

Survey

The survey students were given consisted of five open-ended questions that I asked students to write on at the end of the unit.

The questions were:

1. What did you think of the weather unit? Was it interesting, boring, or just another unit?
2. Since the weather unit, have you begun to think about weather differently? How?
3. Have you talked to people outside of class about weather?
4. What was your favorite part of the weather unit? Why?

5. Did you like the way the unit was structured around storms? Why or why not?

Ecology Unit

In the ecology unit, there were three sources of information used to look for evidence of sublime experiences in students. As in the weather unit, the first source was my recorded observations from the perspective of a teacher. The second source of information came from audio taped student interviews conducted throughout the unit. I decided to use interviews as the main format for collecting student experiences because I thought they would provide the best way of learning about student experiences. I received quite a bit of information from the students in the weather unit from the survey, but I was hoping to get at a different understanding of student experiences through an interview. By not having to write their answers, and instead being able to talk at greater length about their experiences, I hoped to learn more about what sublime experiences are like for middle school students.

All but two of the students were interviewed. Due to timing conflicts at the school, I was only able to interview most students once. Students were interviewed in pairs in most situations, but there were a few students who were interviewed alone when their partner did not attend. With the exceptions of two interviews, they were all conducted after school. It was often difficult for students to attend after school interviews because they relied on the school bus to take them home and the busses left promptly after school.

The third form of information that I collected was through audio taping student interactions with pictures of animals. In these interactions, typically pairs of students would be asked to look at a series of pictures and to tell me what they saw. I used this

type of interaction in an attempt to hear students' spontaneous reactions to pictures of animals as part of the ecology unit. Since it is often difficult to capture student experiences after the fact, I thought it may prove effective to record students' first interactions with potentially sublime objects in such a setting.

Chapter 4: Results - Student Experiences

Introduction

This chapter will discuss student experiences with the weather and ecology units in regards to the having of sublime experiences and content learning.

Analysis of Sublime Experiences

This section discusses sublime experiences first in the weather unit followed by the ecology unit.

Site 1: The Weather Unit

At this site, for both sections of weather that I taught there were three main sources of data I used to determine whether students had sublime experiences: student surveys, student writing projects, and observations from my teaching journal. In both classes, fourteen students answered and turned in the survey. When analyzing student answers I looked for evidence of sublime experiences in each of the five questions. To be considered a sublime experience, I was looking for emotional responses similar to those described in Chapter 1 as being either the extreme or connective sublime. If these types of emotions were shown in connection with scientific content, they were considered scientific sublime. To review the types of sublime: the extreme sublime is brought on by the huge, powerful and terrifying; the connective sublime represented as feelings of connection to nature; and the scientific sublime as feelings of emotions that come from understanding scientific content. I also found sentiments that did not seem to fit neatly into any one of these categories, but instead represented a more general sense of the sublime.

To identify sublime experiences in student survey responses I examined student word choice, their reasoning and support for their answers, as well as responses showing a sense of appreciation or re-seeing of the world. When looking at student word choice, I looked for language that matched those I identified earlier for each category of sublime. The following chart shows the words from the student responses and how I have identified them.

Table 4.1: Words "Weather" Students used in Surveys that Demonstrate An Aspect of the Sublime

Type of Sublime	Examples of Word choice
Potential	Beautiful, exciting, interesting, cool, amazing, "love how they look"
Extreme	Mysterious, fascinating, scary, dangerous, loud, "what they can do", weird, big, "power to destroy", deadly, destruction
Connective	none
Scientific	Complex yet simple, unpredictable, pondered, wondered, knowing, comprehend more, more informed, makes more sense

Along with word choice, I also looked at the reasons students gave for answers as a way of determining if they showed elements of the sublime and if so what type.

For example, scientific sublime responses showed some type of interest that resulted from understanding an aspect of weather – a combination of the cognitive and affective. The following chart gives typical examples of each type of sublime found in student responses. I have also included comments that I am calling 'potential sublime' because they do not necessarily correspond to one particular type of sublime, but demonstrate the potential for having a sublime experience.

Table 4.2: Responses Showing Aspects of the Sublime from "Weather" Student Surveys

Type of Sublime	Responses Showing Aspects of the Sublime from Student Surveys
Potential Sublime	• "I found it the most interesting part of science, it is exciting and fun learning new things about weather, something we've seen every day of our lives." • "Tornadoes are interesting because I love how they look" • "Exciting stuff!"
Extreme	• "Tornadoes are the most mysterious and fascinating thing" • "Storms are interesting because it has the power to destroy whole towns." • "I think storms are interesting because they're dangerous, loud, destructive, but can be beautiful too." • "Storms are cool because of destruction" • "I think weather is a lot more dangerous now" • "I'm fascinated by what they (tornadoes) can do" • "Storms are interesting because they can form into something big" • "In my eyes, storms are the most dangerous source of nature." • "Storms are interesting because they are kind of deadly and exciting."
Connective	None
Scientific	• Storms are "interesting because of all the amazing things weather can do just with the resources from nature". • "Storms are very interesting because they are always changing" • "Before I though of hurricanes as just deadly storms, now I think of them as the weather team" • "I really like those (hurricanes) and how they form because they form really cool" • "Storms are pretty interesting. They are so complex yet simple in the way they form" • "Now I like to see how the weather will be from day to day and I like to look at the sky" • Storms are "interesting because they are made of energy moving." • "I didn't know that weather...has energy, that's something I didn't know"

Based on this analysis, I found that in both 3rd and 4th hour 71% of the student survey responses showed evidence of some type of the sublime (See Table 4.4). In both classes, most of the sublime experiences were the extreme, followed by the scientific, and the potential sublime. No evidence of the connective sublime was found in the student

surveys. The percentage of each type of the sublime shown in survey responses by class is summarized in the Table 4.4

Table 4.3: Percentage of "Weather" Students showing some type of Sublime Experience in Survey Responses

	3rd hour	4th hour
% of Students	71%	71%

Table 4.4: Breakdown of the Percentage of Each Type of Sublime shown in Weather Survey Responses

Type of Sublime	3rd hour	4th hour
'Initial'	21%	7%
Extreme	42%	57%
Connective	0%	0%
Scientific	36%	36%

In each class there were two students whose survey responses showed interest in the unit and weather, but gave responses that I could not classify as sublime because they seemed to lack the emotional aspects that must go with that. For example, one student wrote that she liked the unit because "it was fun and interesting", that she had been thinking of weather differently in terms of "how it affects our land", and reported telling her parents about what she was learning in class. While this student expressed positive reactions to the unit, based on her responses I did not include her in the group of students who demonstrated sublime experiences. Each class also had one student who did not find the weather unit to be anything special, reporting it as "ok" or "ordinary". In addition, one student in each section reported the weather unit to be "boring".

Site Two: The Ecology Unit

At site two, there were three sources of data I used to look for evidence of sublime experiences: student interviews, student interactions with pictures, and my recorded observations from class as the teacher. The semi-formal interviews were typically conducted in pairs, with a few exceptions where students were interviewed alone, and occurred throughout the unit. During the interviews I asked students open-ended questions about their experiences and understandings from the unit such as what parts they found interesting and why, whether or not they had been thinking about ecology outside of class, if their perceptions of animals/nature had changed as a result of the unit, and what they thought of my teaching methods.

As another way to collect information from students about whether or not they were having sublime experiences, I asked students, again typically in pairs, to look at and talk about pictures of animas that I showed them. From these transcribed interviews, interactions with pictures, and from observation notes I took and recorded as the teacher, I categorized student responses in the same way I did with the data from site 1.

Out of the seventeen semi-structured interviews, I found evidence for at least one type of sublime experience in every interview. At this site I did not include a 'potential' sublime category in my analysis as I did at site 1. I chose to do this based on the large numbers of vague comments in the transcribed interviews that could be considered to be expressing some type of general sublime feelings such as "cool!", "wow!", or "pretty!". This is especially true in the interviews where I asked students to look at and comment on pictures. These types of comments were so frequent that it became hard to decide if students were actually expressing some aspect of the sublime or simply reacting to the

pictures. Instead of counting all the initial utterances, I focused on student comments that showed greater evidence of representing aspects of sublime feelings; the extreme being based on the large, unusual, or dangerous; the connective as feelings of connection or calm; and the scientific being an emotional reaction that arises through scientific understanding. The majority of experiences were categorized as the scientific sublime (20), followed by the extreme (10), and connective (7). The following chart summarizes the types of sublime experiences found in the interviews at site 2.

Table 4.5: Percentage of Ecology Students Showing Some Type of Sublime Experience in Interviews

	Ecology Students
% of Students	100%

Table 4.6: Breakdown of the Percentage of each Type of Sublime Shown in Ecology Unit Interviews

Type of Sublime	**% of Experiences**
Extreme	27%
Connective	19%
Scientific	54%

Table 4.7: Words Ecology Students used in Interviews that Demonstrate Some Aspect of the Sublime

Type of Sublime	**Examples of Student Word choice**
Initial	Cool, tight, so pretty, interesting
Extreme	Poisonous, deadly, killers, super predator, huge, fastest, biggest, toughest
Connective	Everything is connected, alike, comforting, see it through others' eyes
Scientific	Thinking about the process..., now I see..., it's interesting how...,

Table 4.8: Examples of Sublime Experiences Ecology Students Showed Evidence of Having – From Interviews

Type of Sublime	Examples
Initial	• "Amoebas are cool looking' • "That's so beautiful!" • "That's tight!"
Extreme	• "He's so huge, he's probably one of the top predators, that's so cool." • "... lions and tigers ... trying to get food, they were killers... and these tigers would like whack them, it was cool" • "that's cool... because um when animals...try to eat him he like sprays something at them" • "It was interesting how the cheetahs and lions they eat the other animals running around...and catch them like super predators" • "I think of them (animals) because like when I go outside ... I want to know what little bugs are crawling on me and it might be poisonous."
Connective	• "I talk to my mom about ... how they're (animals) just really special. We're animals, I just found that out, I didn't think about that last year." • "I like being in nature because when you're outside in a forest or in the woods ... it's like, you're walking and it's just so comforting." • "Everything has its own way of living and it's mostly the same you just have to see it through others' eyes." • "It's interesting how like animals are connected"
Scientific	• "I never knew they (coyotes) lived in Michigan before until I learned that in science, I saw it a few days ago...I didn't think they lived in Michigan, I think that's so interesting." • "when I used to look outside I see a squirrel I didn't really know what that means, but now I see them like gathering food to survive." • "You know what's interesting, why doesn't the shark just eat the fish?" • "When I see a rock, I'll be thinking about the process how it went from bare rock to like a forest." • "I watch my dog and how she reacts, like yesterday my dad brought her a bone and she tried to bury it...I was thinking about how like lions are chasing out the hyenas...when they're eating...she wanted to hide the bone so nobody would take it." • "...you go outside and say you looking in the grass and you find mold on the tree or dead branches on the ground, now I got to pick them up and think it's making the environment and resources grow." • "It's interesting how it grows and breaks it down." • "I think it's cool that when you look at an amoeba how you just see it splitting off and keep on splitting..." • "there's a lot of layers to skin and underneath there's tissue and muscle and everything and I was just sitting there and staring at it... and I was like wow that's cool"

Overall, the students at site 2 had a greater variety of sublime experiences from the ecology unit than the students from site 1 had with the weather unit.

Discussion of Sublime Experiences

Based on the data collected during the weather and ecology units at the two sites, several types of sublime experiences were expressed. The extreme and the scientific sublime were the two most common, but the connective sublime did surface some during the ecology unit. Also, in both units students showed evidence of a potential type of sublime experience, one that showed affect and interest, but did not necessarily fit into one category. For the most part, I found these 'general' sublime experiences to result from a lower level of engagement with the content than the other types of sublime. These were more along the lines of the 'initial' sublime I discussed in chapter 1, instinctual, emotional utterances. While these 'initial' sublime utterances like "cool" and "how beautiful" demonstrate affect and interest, these experiences were not the point of this study and can be found in most types of science teaching. Instead in my teaching and research, I focused on the three types of sublime experiences outlined in chapter one: the extreme, the connective, and the scientific.

Extreme Sublime

From the interview and survey data as well as from my observations it was common for students to have extreme sublime experiences. As previously mentioned, the appeal of dangerous situations and objects is one of the defining characteristics of the extreme sublime. In both studies, students were fascinated with aspects of nature in weather or with plants and animals that they saw as at least potentially perilous. It is not

surprising that students were so drawn to the dangerous, both Kant and Burke wrote of this attraction:

> they are delightful when we have an idea of pain and danger, without being actually in such circumstances ... Whatever excites this delight, I call *sublime* (Burke, 1757).

In fact, Kant (1764) even described the sublime using extreme weather as an example, "... a raging storm ... arouse[ing] enjoyment but with horror." Certainly I had a suspicion that students would be interested in these aspects of the sublime when the weather curriculum was designed around storms. When attempting to highlight the sublime in weather, what could be more awe-inspiring than focusing on some of nature's most powerful, destructive, and dangerous events like hurricanes, tornadoes, and snowstorms? The intentional focus on storms at site 1 predictably resulted in students showing evidence of the extreme sublime in classroom discussions and surveys. A quick look at the chart of extreme sublime experiences from site 1 shows typical survey comments. The following quote from a student in the 4th hour section typifies the reactions many students expressed:

> I think storms are interesting because they're dangerous, loud, destructive, but can be beautiful too.

