A PICTURE IS WORTH A THOUSAND WORDS:

ASSESSING DRAWING AS A LEARNING TOOL IN SCIENCE

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Abstract

Art and science have long enjoyed a symbiotic relationship, one worth re-examining in our educational practice today. Illustrations convey information that the written word simply cannot, hence the old adage, “A picture is worth a thousand words.” Visual literacy, the ability to create and understand images and symbols, may be more important than ever in an increasingly image-savvy culture. Yet, in the current educational climate, art is often seen as expendable compared to academic subjects. Observation and problem-solving skills, crucial to both artists and scientists, can be developed through drawing. Theories of Brain-Based Learning and Multiple Intelligences support that accessing this visual-spatial learning mode, along with direct observation in an outdoor site, enhances cognition and retention of information through a multi-channeled approach. While several broader studies affirm the value of art and science integration, there have been few studies specifically assessing drawing as a learning tool and its practical application in K-12 education. In this study, 390 middle school students in Wisconsin participated in a tree identification lesson with a classroom and field component. A control group completed the lesson using a text based dichotomous key, while the experimental group used an active observational drawing method. Pre- and post- assessments measured student knowledge of tree identification terms and species recognition. Students completed a self-assessment of their learning styles based on Howard Gardner’s Multiple Intelligences theory, and the impact of the observational drawing method was compared between both groups and across the eight intelligences. While there was no statistically significant difference found in the students’ assessment scores, teacher observations of student behavior and student attitudes toward the drawing activity point to its value

Keywords: Observational drawing, brain based learning, multiple intelligences, tree identification, environmental education

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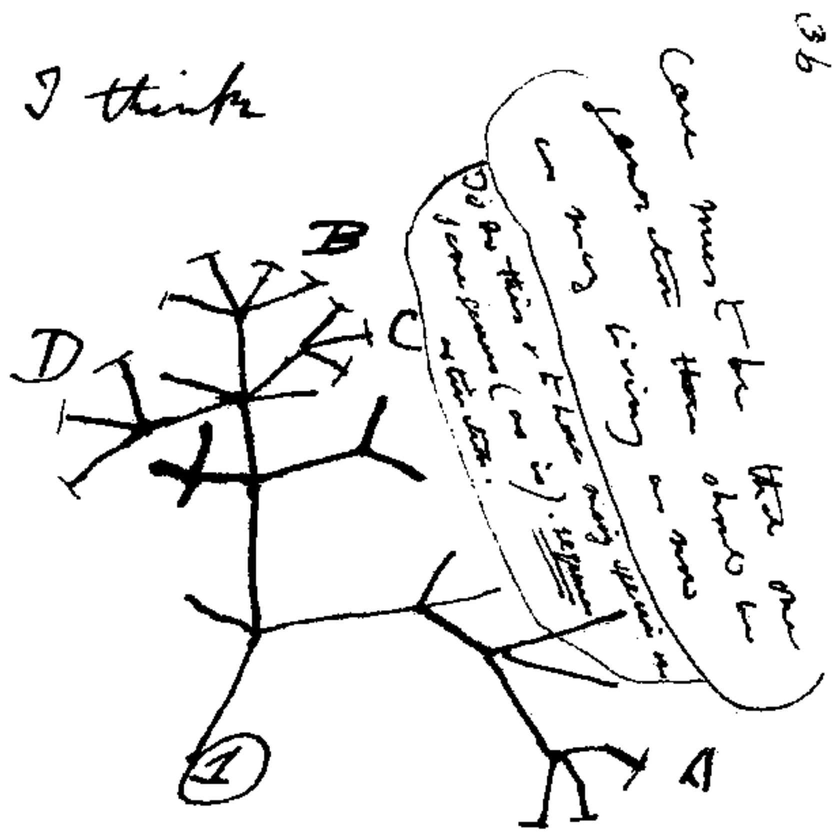
Epigraph



Tree of Life illustration–Charles Darwin, “On the Origin of Species”

“The affinities of all the beings of the same class have sometimes been represented by a great tree. I believe this simile largely speaks the truth. The green and budding twigs may represent existing species; and those produced during each former year may represent the long succession of extinct species.”
—Charles Darwin, *On the Origin of Species* (Darwin, 1869, p.104).

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Chapter 1. Introduction to the Study

Charles Darwin, one of the greatest natural scientists of all time, was obviously a visual thinker–his famous tree of life diagram with the words “I think” written above it are a testament to that. Using a visual strategy, he mapped out his thought process that led to his groundbreaking theory of the origin of species and natural selection. Although he understood the value of drawing to communicate scientific information he observed about organisms and their behavior, in his *Autobiography* he lamented, “another of my occupations was collecting animals of all classes, briefly describing and roughly dissecting many of the marine ones; but from *not being able to draw* and from not having sufficient anatomical knowledge, a great pile of MS [sic] which I made during the voyage has proved almost useless” (as cited in Canfield, 2011, p.102). This loss of precious data due to his perceived lack of skill and training in this area is significant –and points to the vital, but often undervalued, importance of art to the sciences.

Although seemingly two separate worlds, in reality art and science are closely tied together (Eisner & Powell, 2002). Artists and scientists share a common characteristic– they both rely on keen observation skills to collect data and come to new understandings and theories about how the natural world functions. Much of what we know about the function and structure of life forms and the ecological systems they inhabit is based on physical observations of visual phenomena. Artists, especially those in the precise disciplines of botanical and scientific illustration, have played a significant role throughout history in shaping our understanding of the natural world through their ability to observe, capture, and communicate visual data.

Images can convey information that is beyond the grasp of a verbal or written description, hence the old adage, "a picture is worth a thousand words." Before the advent of photography, images had to be hand-drawn and accurate drawing skills were essential for the natural scientist. Draftsmanship was commonly taught in conjunction with biology, botany, zoology, and human anatomy. Even with today's digital technology, the best photograph still lacks the capacity to emphasize or de-emphasize the subtle visual features of a specimen that distinguish it from another similar species. This necessary human element of keen observation and discernment, along with the artist's ability to render what is important for us to see, inextricably ties art and science together in a symbiotic relationship that benefits both disciplines. In a world that relies increasingly on images to convey information, using drawing as a learning tool in the natural sciences to increase students' visual literacy may be more relevant than ever.