This student is drawn to the danger and destruction inherent in storms, but also finds them both interesting and beautiful. All but two of the students from site 1 expressed some level of interest in storms and the large majority of students expressed sentiments similar to the previous quote. My teaching, in efforts to feed student interest and rouse emotions, placed a large emphasis on the power and size as well as the duration and extent of damage caused by particular storms. I found that once students' interests were piqued with images and statistics about the storms, they were eager to learn how

such storms formed and strengthened. It was also in the context of these storms that students learned important, more typical middle school weather content like weather patterns, high and low pressure systems, and the convection process.

The extreme sublime also became quite apparent in many of the writing projects I assigned. After studying each storm, students were asked to write a narrative describing the science involved in the formation, strengthening, and landfall of a storm from the perspective of someone who is able to safely watch the storm's approach. While I did not explicitly instruct students to emphasize the affective aspects of such an event, all students did so. No students turned in narratives that simply stated the weather 'facts'. The danger inherent in the extreme sublime was obvious in each storm story, some more eloquently illustrated than others. A few powerful examples of student writing:

- As I watch roofs being torn off, people dying, cars flying through the air, I can't but watch in amazement how powerful this cyclone is"
- I can hear the deep chilling moan from every direction. Just the sound sends chills down my spine. ... no one will ever forget the destruction and fury of hurricane Chad.
- Hurricanes are mysterious and terrifying natural wonders and I was awed by the immense power of Hugo. I am safe and sound, and I will never doubt the power of Mother Nature.
- I was wide-eyed with excitement. This was an experience of a lifetime! I was so happy to get to observe this dangerous storm without risk of getting hurt. ... This had been a wonderful, but disastrous storm.

While the poetic tone of these examples may not be typical of all student writings from Site 1, the content is. It is remarkable how closely these student comments echo the sublime sentiments of Kant and Burke, feelings of both fear and fascination are obvious in these imaginative speculations.

While I intentionally highlighted the extreme sublime through a focus on storms at site 1, this was certainly not my intention during the ecology unit at site 2. For the ecology unit, I was hoping to take a different approach to teaching for sublime experiences and to highlight the connective sublime. I knew that the much more subtle feelings associated with the connective sublime would be more difficult to foster, but I thought ecology would be an ideal topic to emphasize the interconnectedness of nature. Early into the unit I realized just how difficult it was to maintain student interest and affect without introducing elements of the extreme. With animals as the focus of my unit, I found that my students had experiences and expectations of animals that I had not anticipated. These aspects of my students' experiences will be discussed later in greater length, but for now it is only necessary to understand that students were looking for the frightful awe-inspiring of the extreme sublime.

In the ecology unit, while I would emphasize how all living things were connected in a cycle from a wolf to a rabbit to decomposers like mushrooms, my students wanted to know how big the wolf's fangs were, how it would kill the rabbit, and whether or not the mushroom was poisonous. It seemed that the students' central interests lay in the realm of the extreme. Due to student interest I frequently used aspects of the extreme sublime to get their attention and lead them towards a scientific and at times connective sublime experiences. In general, students found that the connections between living things and their environment became more interesting as long as dangerous animals were at the starting point. For example, much of the unit came to be centered large African predators like lions and cheetahs. Examples of the extreme sublime in the ecology unit were in most cases related to hunting and killing. Students were very interested in how

big, how fast, and how strong the world's top hunters are. While this trend is not as obvious in the results of the interviews as it is in the results of the surveys and narratives from the weather unit, my observation notes are full of examples of the extreme sublime.

Connective Sublime

The connective sublime, associated with feelings of connections to and unity within nature, was completely non-existent in the weather unit, but did surface occasionally in the ecology unit. Predictably, with the weather unit's focus on extreme storms, students did not show evidence of feeling connected to weather, but instead demonstrated feelings of a respect for nature. In contrast, several instances of the connective sublime did appear in interviews with the ecology students at site 2. These instances usually consisted of the student realizing a connection between themselves and animals. Typically, these students thought of animals as something to fear and avoid so being able to identify with them was very new idea. For example,

- I talk to my mom about ... how they're (animals) just really special. We're animals, I just found that out, I didn't think about that last year.
- Everything has its own way of living and it's mostly the same you just have to see it through others' eyes.

The realization that we are animals, and in fact mammals expressed by the first quote, actually led another student to think that eating meat was wrong. She began to question how she could eat a cow now that she realized it was a fellow mammal. Ultimately, she decided hamburgers were too good to pass up, but it still bothered her that she ate mammals, a dilemma she had never pondered before. Similarly, the second quote shows a students' realization of a connection between living things. This same student stared, mesmerized at the minute swimming creatures in a jar of swamp water. While many of

the students were disgusted by the green slimy water, this student reported seeing connections between herself and the aquatic creatures much like Emerson (1844) found connections between himself and an ant.

> The instincts of the ant are very unimportant, considered as the ant's; but the moment a ray of relation is seen to extend from it to man, and the little drudge is seen to be a monitor, a little body with a mighty heart, than all its habits ... becomes sublime.

Scientific Sublime: Affect Coupled with Understanding

The most important type of sublime experience is the scientific sublime. Scientific sublime experiences are emotional reactions that arise from a scientific understanding of the content; a combination of the cognitive and the affective. These experiences are the goal of my teaching and at the heart of my research. Throughout my teaching I worked to incorporate elements of the extreme and connective sublime with content understanding to result in scientific sublime experiences. At both sites through interviews and surveys, and based on my classroom observations, students showed evidence of having these experiences. As mentioned earlier in chapter 2, I have developed three aspects of scientific sublime experiences:

1) Being awed by how science ideas reveal the world;

2) Developing insight through engagement with scientific ideas

3) Seeing and being in the world differently.

In the following sections, I examine these three aspects of scientific sublime experiences for both the weather and ecology unit.

The Weather Unit

During the weather unit many students' interest in the extreme sublime of storms led them to want to understand the inner workings of such events. For many, once

aspects of a storm's formation, strengthening, and landfall were understood the storm become even more interesting. Analysis of the surveys from the weather unit shows that 1/3 of the responses categorized as being sublime were of the scientific variety. The first piece of the scientific sublime that I will examine is the awe and interest experienced by students as the science ideas learned in the weather unit revealed more of the world to them.

1. Being awed by how science ideas reveal the world

In the surveys, many students wrote that as a result of the weather unit they began to understand aspects of weather that had previously seemed inscrutable. Weather is obviously something that we are exposed to everyday and something that directly affects our lives, but despite our enormous experience with it most people know very little about how or why it comes about. Weather reports are typically seen as little more than a guess and weather events like storms are seen as largely unpredictable. At the same time, because of their capacity for both beauty and destruction, storms are something most people are genuinely interested in. My students were no exception to this norm and came into the weather unit with curiosities about weather and storms in particular, but also with a sense that "weather is just weather", not something that is or can be understood. When I first introduced students to storms they were intrigued by their overwhelming enormity, power, and destruction. They wanted to know the details of the biggest, the fastest, and the most deadly – all aspects of the extreme sublime. But soon students also wanted to know how such phenomena came into being as well as how and why they ended. The fact that there is some order and levels of predictability to storms was a new and interesting idea for students. Many students reported that before the unit they thought

"weather was just weather" and that "weather just happens", but as a result of the unit were surprised to learn that "weather has energy" and reported that "now I know how they [storms] start and end".

This was a new and exciting idea for my students; it was as if some secrets of the natural world were being revealed. Students were impressed by their continuing understandings and were excited to delve deeper and to apply their understandings to new weather events. The awe and excitement was clearly evident in class discussions and often spilled over to before and after class conversations. I had several students who would regularly rush to class to talk with me for a few minutes before the bell rang about aspects of their new understandings; from showing me books on weather they had checked out from the library or had at home, to discussing shows they had watched on television or their own personal stories about weather. Other students reported talking about weather with their friends and family after school, sharing the exciting things they had learned in class. I had the sense that my students were impressed with what they were learning, with how they were able to explain the formerly unexplainable. There was one class discussion in particular where several of my 4th hour students talked about how much more they already knew about weather compared to the rest of their family and claimed they were becoming "weather experts". They were proud of their understandings of such a complex yet interest domain. The following quotes from student surveys give a sense of the awe and inspiration expressed by the students as the weather unit revealed new and exciting aspects of the natural world.

Table 4.9: Examples of How Science Ideas Revealed the World From Weather Survey

• "I find it the most interesting part of science. It is exciting and fun learning new things about weather, something we've seen every day of our lives."
• "Tornadoes, I'm fascinated by what they can do."
• "Me and my friends were talking at lunch about how scary and cool it would be if Michigan had a hurricane. It was a cool conversation."
• "I thought it was interesting because I've always wanted to learn about weather."
• "My favorite part was tornadoes; it is something I've always pondered about."
• "It was interesting because I like weather and always have"
• "I like learning about meteorology because I've always been interested in weather."

2- Developing Insight

The second aspect of the scientific sublime, that of developing insight, is an extension of the previous quality. While the learner is first awed by how science ideas reveal the world in new ways, the next part of the scientific sublime experience involves a deeper level of understanding. As the student, compelled by the interest piqued by the extreme sublime, delves deeper into the phenomenon he or she may reach the level I am calling insight. With this insight comes an awareness of connections and patterns within nature and a realization of the coherence between various parts of a phenomenon. In this unit, students came to recognize several examples of connecting patterns in weather. For example, students were told early on that the 'big idea' behind weather is 'weather is the movement of the sun's energy on earth'. As the unit progressed, this underlying principle became clearer with each storm. In addition to the 'big idea', I gave students a guiding metaphor and framework for storm formation that could be applied to each weather event. These principles became powerful lenses for students to use to make sense of weather. Students were eager to apply their knowledge to new weather events and to use weather themes and patterns to take a stab at the difficult process of weather prediction.

Perhaps the most intriguing understandings for students were the necessary ingredients and steps involved in storm formation. They were amazed that every storm was made of the same three components – air, water, and land, and that each of these 'players' interact in predictable ways across all storms with the same 'goal' of moving energy. Since students began the weather unit with little if any understanding of how and why weather happens, being able to use metaphors, a storm guideline, and their understanding of the big idea to recognize themes and patterns was a powerful concept. In the survey, students consistently expressed their excitement and amazement in being able to understand storm formation as is evident in the examples given in the following chart:

Table 4.10: Examples of Developing Insight from the Weather Survey

• "It is interesting because of all the amazing things weather can do just with the resources from nature."
• "I'm more interested in it [weather], I'm more informed too. I comprehend more about it, it makes more sense too."
• "Storms are interesting because they are made of energy moving."
• "The unit was full of how weather forms, I liked these things because I'd always wondered about it as a kid."
• "It was interesting because I enjoyed learning how different types of weather form, those all were interesting to learn about."
• "The best unit was hurricanes, I really like those and how they form because they form really cool."
• "It's been interesting because when I see the weather I know what it is."
• "I've found out things that make me think differently because I now know how the weather system totally functions."
• "I used to think that hurricanes just form when cold and warm water mix together but I never knew how a hurricane formed, that's why I liked it [the unit] so much."
• "They [storms] were really cool how they formed."
• "I didn't know that weather was like that, like weather has energy, that's something I didn't know."
• "Before I thought of hurricanes as deadly storms, now I think of them as the weather team."
• "Tornadoes, they are the most mysterious and fascinating thing...so complex yet simple in the way they are formed."

These responses emphasize how intrigued students were with understanding the structures behind the still mysterious, but now more understandable phenomenon of weather. As is apparent from the survey responses, storm formation was an especially interesting topic for these students. They were amazed that the same principles behind hurricane formation applied to tornadoes, lake effect snowstorms and most other storms. As Heisenberg was awed by the "frightening simplicity and wholeness of relationships" in nature, so too were my students. I am reminded of Heisenberg's statement in the last student response, "..the most mysterious and fascinating thing...so complex yet simple in the way they are formed." This recognition of relationships and patterns seen in insight is the second quality of the scientific sublime.

3. ***Seeing and Being in the World Differently***

The final quality of the scientific sublime comes as a result of the previous two parts. Students are first awed by the ideas, then through deeper content understanding come to recognize and be intrigued by nature's patterns and relationships. Because of these two processes, students see the world differently. These experiences create a new appreciation and respect for nature. As mentioned in chapter one, Dewey believed appreciation comes from an interaction between the appreciator and the object or phenomenon. Summarizing Dewey's idea on appreciation, Jackson described the appreciator as "someone who has spent time with a work, has found it engaging, stimulating, puzzling, perhaps even troubling, and as a result of this sustained exploration of it, has undergone a significant change of some kind." Many of my students underwent this significant change as a result of their experiences in learning weather. They were engaged by the images and ideas, and put in their time puzzling over the processes. Consequently, the weather and the world

around them began to seem different. Now storms are just as awe-inspiring as when students began the unit, but for more than just their powers of destruction. Through a gained insight, students would never be able to look at weather in the same way. Weather is one of the few areas in science that we are constantly exposed to; from how it affects our daily activities to being mentioned in nearly every news report we read or hear. With this constant exposure, new knowledge and awareness of weather patterns markedly widens my students' understandings of the world. The following chart gives examples from student surveys of seeing and being in the world differently as a result of scientific sublime experiences.

4.11: Examples From the Weather Survey of Students Seeing the World Differently

• "I want to know what the weather forecast is, I used to not care about it."
• "I have thought about becoming a storm chaser"
• "I have thought about weather more, like during homework I'm always thinking about school and what I did."
• "I want to know what the weather forecast is, I used to not care about it."
• "Now I like to see how the weather will be from day to day and I like to look at the sky."
• "I looked out my kitchen window and saw that the clouds were gray 'that could be a tornado' is what I thought, then I named all of the clouds that I know about."
• "I've found out things that make me think differently because I now know how the weather system totally functions."
• "I think weather is a lot more dangerous now."
• "I thought that weather was just evaporation, precipitation, and condensation."
• "Now I'm paying more attention to what the weather man says."
• "I think about weather differently because now I know what could happen to us because of tornadoes, hurricanes, and lake effect snowstorms."
• "I watch the weather channel and I understand it now when I watch it."
• "I know a lot more about how storms form and how different weather can change the storms."
• "I found it the most interesting part of science; it is exciting and fun learning new things about weather, something we've seen every day of our lives."

In addition to the examples from the survey responses of seeing the world differently, there were frequent comments and discussions in class. These discussions centered around how students were eagerly using their knowledge to make sense of weather reports or television shows on extreme weather. This knowledge even presented exciting new career aspirations for some students as several of them wanted to know how one becomes a storm chaser.

The Ecology Unit

Like the weather unit, students who were a part of the ecology unit showed evidence of having scientific sublime experiences. During their interviews, many of the ecology students showed evidence of the three aspects of the scientific sublime: being awed by the ideas, insight, seeing and being in the world differently. While the essence of each of these aspects is similar to those seen in the weather unit, the structure of the data is quite different. In the ecology unit, I spent a great deal of time talking with and recording students. These recordings consist of interviews as well as instances where I asked students to look at pictures and describe what they saw. Both of these methods resulted in rich information about student experiences with the ecology unit. From the interviews, it became clear that many of the students did not have much first-hand experience with animals and often, these experiences were negative. Consequently, since much of the ecology unit was about animals, many of the ideas were particularly eye-opening for some students. Examples of how ideas revealed the world in new ways for the ecology students are in the following table.

4.12: Examples from Ecology Interviews of How Ideas Revealed the World

• "I never knew they (coyotes) lived in Michigan before until I learned that in science, I saw one a few days ago...I didn't think they lived in Michigan, I think that's so interesting."
• "You know what's interesting, why doesn't the shark just eat the fish?"
• "It was interesting how the cheetahs and lions they eat the other animals running around like the baby deer."
• "It's interesting how it grows and breaks it down."
• "I think it's cool that when you look at an amoeba how you just see it splitting off and keep on splitting..."
• "oh that's so cool, I'm learning something new"
• "We are all animals, I just found that out, I didn't think about that last year."
• "It's interesting how like animals are connected."
• "I had no idea that like the lions and cheetahs have like glowing eyes in the dark, I didn't know that and it's so interesting."

After students were introduced to some of the scientific ideas behind ecology, they became interested in learning more. As they further explored ecological concepts, the world of plants and animals and their interactions became even more fascinating. At this point, the second level of the scientific sublime progressed and students began to gain insight into the natural world. This insight included recognition of connections between living things and their environment and a greater appreciation for nature. Nature had been something largely alien to my students - as one boy put it, "I'm more of an inside kind of guy", so often the ecology unit fostered a new sense of respect and admiration for nature.

Table 4.13: Examples for Ecology Interviews that Show Insight

• "when I used to look outside and see a squirrel I didn't really know what that means, but now I see them like gathering food to survive."
• "When I see a rock, I'll be thinking about the process how it went from bare rock to like a forest."
• "...you go outside and say you looking in the grass and you find mold on the tree or dead branches on the ground, now I got to pick them up and think it's making the environment and resources grow."
• "there's like a lot of layers to skin and underneath there's tissue and muscle and everything and I was just sitting there and staring at it... and I was like wow that's cool"
• "The most interesting thing is how animals survive like lions and the big cats."
• "He's probably one of the top predators of reptiles." – based on size, sharp claws
• "they're [animals] just really special."
• "I saw a rabbit blending in with the grass...it made me think about when we was looking at the pictures in class and we were talking about it and how it blends in...it helps them with hiding from predators."
• "Everything has its own way of living and it's mostly the same, you just have to see it through others' eyes."

Just as storm formation was the most popular theme in the weather unit, a favorite theme also emerged in the ecology unit. At this second site, students were incredibly roused by the general concept of survival, hunting in particular. Several students also described the process of secondary succession – the breaking down of rock, cement, etc. by plants as a fascinating idea.

Student interviews also showed evidence of the world having changed for the learner as a result of the scientific sublime experiences. Like the weather unit, many of these changes were profound. Since the ecology students began the unit with little knowledge of nature, gaining knowledge and appreciation for the topic left the world drastically different. As one student said, "I just know more about the world, I know there's more to the world now". Other examples of students seeing and being in the

world differently as a result of scientific sublime experiences had in the ecology unit are in the following table.

Table 4.14: Examples From Ecology Interviews that Showed Evidence of Students Seeing the World Differently

• "When I see a rock, I'll be thinking about the process how it went from bare rock to like a forest."
• "when I used to look outside and see a squirrel I didn't really know what that means, but now I see them like gathering food to survive."
• "...you go outside and say you looking in the grass and you find mold on the tree or dead branches on the ground, now I got to pick them up and think it's making the environment and resources grow."
• "Science is all around you, why would you want to put yourself in a position where you don't know what is around you?"
• In reference to microscopic organisms in pond water: "I was just thinking how... like a certain area in the world is just like your own home, there are certain parts of it and there are certain ways that they move around, just the way they interact with things and just like you wake up in the morning and see your father... a fish wakes up and you know they're like watching their father too."
• "Now I look at my dog and I see that she has fur so she's a mammal."
• "I watch my dog and how she reacts, like yesterday my dad brought her a bone and she tried to bury it...I was thinking about how like lions are chasing out the hyenas...when they're eating...she wanted to hide the bone so nobody would take it."
• "Everything has its own way of living and it's mostly the same you just have to see it through others' eyes."

Ecology Student Interactions with Pictures: The Scientific Sublime

Along with more typical interviews, I gathered information from students about their understandings and experiences by showing them pictures of animals and asking them to talk about what they saw and thought. Usually these episodes were not only interesting for the student, but very telling from a teaching and research perspective. Each of these sessions involved students looking at pictures of animals, some they were familiar with, others that were new to them. I carefully chose visually appealing pictures that highlighted sublime aspects of animals, many of which were from one of two books of animal photographs. I was purposeful in selecting pictures that I thought would rouse

an emotional response and, knowing my students I capitalized on the extreme sublime. One of the books I used was a beautiful collection of photos of unusual and often dangerous reptiles and the other contained many wonderful pictures of large cats in the wild. Ultimately, I chose both books because they captured the dignity and splendor of nature.

Once students were given a book to look through, they were quickly mesmerized by the images and wanted to be able to leisurely look through and talk about the entire book. On three occasions I pulled students out of class to work with me around these pictures while a Halloween or end of the marking period party was going on back in the classroom. I had expected students to rush through the interview in order to return to the party, but on the contrary, each group of students asked to continue looking at and talking about the pictures rather than rejoining the celebration. Students were continually amazed and awestruck by what they saw and enjoyed telling me and their fellow classmate about what they could tell about the animal from the picture. They were using their new ecological knowledge to make sense of the animals they were looking at and found the process deeply gratifying. This enjoyment was obvious in both the "ohs" and "ahs" uttered upon the first look, but even more so in the sense of animated urgency with which they talked about what they were seeing. Of course students had become accustomed to looking at and thinking about pictures in this way since I led similar activities nearly every day in class. But it was gratifying for me to see them initiate this type of interaction on their own and to see how they not only had become quite adept at applying their new understandings but also how much they enjoyed the process. Upon reviewing the transcripts from these sessions, I have found elements of the scientific sublime in all of

them. Students generally seemed to experience a Deweyan type of transaction with the picture – scrutinizing, puzzling over, and appreciating the animal. As a result, both the observer and their understanding of the animal were changed in the process. The student often left the activity finding the animal more beautiful, interesting, and awe-inspiring.

In the transcripts of this type of student interview, clear patterns of cognitive and affective processes emerge. Typically, there were sequential steps in these encounters that map onto the four aspects of scientific sublime experiences: Initial interest (general, connective, or extreme sublime), first level of sense making (being awed by the ideas), second level of sense making (insight and appreciation), and seeing and being in the world differently.

The transaction begins when students first look at the picture and are moved by some aspect of the sublime; whether it is a shiver of fear provoked by a stalking panther's defiant, hungry stare; a glimmer of connection seen in an orangutan's curious expression; or the breathtaking beauty of a leopard's shiny spotted coat. Whatever the prompt, some feelings of the sublime surface and pique the observer's interest. This is when the "ohs" and "ahs" were heard as well as typical utterances like "it's so beautiful", "how pretty", "that's huge!", "cool!", "that's tight!", or "look at that!".

In every case, the initial interest provoked by a facet of the sublime was followed by the first level of sense making. This is the step where students begin to apply the concepts learned in the ecology unit. At this point it was as if students verbalized a mental check list, pointing out things they could tell about the animal upon first glance. Examples of this list making include, "It has fur so I know it's warm blooded", "Look at those sharp pointy teeth, it must be a predator", "It has camouflage so it needs to hide

from other animals, probably to not get eaten". I was always impressed with the enthusiasm with which students used their scientific lenses to begin to analyze the animals they were looking at. Students enjoyed applying the knowledge they had gained in class to a new setting and animal. And as they applied this knowledge it was clear that the animal, and I argue the world, become more interesting in the light of powerful ideas like adaptation.

In most cases, students did not stop at this first level of sense making, but instead looked deeper and showed not only awe, but also appreciation and insight. In this stage, students noticed things that only those who have studied parts of ecology like adaptation would notice. This includes a deeper understanding and appreciation for the animal and its relationship with its environment. An example of this insight and appreciation was common in students' quest to identify nature's 'super predators'. A super predator, a term introduced in a nature film we watched in class, would have to be an ultimate killing machine, adapted perfectly for hunting in its environment. Students loved to nominate an animal for super predator status and then to analyze and debate its qualifications for such a prestigious title. A typical scenario is one in which two boys are examining a picture of a particularly elegant cheetah. At first they notice that the cat has excellent camouflage since it blends in well with the African grasslands and must be "good at sneaking up on things". They then call attention to its long slender legs, the flexible spine, and long tail to help it balance at top speeds, and correctly note that this animal "can probably outrun anything". The sharp claws that will enable the animal to "swat at" and knock down its prey and the big teeth that will latch around an animal's throat to suffocate its victim are all noticed. Finally, one of the boys points out the black 'tear stripe' running under the

cat's eyes will help it hunt during the day, serving as an anti-glare device. After this meticulous examination of the picture, the boys cheerfully deem the cheetah a super predator. This typical example of insight in the scientific sublime shows how students apply their knowledge of ecological themes and patterns to create a more complete understanding and finish with a new sense of awe and appreciation.

Content Learning

For both units, students were given a multiple-choice pre-test before the unit and given the same test again approximately six weeks later as the post-test.

Weather Unit

The weather test was based on the state's standards for the content as well as some questions that covered processes or ideas that I found important but were not necessarily covered in the state's standards.

Table 4.15: Average Score for Pre and Post Test by hour for the Weather Unit

Hour	Pre-Test	Post-Test
3rd hour	56%	82%
4th hour	56%	80%

The results from the pre and post tests at site 1 show similar learning outcomes for both 3rd and 4th hour students. The following chart shows the average pre and post test scores for the weather unit.

Ecology Unit

The ecology unit's test was modeled very closely on the school district's ecology unit test. The same types of questions were asked about the same content, only the specifics of each question were changed so the two tests would not be identical since it

would be given to students, and used as part of their unit grade, a few days after I administered my post test.

At site 2, the test was given pre and post to the students I taught and to a similar control class that was learning the same material but with the regular teacher using the teacher's customary ecology unit. The following chart shows the average pre and post test scores for the ecology unit.

Table 4.16: Average Score for Pre and Post Test for the Ecology Unit

Class	Pre-Test	Post-Test
Experimental	71%	83%
Control	70%	77%

While students in both classes began with similar average pre-test scores, my students outperformed the control group on the post-test.

Chapter 5: Results - Efficacy of the Pedagogical Approach

Introduction

Drawing from my experiences teaching the weather and ecology unit and from student feedback in class discussions, interviews, and surveys I have collected information on the efficacy of my pedagogical approach. From chapter two, the basic components of my theory of teaching for sublime understanding are as follows:

1. An emphasis on the big ideas
2. The use of metaphor
3. An emphasis on visualization
4. Highlighting the sublime
5. Encouraging imaginative exploration of scientific ideas
6. Modeling a sublime sensibility

This chapter will describe how these aspects of my teaching approach were manifested in the units and examine the effectiveness of them in terms of fostering sublime experiences. In particular, I will address each aspect of my teaching model in regards to how they materialized in each unit, how students responded to them, and their relative success in fostering sublime experiences. Finally, the chapter closes with a reflection on my experiences as the teacher of the unit and the generalizability of my pedagogical model as a teaching tool.

1. An Emphasis on the Big Ideas

As discussed in chapter 2, identifying and emphasizing the content's essential understandings or 'big ideas' is a critical part of teaching for sublime experiences. In order to inspire students with powerful science ideas and lead them towards sublime

insight, the teacher must call their attention to the essence of the topic. Understanding and applying big ideas throughout the content helps ensure that students form a holistic understanding rather than simply memorizing facts. Scientific sublime experiences rely on this type of deep understanding to move and inspire the learner.