Despite this long working relationship, in the current standardized-test driven educational climate, art is often viewed as an expendable "frill" compared to core academic subjects such as science. Eliot Eisner, a foremost art education expert and longtime advocate for arts integration, articulated this prevailing view, commenting that "art, it is widely believed, is largely ornamental in life—nice but not necessary; science is critical to the future" (Eisner & Powell, 2002, p.132). But is art indeed a valuable and overlooked subject area that can be used to expand and enhance overall student learning and competency in science?

There are common denominators in both subject areas that point to its value. "In science, being able to articulate subtle differences in what we observe is a useful skill in guiding inference, prediction, and classification" (McKinnon, Livingston, & Crouse, 2012). Necessary skills common to both artists and scientists, such as careful observation, problem solving, experimentation, perseverance, and communication, can be effectively developed through the integration of art and science. Concentrating solely on academic subjects at the expense of the visual arts overlooks some of the critical skills that art is uniquely suited to teach. “While students in art classes learn techniques specific to art, such as how to draw, how to mix paint, or how to center a pot, they’re also taught a remarkable array of mental habits not emphasized elsewhere in school. Such skills include visual-spatial abilities, reflection, self-criticism, and the willingness to experiment and learn from mistakes” (Winner & Hetland, 2008, p.29). The art room may be one of the few places in our schools that create the kind of climate where innovation can develop; where students can freely experiment and try creative approaches to solving problems without the fear of being “wrong.”

Art-based strategies can be successfully used outside the art room as well. Observational drawing in particular is a learning tool that has often been used in the science laboratory to make visual notes of observations and specimens. It is important here to distinguish between drawing for visual communication rather than primarily aesthetic or creative pursuits. Often art is “put on a pedestal” and viewed as unapproachable, a skill requiring a special talent or a high degree of creativity to master, but in reality it is a living process (Dewey, 1934). When the creative aspect of art is de-emphasized and drawing is taught as a learnable skill, it increases observation, a foundational skill that is essential for success in science (MacKinnon, Livingston, & Crouse, 2012). While these drawings may very well be aesthetically pleasing, their primary purpose in this instance is to record and communicate scientific information.

Theoretical Frameworks

Brain-based learning. Brain-Based Learning, an educational theory and instructional approach that combines current knowledge from the field of neuroscience with education, forms a framework for this study. This theory asserts that cognition and memory are enhanced by an approach to education that engages several neural pathways and forms many simultaneous connections. Built on a core philosophy of twelve principles, Brain-Based Learning seeks to tap into the natural learning styles of students to optimize synthesis of information and experiences. Of these twelve principles, the following three--outlined here and discussed more thoroughly in the following chapter--are particularly relevant and form the basis of this research (Caine & Caine, 1990):

> ***Principle #1 All learning engages the physiology***. *All students have the capacity to comprehend more effectively when involved in experiences that naturally call on the use of their senses and their bodies.*
>
> ***Principle #9 There are at least two approaches to memory.*** *All students can comprehend more effectively when immersed in experiences that engage multiple ways to remember.*
>
> ***Principle #12 Each brain is uniquely organized.*** *All students can comprehend more effectively when their unique, individual talents, abilities, and capacities are engaged.*

Multiple intelligences. Howard Gardner's *Theory of Multiple Intelligences* (Gardner, 1983, 2011) evolved from neuroscience as well, and has become widely accepted and applied by educators since its introduction over thirty years ago. This theory expanded the narrow Stanford-Binet definition of IQ to embrace eight separate intelligences. Gardner felt these intelligences–Logical/Mathematical, Verbal/Linguistic, Musical/Rhythmic, Visual/Spatial, Bodily/Kinesthetic, Interpersonal, Intrapersonal, and Naturalist–better captured aspects of intelligence that were not conventional "academic" intelligence. The dominant instructional delivery method is verbal-linguistic in most school settings. This singular approach, which relies on the spoken and written language, often fails to effectively engage the other learning styles, such as the visual-spatial learner who learns best through images, charts, or graphs. Based on, this theory, it made sense to use an instructional strategy that could engage the visual/spatial learner in teaching a skill like tree identification–a skill that relies heavily on keen observation and perception of details, pattern recognition, and associating a written word with visual memory.

Purpose of the Study and Research Questions

The purpose of this study was to assess the impact on student learning of using a visual instruction method and an observational drawing activity in an existing text-based tree identification lesson. It also assessed the effect that this technique had on student learning across the spectrum of multiple intelligences. This study was guided by the following questions:

1. To what extent does participating in a drawing activity as part of a tree identification lesson affect student short- and long- term knowledge of Wisconsin tree species?
2. How does participation in a drawing activity impact student learning across different learning profiles, as identified in a Multiple Intelligences Inventory?
3. How does participation in a drawing activity affect students' observation and perception skills of distinguishing characteristics of tree species?

The null hypothesis was that there would be no significant effect of the independent variable of drawing on the students' performance in this tree identification lesson.

Significance of the Study

This study explores the effect of a visual art-based strategy on student learning in science, and fills a small but potentially significant gap in the existing research. While there has been research on the effectiveness of multisensory brain-based learning approaches (e.g. Jensen, 2011), there are few studies that focused specifically on drawing. Studies that have examined the effectiveness of art integration with science tend to be more broad-based, encompassing all of the arts (e.g. music, dance, theater) rather than just the visual arts. Most studies conducted from an art education perspective do not necessarily address the applicability of art-based strategies in the regular or science classroom, and the data gathered is largely qualitative. While these studies certainly have value, they may lack the type of "evidence" that science and regular classroom teachers need to justify trying a new instructional strategy. There is little quantitative research with a large and diverse sample population focusing specifically on the measurable effects of art and science integration on K-12 students in the public school system.

A recent Johns Hopkins summit on neuroeducation, which focused more on the long-term, indirect effects of an arts integration-based approach to education, pointed to this same need for further research. (Hardiman, Magsamen, McKhann, & Eilber, 2009) While it is valuable to study the effects of the arts in general on creativity and student achievement, this is often difficult to measure as these effects tend to be more long term and indirect; pinpointing exactly what aspect of the arts is producing a certain effect is also difficult to ascertain. Based on the summit's discussions among key educators and scientists, the report cited the need for research that "tests the integration of the arts across certain content areas, such as science, social studies, math, and literature" and that can assess the "acquisition of content knowledge on curriculum-based assessments, the level of student engagement in learning tasks, and student satisfaction and self-confidence in learning" (Hardiman et al., 2009, p.66-67).