Big Ideas: The Weather Unit

Both units were guided by what I identified as the content's most essential understandings – the big ideas. In weather this was, "weather is the movement of energy in response to the disequilibrium of the sun's energy on earth". Understanding that weather is driven by an energy disequilibrium gave students a more sophisticated understanding of weather. This big idea helped students understand why we have weather and became a powerful tool for making sense of new weather patterns. For example, when investigating a weather event like blizzards, students used their understanding of the big idea to know that the storm must begin in an area of energy buildup.

The big idea was useful throughout the unit as we examined each storm and also in explaining everyday weather like fog and rain. As the teacher I spent time setting up the big idea by introducing the sun as an enormous ball of energy that gives life to the creatures of earth. Students also examined the unequal ways in which this energy reaches earth and the ensuing disequilibrium that drives weather. It seemed that this introduction was a necessary step for students to understand weather as the movement of energy in response to a global or world-wide energy disequilibrium. In addition, this step served as a powerful way to introduce students to aspects of the extreme and scientific sublime. Many students seemed awe-struck when they learned of the massive size and incredible

heat energy of the sun and were surprised to learn that it was the origin of all weather on earth. For the students, the sun had previously only been associated with what they saw to be an absence of weather - such as a clear, sunny day. As the unit progressed, students learned that weather actually arises in response to the sun – to counteract the sun's concentration of energy at the earth's equator. Understanding this big idea proved not only to be a powerful tool for students to gain a more complete understanding of weather, but was also an interesting idea that helped move them towards scientific sublime experiences.

It is interesting to note that the standard weather unit normally taught at this school did not include any mention of the sun's energy or disequilibrium – concepts that were at the heart of my unit. Instead the regular weather unit focused on the particulars of weather – vocabulary and process like pressure systems and fronts – but largely removed from the context of weather events like storms. In the student survey given after the unit some students made specific mention to the big idea and its role in their interest and understanding of weather. For example, in response to the question of asking if students thought of weather differently because of the unit, a third hour student, Mickey, wrote, "Yes, because I didn't know that weather was like that, like weather has energy that's something I didn't know." Similarly, Kevin, another third hour student wrote that storms are "interesting because they are made of energy moving". Another student, Dan, wrote that his view of weather had changed as a result of the unit "because I thought that weather was just evaporation, precipitation, and condensation." These student comments are gratifying to read and show a deeper understanding of weather than a mere

memorization of weather details. I believe this deep student understanding came as a result of explicitly teaching the unit with a continual emphasis on the big idea.

Big Ideas: The Ecology Unit

The ecology unit also made use of big ideas and metaphors, but in slightly different ways. Rather than one dominant big idea as in the weather unit, the ecology unit included two related big ideas – 1) all living things are connected, and an extension of this idea, 2) animals have adaptations to help them survive in their environment. While adaptation is a large topic I taught it as the way in which animals are almost 'perfectly' designed for their environment. Both ideas emphasize how organisms live and interact with their surroundings although we largely focused on animals rather than other types of living things. These big ideas provided a very different way of thinking about animals for my students. I found that many of the students came to the unit with some understanding of ecology terminology, largely from the nature programs they watched on TV, but they did not have a sense of the science ideas behind the terms. For example, they did not understand how species interact with and affect each other or that animals had specific traits and behaviors to help them survive in a particular environment.

I found that animals were an inherently interesting topic for the students and they were eager to better understand them. For many students these understandings came as revelations, especially when they applied to predator/prey relationships. An example of this surfaced when we studied the big cats of Africa. Students had some sense that the coat colors and patterns of cheetahs, leopards, and lions helped them blend into their surroundings, but they had did not know how much information could be learned from the seemingly trivial detail of the coloring around the cats' eyes. Cats with black around

their eyes hunt by day while those with white 'tear stripes' hunt by night. The black fur serves as anti-glare while the white works to reflect upwards to the eye what little moonlight may be available. The fact that nature had provided these 'super predators' with traits and behaviors to maximize their likelihood for survival was a compelling idea for many students. As with the weather unit, I think that this second group of students gained a relatively holistic understanding of ecology as a result of my continuing focus on the big ideas – that all living things are connected and as a result an animal's environment greatly influences an animal's traits.

2. The Use of Metaphors

As mentioned in previous chapters, metaphors were an essential aspect of my teaching approach. They played an important role in helping students form understandings of the scientific content as well as fostering scientific sublime experiences. By forming comparisons between scientific ideas and things or processes students already know, deeper understandings of the scientific content are likely to result. In addition, metaphors can help many students better imagine or visualize the science to help them see the world as a richer, more interesting place. Both the ecology and weather units made use of big ideas and metaphors, although the ways in which they were used differed between the two units.

Metaphors: The Weather Unit

The weather unit centered around a detailed guiding metaphor that was used extensively: namely, weather as a team. The team metaphor, where air, land, and water are depicted as team members who must work together in an interactive and systematic way to produce the desired outcome (e.g., score a goal in soccer or create a hurricane in

weather), was a way to build on and illustrate the big idea and proved to be a powerful way for students to think about weather. More the most part, students found it easy to apply their knowledge of a sports team to the intricacies of weather.

Before the unit began, there was some concern as to whether or not all students would be able to relate to a sports team, but ultimately this did not prove to be problematic. In addition to assisting with understanding the big idea, the team metaphor also provided a framework that students could use to analyze new weather events. To help illustrate this, recall that the team metaphor was broken down into several levels: each weather event is made up of the same three "players", there are specific "seasons" when each type of game (type of storm) occurs. In this extended metaphor, particular storms, like Hurricane Andrew, can be thought of as "games", and perhaps most importantly, each game is made up of three "plays" -- formation, strengthening, and landfall. These stages or 'plays' allowed students to understand that storms do not merely spontaneously form, but instead progress through a predictable sequence. This framework equipped students with a way of examining and making sense of new storms and proved to be particularly powerful. Weather began to be comprehendible to students when they realized they could apply a consistent framework to almost every weather event.

In addition to the cognitive benefits of using metaphors in teaching, as a literary device the metaphor stirred the imagination and made weather more interesting. Students began to envision weather and storms as an eternal competition between two forces - those with energy and those without. This depiction was an entirely new way of looking at nature, weather in particular. Most of these students began the unit with a sense that

weather just happened, but by giving them an explanative metaphor, weather became a richer, more attractive topic of study.

Storms became more than isolated enigmatic events, but became part of a larger, comprehensible, and fascinating pattern. For example, one student wrote in his survey, "Before I thought of hurricanes as just deadly storms, now I think of them as the weather team (James)." I found that teaching with this extended metaphor was an effective way to focus many of the lessons. As I taught new material I could relate it to the familiar weather as a team analogy. The use of the online weather makers that we created also turned out to be a nice connection to the metaphor. As students worked on the computer to create a hurricane or lake effect snow storm, they used their understandings of the team metaphor to create the 'perfect storm'. For example, I instructed students to think in terms of the three 'players' – air, water, and land – when adjusting variables on the weather makers. I encouraged students to think about the largely consistent role of each of these elements in storm formation and students were able to test their understandings on the weather maker.

Besides the team example, other metaphors were used throughout the unit to help students better understand scientific concepts and to encourage imaginative thinking. As an example of a particularly useful and vivid metaphor, students thought of the atmosphere as an ocean of air and us as the bottom dwellers. This metaphor enabled students to grasp the difficult concept of air pressure by comparing it to the pressure we would feel at the bottom of an ocean of water.

Table 5.1 lists students' survey responses that show evidence of the team metaphor and its framework being used to make sense of the key components of weather and the three stages of each storm – formation, strengthening, and landfall.

Table 5.1: Student Survey Comments that Show Evidence of Learning Through Team Metaphor

"I've found out things that make me think differently [about weather] because I now know how the weather system totally functions." - Brandon
"It is interesting because all the amazing things weather can do just with the resources from nature" – Michael
"Before I thought of hurricanes as just deadly storms, now I think of them as the weather team" - James
"Now I know how tornadoes and hurricanes and lake effect snowstorms start" - Kyle
"It was interesting because I enjoyed learning how different types of weather form" – Gabby
"Now I know how they start and end" – Ken
"Storms are pretty interesting. They are so complex yet simple in the way they are formed." - Steve

Metaphors: The Ecology Unit

As discussed in Chapter 2, the ecology unit had one metaphor that was used throughout, that of thinking of nature as a 'web of life'. The 'web of life' metaphor was given as a visual representation that highlighted the big idea of the interconnectedness of all living things. This metaphor seemed to help students understand ecological processes like food chains where the existence of consumers, producers, and decomposers are contingent upon each other. Again, this type of thinking was new to many students and inspired them to see the world in a different way. An example of something that grabbed their attention was the role of decomposers in the food chain. The fact that decomposers like fungi break down dead things to help return the plant or animal's nutrients back into the soil was both disturbing and exciting for students. Students began to visualize and

talk about the layers of dead things they were standing upon and how without decomposers the surface of the earth would be piled high with corpses.

I also used a computer simulation game called *SimSafari* to highlight the metaphor of the web of life. In this game students build a virtual safari park where the goal is to create a balanced ecosystem of diverse African plants and animals. In the game, students learned about and choose from a large list of plants and animals native to African grasslands to place in their park. They also decided on the number of each species to place in the park. Once students made their selections, the simulation ran and they observed the results. For example, if enough grass and shrubs were not selected the herbivores died off first followed by the carnivores, and only the scavengers thrived. Without exception, my students added far too many large predators like cheetahs and lions for their ecosystem to sustain. As a result, most of their beloved big cats quickly died. Students were allowed to intervene in the simulation and add to the biotic features of their ecosystem until it reached equilibrium. It was exciting to watch as students began to realize how the 'web of life' was playing out in their safari park and came to realize the delicate balance of nature in an ecosystem.

Throughout the unit other metaphors were used to illustrate specific points or ideas. For example, adaptation was compared to the shoes students wore – each shoe having characteristics that make it suited for a specific purpose much like animals have traits that help them survive in their particular surroundings. Perhaps the most powerful metaphor turned out to be a way of thinking of primary succession – the tendency for plants to grow over and break down rock, cement or pavement in the creation of new soil – as a war between human-made objects and nature.

Ecological succession was the last topic required by the district for the unit and I was worried it would come across as a bit boring after the excitement of 'super predators'. In an attempt to reach the sublime, I introduced the process as an epic war between people and nature. Echoing Wordsworth's sentiment in *A few lines above Tintern Abbey*, I told students that we humans were always trying to build grand, strong buildings that would last forever, but in the end nature always reclaimed them. I introduced this idea while projecting pictures of ancient stone castles and churches covered and half toppled by ivy and other creeping plants. I told the class that this war was going on all around us all the time and showed and discussed examples of more modern buildings covered in vines and patches of sidewalk and asphalt crumbling where weeds were poking out. This session included a lively discussion where students gave examples of where they had seen secondary succession and discussed this ongoing war. Examples of scientific sublime experiences based on this class discussion surfaced in several student interviews and it was clear students were looking for and finding examples of this 'war' all around them.

Table 5.2: Student Interview Comments that Show Evidence of Learning Using Metaphor

• "When I see a rock, I'll be thinking about the process how it went from bare rock to like a forest." - Janessa
• "...you go outside and say you looking in the grass and you find mold on the tree or dead branches on the ground, now I got to pick them up and think it's making the environment and resources grow." - Misty
• "It's interesting how it grows and breaks it down." - Allison
• "You know when we were talking about the leaves growing on the buildings? There's one on this street...I say that house must have been there for a long time and one day that house might not be there anymore" - Deanna

3. An Emphasis on Visualization

While I began each unit with the curriculum largely written, I found that throughout both units I continually revised the lessons and my teaching approach. The most significant change occurred during the weather unit where within the first few days of teaching I began to realize the significant impact images, both still and video, had on my students and began to work in more and more of them.

Visualization: The Weather Unit & The Ecology Unit

The longer I taught, the more I became aware of important considerations when using pictures as an attempt to foster interesting and moving experiences in the classroom. Not surprisingly, the more dramatic, unexpected, and extraordinary the better. This meant that I spent considerable time finding just the right picture or video clip for each part of my lessons. The videos needed to be full of suspense and drama but also present the science ideas behind the objects or phenomenon. In the weather unit we watched a video of showing the power and destruction of hurricanes and tornadoes. With the ecology students I showed what turned out to be a very popular video entitled *Super Predators* which focused on the great cats of the African grasslands.

Some of the qualities I looked for in pictures were simply surface elements like sharp colors, clarity, and close-ups or distance shots. But more importantly was the subject of the picture. I looked for images that highlighted the sublime; rare objects students were either not familiar with - like the perfectly camouflaged leaf frog hidden in a pile of autumn leaves, or were seeing in a new way - like the earth from space. Also particularly moving were pictures that emphasized aspects of the sublime -- like a NASA satellite image looking down on a massive hurricane as it swirls over Florida and several

surrounding states; or pictures that call attention to the perfection of the sleek, sinuous body of a cheetah at top speed. Although searching for these pictures was time consuming and often tedious, they successfully evoked feelings of awe and amazement in my students and made many of them eager to learn more.

I also found a seemingly minor detail to be very important when it came to using pictures to their greatest effect in the classroom; the bigger the better. Students were not nearly as impressed with a picture they looked at in a book as they were with a picture I could project from my laptop onto the projection screen. A massive tornado is certainly more menacing when it is projected brightly on a big screen. The students also taught me the importance of creating a more conducive mood by turning out the lights and gathering near the screen to gaze upon and talk about the picture.

Discussing the pictures is the last detail that I found critical to maximize the effect of using images to create sublime experiences. It was not enough to create a slide show to quickly flip through. Instead my students and I spent ample time looking at and discussing each picture. We treated pictures of snowstorms or cheetahs like pieces of art in a gallery, studying each of them and talking about what we saw. It was in the process of teaching the units that I developed this manner of interacting with students around images as a way to emphasize the power, structure, and beauty in science. In the beginning I introduced each picture by asking students a series of questions like, "What do you see?", "What does this remind you of?", "What do you think will happen next?", "What do you think happened before?", "What science ideas to you see here?". At times when students did not seem to have much to say I would help them out by saying

something like, "This is what I see....", or "Let me show you what I think is so cool about this...." or, "I wonder if...".

While I modeled this method for students in the early days, they quickly adopted the process and no longer needed my prompts to think through the pictures. It is important to note that students did not merely comment on superficial aspects of the pictures. They started with their initial reactions but then delved deeper into the object or phenomenon they were looking at by pointing out things like the source of a storm's energy or a particular adaptive characteristic of an animal. Through modeling and scaffolding, my students channeled their feelings of awe, interest, and surprise into a practice where they used their scientific understanding of the content to make sense of the pictures.

Another form of visualization that I used in both units was computer simulations. In the weather unit, students worked on 'weather makers' where they manipulated variables in order to create hurricanes, lake effect snowstorms, and tornadoes. These simulations not only allowed students to test and concretize their scientific understandings, they also had a strong affective quality as well. Students saw the weather makers as being "hands-on activities" that allowed them to better imagine the necessary details in storm formation. This imaginative visualization was a powerful tool that gave students new insight into the inner workings of weather and the necessary ingredients that must come together at the right time to create a massive storm.

As previously mentioned, in the ecology unit students worked on an ecological computer simulation where they were able to control the number of consumers, producers, and decomposers in an effort to create a sustainable African wildlife park.

Like the weather makers, this simulation allowed students to test out existing understandings and form new ones based on the results. Students were able to see what happened when an ecosystem's delicate balance was disrupted and were astonished to see just how fragile the balance was. While a different type of visualization than analyzing pictures and video, computer simulations also proved to be a powerful way to provoke sublime experiences.

This type of interaction with images and simulations became a central theme in my teaching and I think differs from more typical approaches to teaching science. The emphasis on visualization as depicted here is largely dependant on access to technology, but to be effective it also requires some specific teaching techniques as previously mentioned. In the surveys from the weather unit and in interviews from the ecology unit, students often commented on how much they enjoyed looking at and analyzing pictures. The following chart shows some of the responses made by students in regards to the importance of visualization in this approach.

Table 5.3: Weather Unit Student Comments on Surveys Pertaining to Visualization

• Liked the unit "because we got to see what they [storms] looked like" –Ken
• "I thought it was really interesting. The way of using computers to learn and movies instead of just reading our books." – Steve
• "really cool, I liked the pictures we looked at on the projection screen. It helped me to know what a real hurricane/tornado looked like. I liked the weather maker stuff on the computer it let me get in there with my hands and work." – Molly
• "My favorite part was hurricanes because I love how they look" – Jimmy

Table 5.4: Ecology Unit Comments from Interviews Pertaining to Visualization

• "[Mrs. Marcella], when she does her stuff, she talks about it, she tells us, she doesn't show us the pictures, well sometimes she does, but I can't really get a better vision of it when she don't show us the pictures ... and the way you do it is different, you show us the pictures and talk about it so we understand it more." -Janessa
• "I like to look at stuff and I don't like reading stuff out of the book ... most of the time I don't picture it in my head, but if I look at it then I get a better idea of what it is." – Allison
• The unit was fun "because like you give us time to ask questions and we get to look at cool pictures." - Kurtis
• "it gives people a better picture of what the animal looks like and what it does." – Misty
• "It's good to see what you haven't seen before, to learn more about animals." – Brian
• "[pictures] help a lot because when you explain and then there's a picture there, then I can understand more." – Chee
• "I like when I get to see pictures and see how they look and see the way they move." – Jackie
• "It helps me learn to just get an image in my mind when I think about this stuff." - Kurtis

4. Highlighting the Sublime

A critical part of teaching for sublime experiences is to deliberately and actively highlight sublime aspects of the content. This includes calling attention to the amazing, awe-inspiring, and astounding parts of the subject area in an attempt to motivate students. In my teaching this often included showing remarkable pictures or videos, giving astounding statistics, and reading dramatic first-hand accounts. Also, and perhaps most importantly, the structure of the units were designed around a core, at least potentially sublime topic.

Highlighting the Sublime: The Weather Unit

The weather unit represents a drastically different unit than what is typically taught in middle school science class. In my teaching, the weather curriculum was centered on storms, and specific weather vocabulary and processes were taught in the

context of hurricanes, lake effect snowstorms, and tornadoes. The standard weather unit that would normally have been taught at site 1 was not structured around storms; instead the great emphasis was on introducing weather terms like precipitation, evaporation, condensation, and fronts as well as process oriented weather recording. Most of the content for the typical unit comes from the textbook. In this school's textbook, only the last two pages of the chapter were devoted to storms. The unit-long project that the teachers normally used involved keeping a daily journal of weather forecasts from three different sources and commenting every day on how accurate the forecasts were. From my experiences and conversations with other middle school science teachers, this is quite typical of weather units and very unlike the unit I taught.

As previously mentioned, the weather unit focused on the extreme sublime of storms to foster scientific sublime experiences. This emphasis on storms was quite successful in inspiring and motivating students to learn about weather and to gain a more sophisticated understanding of the world. In their surveys students wrote that the unit's structure was "exciting stuff because storms have lots of action in them" (Neil), and that the storm emphasis was "interesting, it made me more involved" (Hannah). I feel certain that organizing the unit around storms was the most effective way to create rich learning experiences and foster sublime experiences around the study of weather.

The following table shows student answers to a survey question, "Did you like the way the unit was structured around storms?"– the main way in which the unit was crafted to highlight the sublime. These student comments show the importance of focusing on core science ideas that are of special interest to students.

Table 5.5: Student Responses to How the Unit Was Structured Around Storms

• "Yes, Storms are interesting because they always change" – Joe
• "Yes, I like storms and because storms are interesting" – Michael
• "Yes, Storms are interesting because they have the power to destroy whole towns." - Brian
• "Yes, Storms are interesting because they are kind of deadly and exciting" - James
• "Yes, Storms are cool and because of destruction" – Charlie
• "Yes, because they're [storms] interesting because they are made of energy moving" - Kyle
• "Storms are pretty interesting. They are so complex yet simple in the way they are formed." – Steve
• "It [the unit structure] was interesting, it made me more involved. I think storms are interesting because they're dangerous, loud, destructive, but can be beautiful too" – Molly
• "Yes, In my eyes storms are the most dangerous source of nature" – Troy
• "Yes, because storms have lots of action in them, so their fun to learn about." – Neil
• "Yes, because they were really cool how they formed" – Gabby
• "Yes, it's cool, storms are interesting because I think water falling from the sky is cool." – Mark
• "Yes because it was interesting to see how different they were." - Sarah

In the weather unit, I also included several other techniques to highlight the sublime. In the beginning of my teaching I talked of the enormous size and power of hurricanes, giving statistics for top wind speed, highest storm surges, the biggest and most deadly hurricanes, showed pictures and video clips, and read accounts of hurricane survivors. A particularly vivid example is in a true story of Hurricane Camille that I read aloud in class. In my most dramatic voice, while projecting pictures of buildings before and after the hurricane, I read the story of the lone survivor of a 'hurricane party'. The account involved a woman swimming out of her 2nd story apartment building window, clutching debris and managing to stay afloat despite the 200mph winds and 23 foot tumultuous storm surge, watching her friends and family drown and the next day found clutching a treetop five miles away. The students were enthralled by the details and eager

to learn the science behind such natural monstrosities. Such a story allowed students to gain a new perspective on the power of storms and the vast potential energy in weather.

Highlighting the Sublime: The Ecology Unit

The ecology unit also included a reworking of a typical unit in an attempt to highlight the potentially sublime aspects of the content. I knew that most students are interested in animals and learning about them, so the main focus of the unit was on animals. Based on student interest, the focus of the unit quickly became further refined to center on dangerous animals (as will be discussed later in Chapters 5 and 6). I reached an initial level of sublime by exposing students to new or particularly astonishing or terrifying creatures. In order to create the potential for the scientific sublime, rather than just interesting experiences, I worked to show students different, captivating understandings of animals. The understandings that I was after were based on science ideas like adaptation.

In addition, I frequently attempted to bewilder students with statistics like the fastest, the largest, the slowest, the smallest, or the most ferocious animal. A seemingly trivial detail, but one that I think increased the potential for sublime experiences was for me to read aloud from the book we used. Rather than have students read silently or take turns reading out loud I was careful to read with drama and interest, pausing at important or interesting information. In this manner I could call attention to the more sublime aspects of the content and model my curiosity and enthusiasm for the material much like I did when we discussed pictures. My students were attentive when I read, listening to me while they silently followed along, asking questions or making comments when I paused. This was again something that I only realized the importance of in the process of

teaching the unit. Following the lead of the regular classroom teacher, I began the unit with having students read silently and leading a discussion based on their reading. This proved to be an unsatisfactory experience for me and the students. I found that many students did not comprehend much of what they were reading – finding it difficult to sustain interest in the text-book writing style. When I read the same book aloud, with strategic pauses, questions, and remarks, I noticed an immediate difference in how the students interacted with the material. Using this method, I was able to highlight the sublime in the book many students otherwise found boring.

The following chart shows examples from interviews of what students thought of the unit's emphasis on animals – the main way I reworked the curriculum to highlight the sublime.

Table 5.6: Student Comments From Interviews on the Unit's Structure Around Animals

• "I like learning this stuff, especially about the earth and animals, how they act' - Kurtis
• " I like learning about animals, in my old school they didn't teach about animals and stuff" - Deanna
• "It's interesting how like animals are connected." – Brian
• "I've just always thought animals were interesting" - Brianna

4. Imaginative Exploration of Ideas

Another essential part of my approach to teaching for sublime understandings is to encourage students to imaginatively explore scientific ideas. This type of social construction is most readily seen in whole class discussions and involves creating a classroom norm where students feel comfortable asking questions, sharing ideas, posing hypothetical situations, and uttering spontaneous comments. I think I was able to create

such a classroom environment with my students and that this was absolutely necessary for the success of teaching for sublime understandings.

Imaginative Exploration of Ideas: The Weather Unit

It takes time to create this type of classroom community but I found that my 4th hour weather students and my ecology students quickly embraced this way of learning. The 3rd hour weather students took longer to come around to this type of classroom interaction, but most of them eventually became accustomed to it.

For the 4th hour weather students who had a history of being lower-achievers, it felt as if they had been waiting for a teacher to come along and ask them to talk about their ideas. Within a few days of my teaching most of the students became quite engaged in class discussions: questioning, sharing, and hypothesizing. Although I had been warned after my first day of teaching that they could not handle such a child-centered approach, my 4th hour weather students seemed to do well in such an environment. Although they were usually loud and a bit hard to settle down, most of them appeared excited to learn and talk about science ideas. I watched several transformations in students as they moved from at least appearing apathetic and annoyed to been active and involved in class. An example of this is with Molly.

Molly rested her head on the desk, covered her face with her hair and rarely looked up in the time I spent observing her classroom before my teaching began and in the first few days of my teaching. The few times I saw her face early on she wore a sneer of contempt. This was a student I was not only worried about reaching, but concerned was going to be a discipline problem throughout the unit. It was within the first week that I saw Molly begin to come around. She would lift her head from her desk long enough to

listen to questions posed by her classmates and I noticed her being drawn into the pictures I was projecting. Soon, Molly was like a different student altogether and was an active participant in discussions. It even became common for her to quiet her classmates so I or others could be heard. Molly went on to write particularly insightful and artistic comments on her survey and reported being moved and inspired by the unit. Her final comment on her survey was:

> I wish we had this kinda stuff all the time...It's more fun than just studying and boring lectures when I feel like people are just throwing information on me. When we discuss stuff with Ms. Cavanaugh I feel more open like I can talk more and give my opinion. – Molly

I think Hannah summed up a large part of the reason why the 4th hour weather students responded so well to the unit -- because they "felt more open" like they could "talk more" and give their opinions. Similarly, Hannah, another 4th hour student reported that she liked the unit because "we do more things together." I think it was essential to create such an environment where students felt free to explore ideas and share their feelings in order to foster sublime experiences.

Along with creating an environment where students felt that they could share their ideas and ask questions, I also worked to create an atmosphere that encouraged students to play with ideas. By this I mean posing hypothetical situations and outcomes. These questions and ponderings arose from students' own curiosities and interests, but should be based on their understanding of the scientific content. For example, students developed and posed questions such as, "Could a hurricane form over Lake Michigan?", "Can a lake effect snowstorm form over a pond?", "If the president made a giant ice cube and dropped it on a hurricane, would it kill it?"

In response to the first two questions, students worked with their understandings of what it takes to form a hurricane or a lake effect snowstorm in order to answer a question that had personal meaning and importance to them. The third question showed great imagination and became a compelling and continuing thought process for both classes of weather students. Students used what they knew of hurricanes to try to develop hypothetical ways to break one apart before it could do any damage. While engaging in this type of thought process, students' understandings of the world were being transformed. These examples typify the type of imaginative playing with scientific ideas that lead to scientific sublime experiences.