As funding and instructional time for arts programs in many school districts are dwindling, demonstrating the value of art-based instructional techniques in core curriculum areas may increase support for art programs in the public schools. Integrating art into STEM (science, technology, engineering and math) subjects has been shown to build valuable skills, such as observation, problem solving, and innovation, that cross over both subject areas (Sousa & Pilecki, 2013). Further research that documents positive learning outcomes of art-based teaching strategies could pave the way for more collaboration between art and science teachers, to the benefit of both fields.

Delimitations

The following parameters were set by the researcher for this study to ensure feasibility of the project's completion:

- Only schools that are in the LEAF database with registered school forest sites were contacted for research participation.
- The total size of the sampling population was limited to 400 students across all sites and groups.
- Only middle school students in selected K-12 public schools were chosen for the sampling group.

- Only one tree identification lesson, with pre-and post-assessments, was administered to all groups.
- This study only assessed the impact of the drawing tool on this tree ID lesson; it will not measure long term effects of arts integration in science.

Limitations

The following were possible factors beyond the researcher's control that could foreseeably affect the implementation or results of the study:

- Academic schedules and availability of research participants.
- Adverse weather conditions for outdoor observations.
- Students' self-consciousness or lack of confidence in using drawing skills.
- Varying degrees of prior student knowledge of tree species based on factors other than instruction given.
- Students' and teachers' varying degrees of comfort and familiarity in outdoor learning sites

Assumptions

For this study, it was assumed the following would be true:

- Students within the same school had the same amount of in-school instruction in basic drawing techniques.
- Students within the same school had the same level of prior instruction in science class.
- Students participated in both the verbal/written and drawing components of the tree ID lesson to their best ability.
- Students gave truthful and complete answers in the pre- and post-assessments.

- Students in the experimental group were willing to draw as part of the lesson.
- Teachers would conduct all assessments and supervise the field component of the tree ID lesson at their school site.

Definitions

The following terms occur throughout this study:

- Classroom Teacher: Teacher who teaches the class on a daily basis.
- Drawing: The act of representing objects or forms on a surface chiefly by means of lines.
- Illustration: A drawing that accurately depicts a biological specimen with the purpose of conveying visual scientific information.
- LEAF: Learning, Experiences, and Activities in Forestry, the Wisconsin K-12 forestry education program. Provides forestry education curriculum resources, professional development, and outreach to school districts with registered school forests
- LEAF Instructor: Outreach staff member of the LEAF K-12 School Forestry program who delivers the Tree ID lesson to students.
- Observation – Receiving of external data through the senses; throughout this study, observation refers to receiving visual external data through the eyes.
- Observational Drawing: Drawings made with the purpose of creating a life-like representation of the object. The illustrator must be directly observing the object while drawing.
- Observational Skill – the level of ability to perceive objects and phenomena in such a way as to generate visual data.

- School Forest: Area of forested land owned or controlled by a school district and registered with the LEAF program.
- Wisconsin K-12 Forestry Lesson Guide: A document created for use by teachers in Wisconsin. It was developed to incorporate forestry education into K-12 classrooms. It contains both classroom lessons and field enhancements.

Chapter 2. Literature Review

The literature that informs this study spans many disciplines and crosses the centuries to arrive at the intersection of art and science where we now find ourselves. Tracing this journey through the overlapping lenses of both disciplines, new educational strategies may be lurking in the lessons of the past, pointing the way to developing the twenty first century skills our students will need.

Relationship of Art and Science

> *"…the more minutely you describe, the more you will confuse the mind of the reader and the more you will lead him away from a knowledge of the thing described. Therefore it is necessary both to illustrate and to describe."*
>
> –Leonardo da Vinci (in Keller, 2008)

Historical foundations. History is filled with multitudes of examples of artists whose work was informed by science, and whose work illuminated scientific discoveries. Spurred on by the curiosity common to both fields, and working from direct observation of the natural world, their considerable talents contributed much to the body of scientific knowledge we have today.

Leonardo da Vinci's notebooks are a glorious celebration of the intersection of science and art. In a time where the line of distinction between artist and scientist was decidedly blurred, Da Vinci walked both worlds. The original "Renaissance man," he left us a legacy of art including *The Last Supper* and the *Mona Lisa*. His notebooks were filled with renderings of everything from flying machines to anatomical dissections. Nothing escaped his prolific curiosity from documentation. Perhaps no artist in history has left us with a better example of the sheer power of creativity combined with a keen eye for observation of the natural world (Gelb, 1998).

Although not as well-known as Leonardo da Vinci, the work of German artist and naturalist Maria Sybilla Merian is remarkable, especially considering she was a divorced woman who worked without patronage in 1699. Leaving her home and daughters to document insect life in Dutch Suriname, her fascination with insects, especially butterflies, and their life cycles added much to science's understanding of metamorphosis. She worked from direct observation of live specimens whenever possible, producing work of painstaking accuracy and detail. She published her folio of paintings in a book, *Metamorphosis,* in 1701. Her writings, which accompanied these images, demonstrated an advanced knowledge of the interrelationship of life, born of acute observation and visually documented. Her vision was remarkably ahead of her time and "it could be argued that the greatest influence of *Metamorphosis* was in its microcosmic vision of nature, for Merian was the first to elucidate through word and art what we now think of as food chains and interactions within ecological communities" (Etheridge, 2010, p.21).

One of the most prolific artists to illuminate the wonders of nature was Ernst Haeckel, whose drawings of ocean life, some of it microscopic, revealed fantastical forms and an underlying structural order that astounds viewers to this day. Himself a physician and scientist, Haeckel is known as the first to have coined the term "ecology" in 1866 (Stauffer 1957) and was fascinated by Darwin's theory of evolution. Although Robert Stauffer, one of the foremost experts on Darwin, contends that Haeckel's work as a scientist was dubious and tainted by personal beliefs in German nationalism, he admits, “In his work as a field naturalist, Haeckel showed a painter's eye for the beauties of nature” (Stauffer, 1957, p. 138) After reading *Darwin’s Origin of Species* (Darwin, 1869), Haeckel believed his mission as an artist was to paint the images that would lend support and understanding for the theory of evolution. Stauffer writes, “Haeckel's major contributions may be best understood as an immediate byproduct of his aim to interpret Darwin's thought for the scientific world” (Stauffer, 1957, p. 138). This he did with consummate skill, contributing as much to our sense of wonder as to our scientific knowledge of the structure of organisms. Books of his images are still in print today, based on his 1866 work, *Generelle Morphologie der Organismen* (Haeckel, 1866).

Merian and Haeckel were just two in the wave of the many artist/naturalists who documented the discoveries of the new world, as Europeans went on expeditions to every corner of the globe. Botanical and biological illustration became an art form in itself, as artists captured the wonder of new species. One of the most famous of these was John James Audubon, whose sumptuous watercolor paintings of American birds documented many species, some now extinct, for posterity. Audubon painted from actual specimens he often shot himself and wired into lifelike poses. His seminal work, *Birds of America*, contained a total of 435 prints and was an instant success in Britain (Audubon,1843).

What these artists captured through their observations could be considered visual data, no less valid than data recorded in written form. Alexander von Humboldt’s discoveries of botanical geography, whereby certain groupings of plants and organisms live in areas of similar soils and climate, depended largely on his visual observations of the natural structures and habits of plants within these communities. While he employed empirical scientific methods, to Humboldt, “aesthetic and emotional responses to natural phenomena counted as data about these phenomena. Aesthetic reactions to the various sorts of vegetation were indications of the particular effect of different natural environments upon human society." (Nicolson, 1987, p.180)

In a similar vein, philosopher Henry David Thoreau's aesthetic and emotional response to forest vegetation and animal activity led to an understanding of forest succession long before the concept was analyzed scientifically. In his 1860 paper, *The Succession of Forest Trees,* he writes

> But on looking carefully along over its floor I discovered, though it was not till my eye had got used to the search, that, alternating with thin ferns, and small blueberry bushes, there was not, merely here and there, but as often as every five feet and with a degree of regularity, a little oak, from three to twelve inches high, and in one place I found a green acorn dropped by the base of a pine (Thoreau, 1860).

This gathering of visual data is the first step in the process of scientific inquiry, and in the cases of von Humboldt and Thoreau, their responsiveness to the aesthetic and emotional experience led to new theories that were just beyond the grasp of the rational scientific method.

But not all scientists valued the use of images and visual data. Curiously enough, the father of modern botany, Carolus Linnaeus, devalued illustrations of plants and promoted the superiority of his written descriptions. The founder of the system of binomial nomenclature, Linnaeus snubbed illustrations as useful only to "boys and those who have more brain-pan than brain" (as cited in Reeds, 2004, p.1). While his system of classifying plants and standardizing the descriptions of their features made botany more orderly and comprehensible, it forever placed the written description of plants above images as the preferred means of description for scientific purposes. In her article "When the Botanist Can't Draw", botanical historian and museum curator Karen Reeds writes, "making pictures of plants was not critical to mastering the Linnaean system, Linnaeus did not recommend it to his own students, and Linnaeus himself was laughably inept at drawing" (Reeds, 2004, p.2). It may be due to Linnaeus's own lack of ability, rather than true superiority of the written word, that he promoted written descriptions and demoted illustrations to child's play.

Contemporary examples. More than a quaint anitiquated pastime, drawing in the scientist's field notebook is still relevant today. For the scientist, drawing is an important observation tool, with some distinct advantages that cannot be matched by the use of photography. In her article "Why Sketch?"*, scientist* and illustrator Jenny Keller argues that, for the scientist, sketching has value in and of itself as "drawing makes you look more carefully at your subject. As an observational tool, drawing requires that you pay attention to every detail, even the seemingly unimportant ones" (as cited in Canfield, 2011, p.162). Creating an accurate illustration requires the same sort of attention that scientific observation does, and keeping an illustrated field notebook is a way to capture and document important information gained from field research.

These field notebooks are important sources of data to reference in later research or to articulate information gained in the field to others in a different–but no less important–manner. In *The Chicago Guide to Communicating Science*, author Scott L. Montgomery asserts that,

> the visual dimension of science forms a language all its own, a kind of pictoral rhetoric, if you will. By this I mean that graphics are often much more than a handmaiden to writing. They don't just restate the data or reduce the need for prose, but offer a kind of separate 'test' for reading and interpretation. (Montgomery, 2003, p.113)

This principle is abundantly evident in the works of contemporary scientist, artist and prolific author Bernd Heinrich. His drawings of flora and fauna grace books that transport us to his remote Vermont cabin, giving us a glimpse through his scientist's eye view of the natural world. Heinrich's scientific observations, peppered with anecdotes, reflect his own thoughts as a steward of the property, as well as a field researcher. One of the best examples of this is in his book *The Trees In My Forest*, in a chapter entitled "Tree Geometry and Apical Dominance (Heinrich, 1997, p. 89). Here his skillfully detailed illustrations of the structural branching patterns of various trees growing in his woodland instantly convey the concept of apical dominance, greatly enhancing his text descriptions. This and his many other popular books have contributed much to the public's understanding of science and ecology by making seemingly complicated scientific concepts more understandable and approachable.

Many contemporary artists whose works illuminate field guides, such as Roger Tory Peterson in the popular *Peterson Field Guide to Birds* (Peterson & Peterson, 1980), have consummate skill for depicting the minute details and subtle differences that distinguish between species. Often these details are impossible to capture in photographs, hence many scientists caution against relying on the use of photographs alone for identification. As a scientific illustration professor, Keller points out those photographs can contain distortions:

> Colors in photographs are typically (sometimes dramatically) inaccurate, proportions are often distorted, and key features of the species may not be recorded clearly (or captured at all). Use of a camera can impart a false sense of security as well, especially when a quick check of the digital screen seems to show us a perfect likeness of our subject. (as cited in Canfield, 2011, p.163).

The work of these illustrators enables countless other scientists and students to make their own correct field identifications, adding to the base of scientific knowledge of the life around us. Their unique human ability to capture and emphasize the essential distinguishing features of a plant or animal species ensures scientific illustration will always have a place and purpose in the natural sciences.