Imaginative Exploration of Ideas: Ecology Unit

Like my 4th hour weather students, the ecology students were also quick to engage in conversations and share their ideas. But I noticed a difference in what types of questions and comments students posed. For example, on the first day of class, in a darkened room, I projected an impressive, vivid picture of the earth. As soon as the picture flashed onto the screen it was met with several "ohs" and "ahs", but one comment was louder than the rest. That first day Brian instinctually exclaimed in a dramatic manner, "Isn't it beautiful!". Several students laughed at Brain and teased him for making such an unrestrained comment, about beauty no less. I was quick to agree with Brian and pointed out what I saw as beautiful, cool, and amazing in the picture of the earth.

As the unit progressed, this became more of the norm and students often uttered expressions of interest, awe, astonishment, or beauty. They also posed hypothetical questions like the weather students and worked as a class to come to some level of consensus as to the answer. Students moved from more simple questions asked at the

beginning of the unit like "What kind of animal is that?" or "What's the difference between a lizard and an amphibian" to more sophisticated, inspiring questions that required imagination as well as content knowledge. As mentioned earlier, the ongoing qualifications of whether or not an animal qualified as a 'super predator' was always popular, but so too were questions like, "Why are penguins black and white, doesn't the black make them stick out against the white background?" and "Who will finally win, nature or people?".

In some of the interviews, students mentioned the changed classroom atmosphere, particularly in regards to being encouraged to ask questions. For example, Kurtis said, "When we're having the discussions I learn. if I have any questions I can ask my questions and then I learn from the questions I ask." Another student, Allison commented on what she saw as the class working together to learn:

> I like working with the class... it's different now, you get to like be more open and like ask all the questions that you need to ask and get all the answers that you need. – Allison

While Allison and Kurtis' comments about having a classroom environment that encourages questions and discussions characterize all models of constructivist teaching, it is but one critical aspect in the model of teaching for the scientific sublime I developed.

5. Modeling a Sublime Sensibility

The fifth aspect important in fostering sublime experiences is that of modeling my own sublime sensibility. This involved showing my enthusiasm and appreciation for what I saw as great, awe-inspiring, terrifying, or perfect in nature. I shared my excitement for the content as well as how moved and inspired I am by the images and ideas. Although there were certainly times when the students thought I was odd or amusing for

being so enthused about things they could not care less about, for the most part they responded positively to my enthusiasm. I worked to create a compelling image of science and nature, one which I hoped students would find so exciting that they could not help but be swept up into. Of course it is hard to identify exactly what I modeled for my students since this modeling is so entangled in my personality and my teaching persona. However, I can say that this modeling was more than simply having an unreserved and excitable personality (although this surely helped); it was about sharing my own sublime feelings for the science. In their interviews, Jackie from the ecology unit told me that I "make it more fun" and Kurtis, also of the ecology unit, paid me a great compliment by saying, "You have like a big way of teaching, it's more exciting...it's like you have more enthusiasm than Mrs. Marcella does."

Along with students recognizing and appreciating my genuine enthusiasm and sublime feelings for science, I saw the affects of my modeling in other ways.
In both units, I noticed that the behaviors and verbalizations of many students came to reflect those of my own. Students became more likely to talk about what they saw as awe-inspiring, surprising, or cool in the idea or picture we were studying. This was especially apparent in the portion of the interviews with ecology students where I asked them to look at and discuss pictures of animals. It was interesting to see how most of them used the same process I had modeled in class and described in Chapter 4. This process involved three levels of observation: the initial, instinctual examination followed by the first and second level of out loud sense making – all with enthusiastic, excited comments. These similarities also appeared in writing as was the case when students completed an assignment where they wrote 'hurricane stories'. In these stories they

described what they would see, hear, and feel if they could safely be in the midst of a hurricane making landfall and what weather processes would be occurring at every point. It was remarkable how frequently many students used words and phrasings similar to Kant and Burke – things that they surely heard from me.

Finally I want to mention an interesting aspect that I observed in several of my students related to my intentional modeling of the sublime - their trust in me and my ability to show them something interesting. I began to think about this quality of teaching as a result of a comment made by one of my weather students from the previously low achieving 4th hour class. This student, Neil, asked me to help him with a concept that he was having difficultly understanding. I began by saying, "You'll like this, let me show you..." to which Neil responded, "Ok, what's cool about this...". This certainly sounds like a trivial bit of conversation, but it was Neil's trusting, expectant manner that caught my attention. Although he had been frustrated with his inability to understand the material, he believed that I was able to not only clarify the topic, but to help him see something "cool". This episode stayed with me as an ideal for me to work towards – a classroom environment where my students were motivated to learn and experience the sublime in science as a result of what I showed them.

Teacher Narrative

This research represents my attempt at a lofty goal. I sought to understand how to teach complex science ideas in ways that would be both exciting and motivating. As I shared my excitement and enthusiasm for science I hoped to ultimately leave my students with a richer, more complete understanding of the world. In much of my past experiences as a science learner and teacher, science was taught as a series of facts to memorize or processes to become proficient in. I was never satisfied with these experiences because science and nature meant so much more to me. I wanted my students to gain more than conceptual understanding and inquiry skills – I wanted them to be inspired, stirred, and fully engaged with what they were learning. I was as interested in the affective qualities of my students' learning experiences as I was the cognitive. I felt confident that I could teach the material and students would learn, but I wanted to see if I could also teach in ways that would create more interesting affective learning experiences with science.

As a means of accomplishing these lofty goals I turned to the study of aesthetics as outlined in chapter 1. From my readings in aesthetics I found the sublime -- the ultimate emotion that induces "the strongest passions" (Burke, 1757, p.51). Using my understandings of the sublime in philosophy, literature, and science I developed a pedagogical approach to identifying and creating scientific sublime experiences in the classroom. I created two units in this manner and then found three teachers who were willing to let me try it out. In these environments I undertook the difficult role of teacher/researcher. Throughout most of this dissertation I have tried to record my methodology and findings as a researcher, but it seems that more of a reflection on my role as the teacher is also pertinent to the discussion.

This discussion needs to begin by acknowledging that in this study I found myself pulled into my role as a teacher first and researcher second. I had anticipated and planned on these two roles holding equal importance, but the reality of being accountable for the learning of some 80 children quickly overwhelmed my responsibility as a researcher. This is not to say that I did not think or act as a researcher, it is just that my duties as a teacher were my primary concern. However, for the purpose of this study I see these two areas as being intricately connected – it was only through my efforts as a teacher that I was able to research my students' sublime experiences. I also felt that I could not adequately articulate my newly emerging and constantly developing understandings of a sublime pedagogy to pass it off to another teacher. In order to understand this type of classroom experience it was necessary for me to act as both teacher and researcher.

In addition to the sometimes awkward role of teacher/researcher, I held another ambiguous role – that of a temporary teacher in other people's classrooms. While the students quickly accepted me as a guest teacher, my presence was at times more difficult for the regular teachers. Taking over someone's classroom for five weeks is a great deal to ask of someone. The teachers, all of whom I had no previous connection with, were gracious in their willingness to allow me to do my research in their classrooms. The teachers surely had several legitimate concerns, some that they voiced to me and others that I only guessed at. At the same time I often felt awkward and even anxious in their classrooms. I felt like I was imposing on these teachers and was at times worried that they saw my approach as too discussion rather than action based, too content oriented, too student-centered, too long, too loud, or just too different from what they knew. With a

growing sense of student support for my teaching I was able to overlook most of these feelings of uneasiness and continue with my pedagogical approach.

Yet another pressure that I experienced was the need to make every day 'count' in the short amount of time I had to make an impact on student thinking and learning. Each lesson had to be researched, structured, and presented in a way that I thought would maximize the scientific sublime experiences of my students. Sometimes this was easy, but other lessons or ideas proved to be more challenging and I spent enormous amounts of time thinking through and re-working many of the lessons, not to mention searching for just the right picture to use. Regardless of the pressures and tensions I sometimes felt acting as a teacher/researcher, the entire experience was incredibly rewarding. I typically left the classroom exhilarated by the discussions and activities of the day and the success I was feeling in my teaching.

Reflections on the Pedagogical Approach

A clear advantage of acting as the teacher in this research was being able to continually revise the lessons and help crystallize my understandings of the unique pedagogical approach I was developing. I was able to instantly respond to student reactions - or lack of reaction - and even modify the direction of my curriculum based on this. At the same time, this freedom to change course in response to my students may have been a detriment to my goals. For example, in my attempts to sustain student interest in ecology I shifted my emphasis from the connective sublime to the extreme sublime (this topic will be discussed in some length in the following chapter).

In previous discussions of my pedagogical approach for scientific sublime teaching I have tried to include examples of how I developed or refined the various

aspects of my approach (big ideas, metaphors, visualization, highlighting the sublime, encouraging imaginative exploration of ideas, and modeling the sublime). The process of developing, teaching, and refining the approach has given me new insights into the act of teaching. Some of these aspects proved to be more influential than others. For example, keeping the big idea at the core of the teaching was a critical difference between these units and my past experiences as a science teacher, and I would argue, most science teaching. In my previous experiences I focused on teaching several concepts rather than structuring the unit around a big idea. While this may seem like a subtle difference, through my work in creating and teaching these units I became aware of how valuable the big idea approach is. Simply by forcing me, the teacher, to identify and understand the reason behind weather or the interconnectivities in ecology influenced how I approached and taught the unit to my students.

It is interesting to note that the standard weather unit normally taught at this school did not include any mention of the sun's energy or disequilibrium--concepts that are at the heart of my unit. Instead the typical weather unit focused on the particulars of weather--vocabulary and processes like pressure systems and fronts--but largely removed from the context of weather events like storms. This standard way of teaching weather represents the way I believe most science curriculum is taught – around particulars. In teaching the model unit, I found that the big idea provided a useful framework with which to connect these weather specifics. I also found it relatively easy to teach in this manner, but this is likely a result of the large amount of time I put into developing the unit. Through the extensive development process, which included meetings with MSU faculty, other graduate students, and a meteorologist, I gained a solid understanding of

weather and the big idea underlying it. I am convinced that strong content knowledge is an essential part of teaching science from this pedagogical approach. The teacher must be able to identify the content's big idea, be able to connect the science specifics to this, and convey the beauty, awe, and power in these ideas.

In addition, the experience of teaching this unit through highlighting core and inherently interesting content has led me to a new understanding of teaching science. Science teachers are typically drawn to the field of science because of their intense interest in the subject. Unfortunately, many curriculums and textbooks are unsuccessful at conveying the sublime aspects of the domain. It then becomes a challenge for the teacher to work with the existing resources to create a compelling science experience for students. As a result of teaching this unit, I realized how important it is for students to be interested in what they are supposed to be learning. This does not mean that essential yet perhaps seemingly dry concepts are not taught. Instead, if they are worked into an overall more intriguing structure, like storms or animal adaptations, the learning can become a more rewarding experience for students and teachers.

Generalizability Concerns

While I saw many positives that resulted from acting as both teacher and researcher in this study, I have one main concern that has arisen from my dual role. For a variety of reasons, I am concerned that the pedagogical approach I developed for sublime teaching will be difficult for teachers to use and the experiences my students and I had will be difficult to replicate. One of the main reasons I am concerned about this is based on the fact that teachers do not have the time to develop the type of units I created. I spent months developing each unit and this time was critical. Only with extended periods of

time was I able to: learn the content material that proved at times to be quite difficult (this was especially true with weather) and decide on the big ideas; gather teaching tools like pictures, video, and simulations; try out my ideas on others; and read aesthetic theory and educational research.

For example, the creation of an extended metaphor like the one in the weather unit may prove to be difficult for teachers to replicate. It took a great deal of time to develop the extended 'team' weather metaphor and it came about as a result of strong weather understandings the group formed in the development process. This development process included periodic discussions with a university meteorologist. If a teacher was to try to replicate this approach with new content it would likely involve a similar lengthy development process. In addition, I taught these classes for only one or two hours a day which enabled me to reflect on each lesson and plan for the next one. This type of preparation for only one unit would simply not be feasible for a full-time classroom teacher.

While it may not be realistic to expect teachers to develop these types of units, could they conceivably take one of the units I wrote and obtain similar results in terms of learning and sublime experiences that I found? Each aspect of my pedagogical approach may prove a challenge to teachers. I base this statement on more than presumption, but on my experiences of watching much of the weather unit that I developed taught by other teachers. During the five weeks that I taught the weather unit, the two teachers whose students I was teaching decided that in order to keep all their classes aligned they would also each teach my unit. To say the least, I was uncomfortable with this situation.

The teachers did not have the same pedagogical goals that I had nor were they familiar with the extent of my still developing teaching approach. They did not understand what I meant by the sublime or why it was my goal. This problem was a product of my inability to concisely explain my theoretical framework or my intended outcomes much beyond saying that I hoped to motivate students and help them see the power and beauty in the science ideas and processes. In addition, these teachers did not have the time to delve deep into the material and theories like I had. For all these reasons, their teaching of the weather unit looked very different than mine. Although I did not observe all of their classes, I did see enough of them to notice the biggest differences.

The use of big ideas and metaphor by the two regular teachers was similar to the way I used them in my teaching. This is not surprising since the teachers used the curriculum I developed and the big idea and guiding metaphor were the central components of the unit. The areas of my pedagogical approach that I observed to be the most different in the hands of the other teachers were the use of visualization; encouraging students to play with the ideas; and modeling a sublime sensibility. Each of these aspects of my teaching approach is connected to affect and the emotional aspects of learning. For example, although the teachers were given the same pictures that I used with my classes, they used them quite differently.