Art and Science in Education

> *"The science of ecology needs the joy of art. Students can name a moss, count a moss, and there is praise, but when they draw a moss, it is not just their eyes, their mind, that know moss, it is also their hand, their arm, and their heart." (Farnsworth, Baldwin, & Bezanson, 2014)*

Historical precedents. In years past, observational drawing was often utilized as a learning tool at the university level. In the mid-19th century, Harvard zoology professor Louis Aggasiz taught his students to actively observe specimens in the lab and draw them claiming, "a pencil is one of the best eyes" (as cited in Lerner, 2007, p.1). Often his students would remark that, through being forced to draw, they saw details they would not have seen through observation alone.

Anna Botsford Comstock, in her 1911 book *The Handbook of Nature Study*, saw drawing as a natural extension of a child's curiosity. The nature study movement aimed to teach children by engaging their sense of wonder and inspiring inquiry, rather than imposing facts and knowledge upon them. The teacher's role was more of a facilitator than instructor, encouraging the development of students' observation skills and knowledge by providing them with the access and opportunities to observe the life around them, rather than direct instruction.

Comstock felt "the correlation of nature-study and drawing is so natural and inevitable that it needs never to be revealed to the pupil" (p. 17). Driven by interest in the natural world around them, she often observed that students chose to make art without prodding or teacher interference. She extolled the virtues of the illustrated field notebook, both as a way for the child to record their observations, and for the teacher to gain insight into the child's learning:

> The field notebook is a veritable gold mine for the nature-study teacher to work in securing voluntary and happy observations from the pupils concerning their-out of-door interests. It is a friendly gate which admits the teacher to a knowledge of what the child sees and cares for." (Comstock, 1911, p.14)

The current trend in education of using student journals as assessment tools would certainly be nothing new to Anna Botsford Comstock. The nature study movement she nurtured seems a precursor to the natural learning styles, multisensory experiences, and individualized, student-driven learning that is the foundation of modern educational theories, such as Brain-Based Learning, of today.

Contemporary value of art in science. In today's educational climate--where achievement, competition, and pressure to succeed reign supreme–how can we retain the charm and wholesomeness of the nature study movement while meeting the demands for student learning? The answer may lie in time-honored practices that create a place for inquiry to flourish. One such tool is the scientific field notebook. In their article *An Invitation for Engagement: Assigning and Assessing Field Notes to Promote Deeper Levels of Observation,* Farnsworth, Baldwin, and Bezanson (2014) write that field journals have value in building the inquiry and observation skills, that are critical for students to develop to succeed in science:

> When students engage with drawing and sketching as part of their field notes, their attention to the natural world becomes transformative, moving beyond mere documentation. Describing, recording, and drawing field observations represent the first steps of field-based scientific inquiry and creativity. These observations fuel description ("what" questions), hypothesis testing ("why" and "how" questions), experimental design, and ultimately management decisions. (p.12)

Keeping a field notebook encourages students to actively engage with the natural world around them, and record what they see, rather than passively take in information. They are a valuable learning tool that seamlessly integrates art with science, encouraging the development of literacy and written communication skills as well.

Art-based strategies may have immeasurable benefits as well. Elliot Eisner, one of the top theorists in the field of art education and longtime advocate for the value of the arts integration in K-12 education, believes that art has far reaching effects that may not be readily apparent. He asserts that while art integration may not necessarily produce a direct and immediate link to higher test scores in academic subjects, in the long term, they build critical skills for success in academics and in life (Eisner & Powell, 2002). Eisner focused on the development of functional working processes for lifelong learning from participation in the arts. These lessons can be learned indirectly through the lens of art, and have broad-based applications across many subject areas. These included the following:

- *The arts teach children to make good judgments about qualitative relationships*. Unlike much of the curriculum in which correct answers and rules prevail, in the arts, it is judgment rather than rules that prevail.
- *The arts teach children that problems can have more than one solution* and that questions can have more than one answer.
- *The arts celebrate multiple perspectives.* One of their large lessons is that there are many ways to see and interpret the world.
- *The arts teach children that in complex forms of problem solving purposes are seldom fixed, but change with circumstance and opportunity*. Learning in the arts requires the ability and a willingness to surrender to the unanticipated possibilities of the work as it unfolds.
- *The arts make vivid the fact that neither words in their literal form nor numbers exhaust what we can know*. The limits of our language do not define the limits of our cognition.
- *The arts teach students that small differences can have large effects*. The arts traffic in subtleties.

- *The arts teach students to think through and within a material.* All art forms employ some means through which images become real.
- *The arts help children learn to say what cannot be said*. When children are invited to disclose what a work of art helps them feel, they must reach into their poetic capacities to find the words that will do the job.
- *The arts enable us to have experience we can have from no other source* and through such experience to discover the range and variety of what we are capable of feeling.
- *The arts' position in the school curriculum symbolizes to the young what adults believe is important* (Eisner &Powell, 2002).

The numerous potential benefits of art integration in our schools suggested here point to the need to further investigate how we can best accomplish this. In his article *What Education Can Do for the Arts,* Eisner writes, "education can learn from the arts that slowing down perception is the most promising way to see what is actually there" (Eisner, 2009, p.8). Art-based strategies can provide a way to do just that.

Observational drawing and science integration. Drawing is an activity that has a great potential to impact science learning in several ways. In *Drawing to Learn in Science,* Ainsworth, Prain, and Tytler (2011) outline many of the ways drawing can effectively develop and reinforce skills that scientists need. In this well-cited article, they make the case for actively drawing in science education as a way for learners to create their own visualizations, rather than just passively interpreting images from photographs, textbook illustrations, and other visual media. The physical act of drawing requires and demonstrates a synthesis of knowledge that does not necessarily occur from passive viewing. Stating that “becoming proficient in science also requires learners to develop many representational skills,” the authors argue “student drawing should be explicitly recognized alongside reading, writing, and talking as a key element in science education” (Ainsworth, Prain, and Tytler, 2011 p.1) and point to five key values of drawing in science:

> ***Drawing to enhance engagement***. — surveys have shown that when students draw to explain they are more motivated to learn compared to traditional teaching of science.
>
> ***Drawing to learn to represent in science.*** — the process of producing visual representations helps learners understand how scientific representations work.
>
> ***Drawing to reason in science.*** — students learn to reason like scientists as they select specific features to focus on in their drawings, aligning it with observation, measurement and/or emerging ideas.
>
> ***Drawing as a learning strategy*** — if learners read a text and then draw it, the process of making their understanding visible and explicit helps them to overcome limitations in presented material, organize and integrate their knowledge and ultimately can be transformative.
>
> ***Drawing to communicate.*** — discussing their drawings with their students provides teachers with windows into students’ thinking as well as being a way that peers can share knowledge, discovery and understanding. (Ainsworth, Prain, & Tytler, 2011).

Of these skills that students need to succeed in science, observation is crucial since it is a fundamental first step in understanding the structure and processes of life around us. This is a skill that drawing is most uniquely suited to develop, as it naturally invites the learner to focus on the object at hand. One student who used this approach in a botany lab commented, "You really have to look at something to be able to draw it correctly and you usually notice things about it you wouldn't otherwise if you just read about it or looked without drawing" (Baldwin & Crawford, 2010, p.22). In a year-long project called *The Seasonal Investigation of Trees*, which involved middle school students choosing a personal tree and drawing it periodically throughout the seasons, the researchers noted "the act of sketching most often requires longer observation of a subject or object than students who are not sketching are willing to do" (Levine, 2005, p.5). The process of observational drawing naturally encourages students to slow down and pay closer attention to the details, while the hand records what the eye sees.

Unfortunately, many students lack confidence in their drawing abilities simply because they have not been taught methods for drawing from observation that are effective in helping them accurately draw what they see. Part of this comes from lack of instruction, as Farnham et al. observed that "the greatest impediment to incorporating visual representation into curricula is that most individuals have little experience beyond early childhood in using visual representation" (Farnham et al. 2011, p.20). This impacts the use of drawing as an effective learning tool.

In order for drawing to be a truly effective tool in science, it seems that some instruction in drawing techniques is needed. We have a tendency to draw what we "think" we see rather than what really is. In her book, *Illustrating Nature,* scientific illustrator Irene Brady explains "to illustrate realistically, you must learn to listen to your right brain so that you can draw what you actually see, not a symbol for what you 'know' is there" (Brady, 2004, p.5). Examples of this are children's stereotypical drawings of "lollipop trees." When students are guided through exercises that short circuit analytical processes–such as drawing upside down, blind contour drawings (a process of not looking at the drawing but concentrating only on the subject) or drawing looking through a grid that breaks objects into shapes--their drawing ability dramatically improves with practice. We often think of drawing as inborn talent rather than a learnable skill, and so often students become discouraged with their attempts.

In her study *Perceptual Drawing as a Learning Tool in a College Biology Laboratory,* biology professor and artist Jennifer Landin looked at three different treatments to assess their effect on student learning in an introductory biology lab. These included writing a description, drawing a perceptual image, or drawing a perceptual image after participating in a short drawing lesson (Drawing with Instruction) over the course of a semester. Results indicated that "the students in the 'Drawing with Instruction' group exhibit a small but significantly higher level of content knowledge by the end of the semester" (Landin, 2011, p.56). Interestingly, there was no statistically significant difference in scores between the Writing and Drawing only groups; this supports the need for instruction and guidance in order for students to make effective use of this learning tool.

One way to offer this kind of instruction was through collaborative classes with an art instructor. In their study *Linking Art and Science with a Drawing Class*, Biology professor Edmund Aklaslassy and art professor Terry O'Day collaborated by offering a separate drawing class to students concurrently enrolled in an introductory biology course. Out of the 142 students in the course, only 18 chose to enroll in the drawing class.

While the drawing class used biological specimens as subject matter, “the primary goal of the drawing course was the improvement of the students’ ability to draw” (Alkaslassy & O’Day, 2002, p.8). Students were given assignments that involved observing and drawing specimens without any exposure to the scientific terminology or knowledge of them. This approach did not result in any significant gains in student knowledge, and while students agreed it helped their overall observation and drawing skills, they were somewhat frustrated at the lack of a direct link between content in the biology and drawing classes.

Combining these two approaches by providing instruction along with specific objectives that are meant to enhance the content of the science class seems to be the most potentially effective approach, since visual arts seem to “have the strongest effect on cognition when used as a *tool* for academic learning” (Jensen, 2001, p.58). One study, *Art Instruction in the Botany Lab: A Collaborative Approach,* took this approach. All 41 students in the introductory college level botany class were required to keep an illustrated journal throughout the course. This was described to the class as “an exercise book in which you must practice looking at plants and recording what you see” (Baldwin & Crawford, 2010, p.20).

The researchers noted that students had a certain level of anxiety about their drawing ability; the instructor of the botany class reported that he also felt inadequate to teach basic drawing skills that the students would need to successfully complete the illustrated journal assignment. As a solution to this problem, a professor from the art department taught two sessions on drawing from direct observation to give them foundation of needed skills. The instruction emphasized the type of drawing they would need to accurately record and communicate their experiences in the botany lab, and the aesthetic/creative aspects of the assignment were de-emphasized. This seemed to make the students more comfortable. Even though the drawings were not judged on their artistic merit, a three-part rubric was used in grading the assignments based on the accuracy and completeness of scientific information contained in them.

The results of this study did not measure student achievement in the botany class itself, but rather the perceived value of the drawing component. The researchers administered an end-of-term survey to students with questions such as "Did drawing teach you anything about science?" Overall, students indicated that the journal assignment had a positive influence on their learning, although this was not correlated with test scores or class grades.

Art and the Brain

To understand and appreciate the theories of Brain–Based Learning and Multiple Intelligences that form the foundation of this study, one needs to have a basic working knowledge of the structure and processes of the brain involved in learning and memory. From the initial collection of visual information, to the creation of an image, and ultimately the formation of long-term memory, there are many unseen processes at work.

Brain based learning theory. The foundations of brain-based learning began with research in neuroscience made possible by new technologies such as MRIs, EEGs, PET and CAT scans; this has led to an ever-increasing understanding of how the brain naturally learns. Some of the first modern research into the inner workings of the human brain was done by Nobel prizewinner Roger Sperry. Although it has led to oversimplifications and persistent right vs. left brain myths, Sperry's groundbreaking research in the 1960's established the widely known "split brain theory". By studying the brain function among epilepsy patients whose corpus collossum (the connective tissue between hemispheres) was surgically removed to alleviate seizures, he discovered that the left and right sides of the brain had distinctly different functions (Sperry, 1968). It was thought that abstract, linear functions such as mathematics and the ability to use written language are primarily left brain functions, while understanding and communicating images, creativity, and Gestalt processing is the right brain's primary domain. One hemisphere supplied the "picture," the other the "thousand words" (Pink, 2006, p.19). This led to many "right-brained" teaching methods, especially popular in the visual arts, such as Dr. Betty Edwards landmark book, *Drawing on the Right Side of the Brain* (1999).