Although both teachers had watched me teach the lesson before they later taught it with their other classes, they did not use the pictures in the same way I did. In the beginning they each dutifully projected the pictures in the same places that had done, but they tended to go through them quickly with little or no time for discussion. Both teachers pointed out the cognitive aspects of the pictures - science terms like the eye of a

hurricane - but generally did not highlight what I saw as aspects of the sublime that could be evoked from these images. I did not see them encourage much conversation around the pictures; I never saw them treat the images as something to analyze, wonder about, or even gawk at in the way that I tried to use them. The affective qualities of the experience seemed to be lacking in comparison to my teaching.

This under emphasis of the affective qualities of learning weather explains why I did not observe the teachers modeling a sublime sensibility or encouraging the imaginative exploration of science ideas. As is often found in science teaching, both teachers emphasized the cognitive aspects of learning science and largely ignored the affective. It seems that the parts of my teaching approach that looked most different when taught by other teachers are perhaps the areas most connected with my personality and teaching persona. Of course it makes sense that I created a way of teaching that would come naturally to me, but it also calls into question the generalizability of this study. This is troubling for me since it could mean that this type of teaching and the experiences evoked by it are tied to the personality of the teacher. I am inspired and moved by nature and science, and I tend to be excitable and expressive. Does this mean that teachers must possess similar personality traits to use my sublime teaching pedagogy and expect similar results?

On some level I believe the success of my teaching approach does lay in who I am as a person and teacher. I think at least part of the reason that my teaching successfully evoked sublime experiences was because my students sensed the genuineness in my excitement and passion for the material. Some students made such comments in their surveys or interviews. For example an ecology student said, "You have like a big way of

teaching, it's more exciting...it's like you have more enthusiasm". This enthusiasm and 'big way of teaching' were authentic and I doubt someone who has not had sublime experiences with nature could evoke these types of experiences for students.

However, the vast majority of students taught the weather unit by the two regular teachers, rated in a survey that the weather unit was one of their favorite science units. This was interesting to me since the unit, which was based on the same lessons I used, looked so different when taught by the other teachers. I think part of the success of the unit may be attributed to the design – teaching focused on a powerful big idea, using a guiding metaphor to make sense of complex processes, and highlighting the sublime through storms. Perhaps teachers who are not accustomed to teaching the affective aspects of science can still achieve some of the motivating characteristics of the sublime based on the curriculum they use. This finding can be taken to mean that my units on weather and ecology could be taught by other teachers and still induce at least some of the sublime experiences that my students had. In addition, it is conceivable that such units could be used as professional development or teacher education tools for helping teachers to understand how to incorporate the affective, sublime aspects of science learning.

Chapter 6: Implications

Introduction

This research began by addressing the following three questions:

1. Will students experience the sublime as a result of my teaching?

- What types of sublime will they experience – the extreme, connective, or scientific?
    - Will students feel a combination of awe, horror, and delight?
    - Will students experience feelings of connection, unit, and harmony?
    - Will students be awed by how science ideas reveal the world?, Develop insight through engagement with the ideas?, See and be in the world differently?

2. To what extent did the various aspects of my teaching help to foster students' sublime experiences?

- An emphasis on the unit's 'big ideas' and the use of metaphors
- An emphasis on visualization
- Highlighting the sublime
- Encouraging imaginative exploration of scientific ideas
- Modeling a sublime sensibility

3. To what extent will students learn science content when taught in ways that promote sublime experiences?

The data reported in chapter 4 supports a positive answer to the first question. It appears that I was successful in fostering sublime experiences for the majority of my students, as defined by the qualities of sublime experiences listed in Chapters 1 and 2. In

fact, much of the language used in the extreme sublime experiences closely resembled the language used by Kant and Burke to describe the sublime. In terms of the types of sublime, the extreme and scientific sublime experiences were more common than the connective sublime. This is an interesting issue that will be discussed later in this chapter.

In regards to the second question, the teaching approach developed to foster sublime experiences was overall quite successful. Chapter 5 discussed how each aspect of the teaching approach materialized in the units and how they helped to foster sublime experiences for my students. Overall, the approach was effective, with each piece playing an important part in the experiences of my students. Perhaps the two most influential aspects of the approach were the emphasis on visualization and highlighting the sublime. In response to the third research question, students from both units showed evidence of learning the scientific content as measured on the pre and post-tests.

Themes that Emerged from the Research

Beyond the research questions that guided this study, two themes emerged that I found particularly interesting any may have implications for the field of science education and future research.

Fascination with the Extreme Sublime

In both the weather and ecology unit, students consistently showed an intense fascination with the extreme sublime. More than 200 years ago Burke and Kant described a type of sublime that arose from fear of danger, terror, and obscurity resulting in a sense of "delightful horror" (Burke, 1757, p.73). These "strongest of all the passions" (Burke, 1757, p. 51) creates a situation where "The mind feels itself moved in the representation of the Sublime in nature ... quickly alternating attracting towards, and repulsion from, the

same Object" (Kant, 1790, p. 120). Be it a dark towering tornado, or a cobra poised to strike, the extreme sublime astonished, moved, and ultimately delighted my students. The extreme sublime often created experiences that compelled students to look further into the phenomenon and begin to grapple with the underlying scientific ideas.

A striking similarity exists between the experiences with the extreme sublime and what Dewey (1934) described as educative experiences. Dewey described the aesthetic essence of educative experiences that hurried students along, pushing them towards the consummation or completion of the experience. He writes, "The experience is of material fraught with suspense and moving toward its own consummation through a connected series of varied incidents" (p. 43). Certainly extreme sublime experiences can be described as "material fraught with suspense". Students felt suspense along with horror and delight as they viewed and thought about storms and dangerous animals. The suspense is perhaps the ultimate of its kind since it deals with what Burke calls "self-preservation". An essential part of Dewey's educative experiences is anticipation as described by Wong & Pugh (2001):

> Anticipation is the intellectual and emotional energy that both drives and holds together the development of an experience. Because the consummation of an experience is the object of anticipation, it colors the entire activity. The individual looks forward to, imagines what may or may not be, and is surprised, disappointed, or fulfilled when consummation occurs (p. 340).

In the extreme sublime experiences of many of my students, this Deweyan sense of anticipation seemed to be a part of the process. Anticipation in sublime experiences is difficult to capture on a survey or in an interview, but was often apparent in the classroom as I worked with my students. When I presented a new object or idea, and if it was connected to the extreme sublime, I often noticed not only outward displays of awe

and astonishment, but also a sense of urgency on behalf of the students to make sense of what they were seeing. Because students were so moved by the object, they felt compelled to learn more about it. This is where the scientific sublime comes in, through the anticipation built by the extreme. Much of the time students were equally awed with what they learned about the phenomenon in light of the scientific ideas.

An example of this comes from the ecology unit on the day I introduced the idea of adaptation and how animals have characteristics that help them survive in their particular environment. I began by showing students pictures of some extreme cases, the first of which was a walking-stick bug. I dimmed the lights and projected the picture onto the large screen in the front of the room and asked the students what they saw. By this point in my teaching, students had become accustomed to my methods and most sat in the dark, seemingly full of eagerness and expectation for what I would show them. When the picture of a nearly perfectly camouflaged walking-stick bug appeared amongst leaves on a branch, students seemed puzzled and a bit disappointed, seeing a stick and expecting to see something better. Within a few seconds some began to recognize what they were looking at and rushed to tell the rest of us what they saw. Instantly the class was buzzing with their reactions.

For many students the bug was yet another example of the potential danger found in nature. The fact that an insect, which many of them immediately assumed to be poisonous, could be so hidden was horrifying. I was completely surprised by this response; it had never occurred to me that it could be seen in such a way. I had anticipated some students being disgusted, but I never imagined it would induce such

sublime feelings of horror. The sentiment of many students was that nature was not only dangerous, but now deceptive; threatening animals could be hidden everywhere.

However, students were not just frightened, the delight was also apparent in comments about the walking stick bug like Brian's, "them things are sweet!" Prompted by their fascination with the bizarre appearance of the animal, many students wanted to know why these insects look the way they do. At this point, we began our discussion of adaptation. In this example, the horrifying aspects of the sublime created anticipation in the Deweyan sense and rushed students towards completion of the experience – scientific understandings.

The Extreme Sublime and the Dangerous Aspects of Nature

While the sublime of Burke and Kant is in some way a gripping and moving force for us all, my students often seemed to go to extremes themselves in the way they viewed nature as being dangerous. Nature as an ever-present potential peril became a particularly compelling idea for the students. This was not surprising in regards to the weather students since I designed their unit around hurricanes, tornadoes, and lake effect snowstorms. Admittedly, I capitalized on the enormous size, overwhelming power, and chilling effects of these storms to pique their interest in learning the patterns and processes behind such incredible events. These students were drawn-in by the extreme sublime, and I feed their fascination for the huge and horrific storms. I very overtly highlighted the dangerous parts of weather in hopes of fostering interest an appreciation for the energy and processes involved in weather. Conversely, I set out to teach the ecology unit to highlight aspects of the connective sublime rather than the extreme sublime of the weather unit. I knew this would be a difficult task since feelings of

connections and unity are often less interesting than death and destruction, especially to 7th graders.

For my second teaching experience, I purposefully picked the topic of ecology in an attempt to teach the connective sublime, thinking the two were a natural fit. I planned to stress the connections between all living things and hoped to inspire Emerson or Thoreau like experiences with nature. While I did teach about these connections, my students were more intrigued by the biggest, fastest, and most dangerous specimens in the animal world. Students were so enthralled by the extreme sublime, that it became difficult for me to include aspects of the connective sublime in my teaching.

It was difficult to foster the formation of little Emersons and Thoreaus when my students were more interested in *The Crocodile Hunter*. Yet as anyone who has watched *The Crocodile Hunter* knows, he exudes feelings of awe, astonishment, and admiration for these dangerous animals. I quickly came to the conclusion, right or wrong, that if I was to promote scientific sublime experiences I was going to have to do so via the extreme sublime. The perilous aspects of the extreme appealed to my students far more than anything else I tried. This was obvious when I asked Misty, an ecology student, what parts of the unit most impressed her. She appeared to think about her answer before she replied, "Well, I really like the tapeworms and the poisonous salamanders."

Besides the Kantian sense of delight we get from the extreme sublime, I think my ecology students had other reasons for being drawn to the dangerous aspects of nature. As previously mentioned, very few of these students had much of any experience with animals or nature, and the experiences they did have were largely negative. On the second day of my teaching I asked Jackie, a particularly candid student, if he spent much

time outside in nature and received a quizzical look as he explained, "I'm more of an inside kind of guy." This was a typical sentiment. These students were 'city kids', they attended a large urban school and were not in close proximity to the forests, fields, and swamps that were the backdrop of the stories I told. As an illustration of this, I am reminded of a time when the class was discussing animals with warning colors. I mentioned that while lethal animals like the poison arrow tree frog had bright markings to warn its prey, so too do animals more common to us like the skunk. I asked the class where they would be likely to find skunks, expecting to hear something along the lines of forests or meadows, but instead Jackie replied, "in the projects". Perhaps since the students had few positive experiences with nature and were more familiar with its dangerous aspects, they were more drawn to the extreme sublime and resistant to the connective sublime.

As a further example, in the first week of class we studied the role of decomposers in the web of life and I brought in examples of tree fungus, mushrooms, and mold that I found on a forest floor the day before. The majority of students made it clear that they had never seen such things before, that they were not about to touch them, and that they could not believe I had nothing better to do than look for such things in a forest. There was only moderate interest in the objects until one of the students mentioned that he heard mushrooms were poisonous, at which point a large crowd gathered around the mushrooms in an attempt to get a better look. When it came to animals, some of the students had pet dogs or cats, but they often had sad or scary stories to tell of these animals. Many of the dogs students knew were 'tough' dogs who were not so much pets as they were potential sources of danger. Several students had violent dog stories like

Allison who explained that, "Dogs are good predators 'cause when my dogs killed my cat, they broke his back legs."

The other common experience the majority of my students had with plants and animals was what they saw on nature television shows. Most students reported frequently watching such programs, the content of which tended to focused on predatory animals. In interviews when I asked students if they had begun to look at animals differently as a result of what they were learning in class, only a few students mentioned animals they had actually seen. Many more talked about TV shows they were watching and how the actions of animals were making more sense to them now. Of course I added to this common collection of experiences by showing the *Super Predator* nature documentary early on in the unit. An informative yet graphic movie that seemed to have made more of an impact than anything else we did in the five weeks I spent with them.

Given that the majority of experiences students had with animals involved some type of violence, it is not surprising that they were drawn to aspects of the extreme sublime in ecology. Animals and many plants were seen as something to be fearful of, as Misty made clear when I asked her if she was afraid of animals. She looked at me as if this were a ridiculous question and sarcastically replied, "Duh, if I like walked up to a lion it would eat me." Like Misty, many of these students saw the world as being full of potentially dangerous plants and animals and they were eager to learn more about them. They saw science as a way to better understand the risky natural world; knowledge that could help keep them safe. Instances of the nature as danger theme from student comments during interviews are given in the following table.