In reality, all parts of the brain work together as a whole, and it is more accurate to think of brain function in terms of relative lateralization than right/left hemisphere compartmentalization (Jensen, 2008). Tasks such as producing artwork actually involve *both* sides of the brain, as they require the use of materials, planning, structure, and methods to give shape to the creative thought and make a tangible image. Brain-based learning taps into this whole-brain approach to learning and memory formation, and rests on a foundation of twelve core principles (Appendix A). This study, with its use of a visual teaching method combined with a written dichotomous key, employs several of these principles (Caine & Caine, 1990). The three most relevant to this study and its methods were:

Principle #1 All learning engages the physiology. *All students have the capacity to comprehend more effectively when involved in experiences that naturally call on the use of their senses and their bodies.*

Engaging students in a multisensory experience in the outdoors, in this case directly observing trees and actively drawing them, provides a richer educational experience than passive classroom instruction from a textbook or photographic sources. Providing students with the opportunity to observe the growth patterns and species characteristics of trees in the context of their environment helps them to see differences between species and gives a holistic sense of the forest community. Salient features such as texture and three-dimensional structure, while difficult to sense from photographs, are easily grasped through the sense of touch.

Principle #9 There are at least two approaches to memory. *All students can comprehend more effectively when immersed in experiences that engage multiple ways to remember***.**

There are two types of memory involved in learning and retaining information– implicit (automatic) and explicit (through effort). Implicit and procedural memories are forged through hands-on experiences, while most of what we consider "knowledge" is explicit, semantic memory-the facts, figures, and terms learned by rote through conventional teaching methods. The existing text-based LEAF tree identification activity primarily engages the explicit, semantic memory, through logical/mathematical and verbal/linguistic learning modes in a sequential step-by-step process. This memory pathway forms the weakest links to long-term memory, while requiring the greatest effort on the part of the students. Using an image-based strategy with an active drawing component engages the visual/spatial mode, while the physical act of drawing engages students kinesthetically. The addition of these two learning modes, as well as a component of multisensory and emotional engagement, heightens the likelihood of comprehending and retaining new information.

> ***Principle #12 Each brain is uniquely organized.*** *All students can comprehend more effectively when their unique, individual talents, abilities, and capacities are engaged.*

This research principle overlaps with Howard Gardner's *Theory of Multiple Intelligences*. Developed in the 1980s, this theory identified an original seven intelligences that were based on research in neuroscience and cognitive psychology. This expanded the Stanford-Binet definition and measures of IQ that were accepted at the time, which he felt fell short of explaining phenomena such as exceptional musical ability. The eighth, Naturalist intelligence, was added by Gardner after a noted science historian and authority on evolution told him, "You will never explain Charles Darwin with the set of intelligences you proposed" (Gardner, 2003, p.19). Naturalists excel at distinguishing and categorizing species of plants and animals, and much of this also depends on a high degree of visual/spatial intelligence. Table 1 includes additional information.

Table 1. The eight multiple intelligence types

Intelligence	Characteristics
Verbal-Linguistic	well-developed verbal skills and sensitivity to the sounds, meanings and rhythms of words
Logical-Mathematical	ability to think conceptually and abstractly, and capacity to discern logical and numerical patterns
Visual-Spatial	capacity to think in images and pictures, to visualize accurately and abstractly
Bodily-Kinesthetic	ability to control one's body movements and to handle objects skillfully
Musical	ability to control one's body movements and to handle objects skillfully
Interpersonal	capacity to detect and respond appropriately to the moods, motivations and desires of others
Intrapersonal	capacity to be self-aware and in tune with inner feelings, values, beliefs and thinking processes
Naturalist	ability to recognize and categorize plants, animals and other objects in nature

According to Gardner, verbal-linguistic and logical-mathematical intelligences have been strongly favored in our public schools; these two make up what we commonly think of as "academic" or "scholarly intelligence". Gardner's theory challenged the prevailing "one size-fits all" approach to instruction and has since led to development of more individualized teaching methods that address the needs of many different types of learners.

Hemisphericity and the right-brained myth. One of the prevailing myths in education, especially art education, is that of hemisphericity, where "each hemisphere...has its own...private sensations, perceptions, thought, and ideas all of which are cut off from the corresponding experience in the opposite hemisphere. Each left and right hemisphere has its own private chain of memories and learning experiences that are accessible to recall by the other hemisphere. In many respects, each disconnected hemisphere appears to have a separate mind of its own" (Sperry, 1975). While the popular terms "left-brained" and "right-brained" loosely describe the specialized jobs each hemisphere perform, neuroscientists now tell us it's not quite that simple. David Sousa, explains the structure of the brain as "divided into two main hemispheres that are connected by a thick cable of nerves called the *corpus callosum.* This cable allows information to travel between the hemispheres so that the individual gets the benefit of whole-brain participation and integration" (Sousa & Pilecki, 2013, p.38). Some generalizations, though, do help us to understand the roles of each hemisphere. Daniel Pink explains in his book, *A Whole New Mind*, four basic truths about the left/right hemispheres:

- The left hemisphere controls the *right* side of the body, and vice versa.
- The left hemisphere is *sequential* while the right is *simultaneous*.
- The left hemisphere specializes in *text,* while the right specializes in *context.*
- The left hemisphere *analyzes* the details, while the right hemisphere *synthesizes* the big picture (Pink, 2006, p.17-22).

While the questions surrounding hemisphericity are beyond the scope of this study, the basic premises of the theory gave birth to the evolving theories of brain-based learning and multiple intelligences that inform this study. Since the subject of art and science integration is rife with "right-brain" references, it's important to understand the science behind them to dispel the myths and oversimplifications. The true dangers of perpetuating this myth lie in pigeonholing learners as a "left-brainer" or "right brainer," and possibly creating self-limitations, when in reality all students benefit from a whole brain instructional approach.