Table 6.1: Nature as Danger Theme: Examples from Student Interviews

• "I think of them [animals] because like when I go outside … I want to know what little bugs are crawling on me and if they might be poisonous." -Dameka
• "If I don't know what they [animals] are I don't know what they'll do to me." -Misty
• "If you think about it, if you don't know what plants are poisonous, if you're outside than you might accidentally eat it because that's all you have to eat." -Kevin
• "... you need to know things about plants so you can avoid things like poison ivy."- Jensine
• "I watched a good show about people having lions and tigers as pets and this girl got killed by one 'cause she was stupid and had it as a pet." -Dion
• "Dogs are good predators 'cause when my dogs killed my cat, they broke his back legs." - Allison
• "...if I like walked up to a lion it would eat me." - Misty

The Elusive Connective Sublime

I have already mentioned in some detail that my hopes of creating connective sublime experiences in the ecology unit went largely unrealized. I have identified three rationales to help explain my lack of success in consistently conveying the connective sublime in my students:

1. My teaching approach for fostering scientific sublime experiences is not adequate for fostering the connective sublime.
2. The students, for perhaps several reasons, were less inclined towards the connective as they were the extreme sublime.
3. The connective sublime in itself is a more intangible, elusive sense than the extreme sublime.

1. The Teaching Approach

It is likely that aspects of the teaching approach that I developed to foster sublime experiences are actually more fitting for teaching the extreme rather than the connective sublime. In particular, my heavy reliance on imagery to convey the sublime seems better

suited to the enormous and terrifying than the calm and connected. Projecting an image of a swirling tornado onto a large screen in a dark room stirred more emotions than an image of three deer in a meadow. This brings up another difficulty; it is hard to identify images to explicitly communicate the feelings of the connective sublime.

In addition to my use of imagery, an aspect of my teaching approach that I was certainly more successful at with the extreme sublime was my modeling of a sublime sensibility. I could effectively convey my awe and excitement when discussing a hurricane or a stalking lion, but my wonderment and enthusiasm were not realized or appreciated when I described the peace and ease I felt observing wildlife in a forest. In the previously discussed mushroom episode, I clearly remember describing my feelings of the connective sublime. I told my class of the amazing afternoon I had, of the incredible things I saw – mint green tree mold, a perfectly hidden (non-poisonous) salamander, a rabbit scurrying along the trail, a delicate little mushroom colony – and receiving back bewildered looks. They had no interest in my story and instead let me know that it was a sad thing that I had nothing better to do after school. My extreme stories were much more interesting to students, they could not hear enough about the time my horse and I were engulfed in a bottomless bog. I was clearly not an effective modeler of the connective sublime.

Or perhaps I just gave in too soon. As I mentioned earlier, I was eager for students to experience some sort of sublime, for them to be interested, amazed, and awed. After the rousing experience I had teaching the weather unit, it is likely that I was not patient enough for the connective sublime to emerge.

Along with evaluating the efficacy of my teaching approach in fostering the connective sublime, I question the expectations I had as to what sublime experiences look like in the classroom. I was quite consciously aiming for a classroom full of strident, enthusiastic discussions; students brimming with comments, ideas, and questions. It occurs to me now that the connective sublime is likely a more subdued, personal type of experience. It also seems that forming feelings of connection to nature would have been easier to do if we had actually been able to go outside. Before and during the ecology unit I wanted a chance to immerse my students in nature -- to expose them to some of the wondrous plants and animals we were learning about. Unfortunately, there was not any sort of natural area directly around the school, so it would have required a filed trip and for several reasons this was not a possibility.

Even if I had I been able to, simply taking my students outside would certainly not have solved the problem. Countless groups of children have tromped through nature centers all over the world without experiencing sublime feelings of unity with their surroundings. For any hope of the field trip being successful, I would have had to take some cues from the best hiking and safari guides. I would need to impress students with the often unseen beauty, delicacy, and peace of the woods. To convey to students that they have entered another world where all organisms are connected in an intricate web of life, a world that has gone on in much the same way for thousands of years. While I think a carefully performed field trip would help foster feelings of the connective sublime, it may still be difficult to interest students in a natural setting where there is no chance of a lurking super predator.

2. Students are Less Inclined Towards the Connective Sublime

Since I did not attempt to convey the connective sublime with my weather students I cannot be sure how they would have responded to it. But I hypothesize that the weather students, with a very different background than the ecology students, may have been more open to the connective sublime. I base this only on an assumption that the weather students, who attended a semi-rural school, had more experiences with nature and animals. I know that several of these students went hunting with their fathers, others lived on farms and raised animals, and they all generally lived near some type of natural area. Of course this does not mean that they would have responded any differently to the ecology unit than the ecology students did. However, in contrast to the weather students, the ecology students were 'city kids' and seemed to have few if any experiences with nature. When I first started observing their class I was amazed how few Michigan wild animals they could recognize. Mrs. Marcella showed them a picture of a common red-tailed hawk and asked what it was; no student in the class could identify it as a hawk, instead most called it 'a big bird'. Although these children did watch nature TV shows, they were only familiar with the more extreme animals. I think the fact that these children did not have many positive first-hand experiences with nature likely affected their lack of inclination towards the connective sublime.

The effects of popular culture on both the weather and ecology students cannot be ignored. The ease with which students became swept-up in the extreme sublime may at least partly result from their exposure to TV shows and movies that focus on the extreme and dangerous. Students were eager to study potentially perilous phenomena; events and animals many of them were already familiar with from nature programs.

3. The Connective Sublime as Intangible

The final reason I think the connective sublime was more difficult to foster in my students than the extreme sublime goes back to the writings of Burke and Kant. Both philosophers wrote of our human fascination with the dangerous and terrifying. We are both repulsed and attracted to the extreme sublime; we enjoy looking upon danger from a safe distance. This explains why many enjoy scary movies and stomach churning roller coasters; why *The Discovery Channel* devotes an entire week to sharks and why *Storm Stories* is a regular show on the weather channel. The extreme sublime is popular with students because it is part of our human nature to be fascinated by what can hurt us. In contrast, the connective sublime may not be as common of an experience for all people. Certainly, I believe that everyone has the potential for experiencing the connective sublime, but it seems that many people will go their entire lives without feeling "the perfect exhilaration" of "Crossing a bare common, in snow puddles, at twilight, under a clouded sky" that Emerson described or begin to feel "the sense sublime" that Wordsworth wrote of. While the connective sublime results in feelings that are just as intense and overwhelming as the extreme sublime, they are of a decidedly different hue. The connective sublime is not only more elusive and intangible than the extreme; it seems much more personal and relative. What may be deeply moving in the connective sublime to one person may be of little value to another. In contrast, it is likely that if something in the realm of the extreme sublime is awe inspiring and a bit terrifying to someone, it will be to most people. For these reasons, I think truly fostering the connective sublime to a classroom of students is much more difficult than it is cultivate the extreme sublime.

Concerns from My Teaching: Did I Merely Scare My Students?

My ecology students clearly saw the natural world as a dangerous place; a world full of potentially poisonous plants, venomous reptiles, and ferocious mammals. While many of them came to the unit with some fear of nature, I have to wonder how much of this trepidation I instilled in them through my teaching. I did not intend to make my students afraid of nature, in fact I was hoping for the opposite. I have an intense feeling of connection to nature and I hoped to model some of these feelings of harmony and awe for my students. In this regard, I was clearly ineffective.

My students were not so interested in these things and were always asking for aspects of the extreme sublime – the dangerous, the massive, the overpowering. Along with the previously mentioned example involving the excitement over the idea of a possibly poisonous mushroom, I remember another pivotal point in my teaching where the extreme sublime crept in and took over.

We were discussing the important animal adaptation of camouflage and I was hoping to expose students to the wondrous abilities animals in our part of the world have to blend into their surroundings. We were looking at a picture of a grassy meadow where three very alert white-tailed deer stood like statues almost dissolving into their surroundings. My students were hardly impressed. Out of courtesy to me, they looked over the picture and agreed that 'yes the deer had good camouflage'. But they knew enough about prey animals now to know that these deer were trying to hide from something and they wanted to know what that was. I explained that in our area humans were really the only predators these deer needed to fear. As I said this I saw some of them lose interest. Many sat back in their chairs, others looked up at the clock or at their

friend, some went back to work on the note they were writing. I wanted so badly for my students to be engaged, interested and even entertained that I abandoned my hopes of the connective sublime and added, "but maybe the deer saw a coyote."

The mention of a coyote instantly aroused their interest. Some students actually sat up straighter in their seats and leaned in towards the screen to take another look at the deer. Excited by their attention, I began to talk about coyotes. I explained that the animals had recently made a comeback in our area and that there had even been reports of them killing farm animals. Although I explained that coyotes were too small and skittish to be a threat to anything bigger than a rabbit or new born calf, students were fascinated with the very idea of a predator roaming the area. For my students this was an influential experience that changed the way they saw the world -- as was evident from the several student-reported coyote 'sightings' that occurred throughout the unit. For me, this was also an important moment, because it was when I too easily gave up my quest for conveying the connective sublime in the ecology unit.

To return to the issue as to whether or not I intensified my students' pre-existing fears of nature, I have to conclude that in many ways I did. I have described what happened in the ecology unit in terms of giving up on the connective sublime and giving students what they wanted – danger. In the weather unit, I showed my students the most dangerous parts of 'the movement of energy' – violent storms. In response to a survey question that asked if students were looking at weather differently as a result of the weather unit, Mark, a 4th hour student wrote, "Yes, I think weather is a lot more dangerous now." However, Mark also wrote that he liked learning about storms, hurricanes in particular, and that storms were "cool".

Teachers know what Kant and Burke so laboriously described; students are fascinated with the dangerous aspects of science. The interesting question then becomes, is it wrong to explicitly teach to the extreme sublime in order to reach the understanding and affect of the scientific sublime? Should science teachers use their students' fascination with the terrifying and awe-inspiring to act as a motivator for content learning?

This is obviously a complex issue and one that I have mixed feelings about. Looking back on the experiences of my students, I find some justification in teaching towards the extreme sublime. In both classes, my students were more often than not engaged and excited about learning science. I was able to use their fascination with the extreme sublime to teach scientific processes and ideas that enabled them to make sense not only of nature's extremes like tornadoes and lions, but also of the more common and everyday like a cloudy sky or a pet dog. These are all positive, yet difficult to attain things, so I certainly see some merit in the approach. But is engaged, active learning worth encouraging a fear of nature? Ultimately my answer to this question is yes, for the following reasons.

If respect and appreciation for nature is a goal in science education, then teaching to foster the extreme sublime is an effective way of instilling these feelings. I argue that the feelings of appreciation for nature may initially arise out of a fear and our fascination with this fear, but I think through increased understanding, the fear becomes something different. Rather than an ignorant fear, a positive first step for our students may be a fear based on knowledge rather than ignorance. My ecology students began the unit afraid of lions simply based on their alleged ferocity. As we progressed through the unit, students

were still afraid of lions, but at least this fear was now based on an understanding of the lion's incredible physical prowess and behavioral traits that make him a 'super predator'.

As a result of the unit students had a much more complete understanding of lions and the animals became more than just mysterious, ferocious killers. Once we have some understanding of what makes the animal terrifying, some of the terror must begin to subside. As discussed in Chapter 1, in Burke's types of the sublime "obscurity" was second on the list. Of this topic he wrote (1757, p.58),

> To make anything very terrible, obscurity seems in general to be necessary. When we know the full extent of danger, when we can accustom our eyes to it, a great deal of the apprehension vanishes.

By teaching to the extreme sublime, perhaps I not only engaged and motivated my students to learn science ideas, I also helped "accustom" their "eyes" to their fears. Similarly, Burke (1757) also wrote,

> Astonishment, as I have said, is the effect of the sublime in its highest degree; the inferior effects are admiration, reverence, and respect.

While I am troubled by the thought of leaving my students with an amplified fear of nature, these last two lines by Burke help ease my conscience. I did capitalize on my students' natural fascination with the extreme sublime, but I also taught them a great deal about the natural world in my attempt to reach the scientific sublime. If I was able to help them understand the things that scare them, perhaps my students moved beyond pure "astonishment" and were left with what Burke calls the lesser effects of the sublime – "admiration", "reverence", and "respect".

Limitations and Future Research

The most serious weaknesses of this research come from the fact that I was both teacher and researcher. First, I have no way of knowing whether the effectiveness of my teaching approach should be attributed to the approach or simply to who I am as a teacher – the excitement, energy, and sublime sensibility that I bring to science learning. I suspect that these aspects of my personality account for some of the sublime experiences my students had.

Other weaknesses exist as a result of acting as both teacher and researcher. I found it difficult to focus on both tasks at the same time and tended to put the majority of my emphasis on the more pressing job of daily teaching. I was able to use the general outline of the units that I had developed before teaching, but found that I was constantly changing my lessons based on the previous day's experiences. I put in considerable effort to be sure that in every lesson I did the best I could in terms of fostering sublime experiences. The teaching process of writing and re-writing lessons, identifying materials, reflecting on each class, and actually teaching every day often superseded my role as a researcher. As a result, I was not able to collect as much data from the students around their experiences as I would have liked.

A solution to address both of these problems would be to conduct similar research in a situation in which I was not the teacher. This type of research would allow me to better determine how much of a role my personality as a teacher and science learner had in the students' sublime experiences as opposed to the teaching approach I worked from. In this process it would also force me to become clearer in regards to my teaching approach, and allow me to discover effective ways of instructing others to teach using the

approach. Perhaps most importantly, it would give me the chance to act solely as a researcher to better record the experiences of students. In this role I would be interested in investigating:

- How student sublime experiences change over time
- How student experiences taught using this approach compare to the experiences of students taught using another approach (e.g.. inquiry teaching)

Along a different line, I am also interested in whether or not this type of teaching could be taught to others. Given the teaching framework I developed, would other teachers be able to replicate the experiences my students had? This could prove to be a challenging task for many of the reasons I outline in the teacher narrative at the end of chapter 5.

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