Sight and perception We are all, in a sense, visual learners since "between 80 and 90 percent of all the information that is absorbed by our brains is visual" (Jensen, 2008,

p. 55). It's important to start with an understanding of the physiological process of how we see, and how the brain processes that information, as this is where all visual information first enters our circuitry. Sight is different from perception–sight is a physical process, whereas perception is a process where the brain sorts the incoming data and attaches meaning to it.

Sight occurs as visual stimuli enters through the eye and follows pathways in the brain to the visual cortex for processing. Traffic on these visual pathways is a very busy street, and with this flood of information pouring in, the brain needs to decide what is important, and what is not. Images that are high bias, colorful, and high contrast get the attention, as do images that are tied to prior information. Perception is *"*the act of the brain constructing a map" (Jensen, 2008, p. 182) and is dependent on our ability to make connections, detect patterns and attach personal meaning to visual data. If there is nothing the brain sees as relevant or important, the information will not be stored as a long-term memory. The more ways that learners can be guided in seeing patterns and making connections to their own personal experience and knowledge, the better they will store and retrieve the new information.

Drawing can be very useful in helping the learner to focus on the object at hand, using the process as a tool for observation and constructing this map. In order to create a realistic drawing, such as an accurate rendering of a leaf, one needs to use their sense of sight as well as their perception skills to discern shapes and relationships between them. According to Dr. Betty Edwards, the five basic skills of drawing are:

1. The perception of edges
2. The perception of spaces

3. The perception of relationships

4. The perception of lights and shadows

5. The perception of the whole or gestalt (Edwards, 1999, p. xviii)

In other words, in the act of drawing, sight and perception are inextricably linked. As the eye follows the contours of the object, the mind is engaged in a reciprocal process of understanding spatial relationships and communicating to the hand how to physically produce a line that captures them.

Edwards, in her now-classic book, *Drawing on the Right Side of the Brain,* espoused a new right-brained approach to drawing, based on the earlier split-brain research of Richard Sperry. Working with Dr. Sperry, she developed techniques that were remarkably effective for training students in "visual, perceptual ways of thinking" (Edwards,1999, p. xiii). Although Edwards's work was entitled *Drawing on the Right Side of the Brain*, she acknowledges the value of the *whole* brain, and the important role of both types of thinking: "I believe both thinking modes –one to comprehend the details, and the other to 'see' the whole picture, for example, are vital for critical-thinking skills, extrapolation of meaning, and problem solving" (Edwards, 1999, p.xiii).

Memory processes and brain based learning. Memory can be thought of as a process rather than as information taking a linear route to a particular location in the brain. Jensen (2008) explains there are two basic types of memory–implicit (automatically learned) and explicit (learned through effort). Of these two types of memory, there are two subcategories, depending on how the information is acquired. Implicit memory can be procedural (hands on skills, e.g. riding a bike) or reflexive (absorbed from one's environment, e.g. social behaviors). Explicit memory can be semantic (consciously learned, e.g. rote memorization) or episodic (tied to a particular place or experience, e.g. a field trip) (Table 2). According to Jensen, one of the foremost experts in brain based learning, semantic memory has the weakest memory pathway, and is the most unnatural to acquire, yet is the most commonly used in classrooms. Memory is also dependent on our ability to retrieve information stored in the brain. Engaging multiple memory pathways ensures a greater chance that the information will be committed to long-term memory and can be retrieved through several pathways.

Table 2. The four types of memory

Four Types Of Memory			
Implicit Memory (Acquired)		Explicit Memory (Learned)	
Procedural Physical skills like riding a bike, and other "hands-on" learning. Unlimited storage capacity.	Reflexive Emotional, automated, non-conscious learning that we absorb from our environment, such as social behaviors.	Semantic What we think of as "knowledge"–facts, figures, and information memorized	Episodic Tied to the place or circumstances that the learning occurs in. Novel and emotionally charged experiences will produce the strongest episodic memories.

In this study, multiple types of memory pathways are engaged through using a visual-spatial instruction method in an outdoor setting. Drawing primarily engages *implicit, procedural* memory, as it physically engages the body in learning a skill. Drawing from direct observation in nature involves the *explicit* memory as well, when the activity is tied in to semantic content (such as learning the names, classification or identification of plants or animals) and episodic memory (occurs in a novel setting such as a school forest).

In terms of arts integration, "the arts enhance the *process* of learning. The systems they nourish which include our integrated sensory, attentional, cognitive, and emotional capabilities are in fact the driving forces behind all other learning" (Jensen, 2001, p.2). Art-based strategies can provide *processing time*, a crucially important factor needed for cementing new knowledge and long-term memory formation, but one of the most overlooked and neglected parts of the learning process. In order to fully integrate new information, the brain needs periods of rest, or an entirely different type of activity. Joseph Cornell, nature educator and author of *Sharing Nature with Children,* also emphasizes the importance of reflection and processing time. This valuable part of the learning process serves to strengthen and deepen students' experiences; this can easily be accomplished through taking the time to reflect through discussions, writing a journal entry, or drawing a picture (Cornell, 2009). The act of drawing can be a way to sort out and make sense of new learning by creating a spatial model or mind map in the brain.

Chapter 3. Method

In this chapter, I describe in detail the sample group selection process, assessments, study design, field studies, and procedures I used in conducting the study. These research methods enabled me to test the hypothesis, answer my research questions, and ultimately assess the effect of the drawing strategy in the tree identification lesson.

Hypothesis and Research Questions

The purpose of this study was to assess the impact on student learning of using a visual instruction method and an observational drawing activity in an existing text-based tree identification lesson. It was also to determine the effect that this technique had on student learning across the spectrum of multiple intelligences. To evaluate the effect of the drawing tool, I conducted my research using a tree identification lesson with middle school science classes. The methods were used to answer these three research questions:

1. To what extent does participating in a drawing activity as part of a tree identification lesson affect student *short- and long- term knowledge* of Wisconsin tree species?
2. How does participation in a drawing activity impact student learning across different learning modes, as identified in a Multiple Intelligences Inventory?
3. How does participation in a drawing activity affect students' *observation and perception skills* of distinguishing characteristics of tree species?

The null hypothesis was that there would be no significant effect of the independent variable of drawing on the students' performance in this tree identification lesson.

Method

To study the effectiveness of observational drawing as a learning tool, I chose to engage students' visual/spatial intelligence by using simple field illustration techniques in conjunction with an existing text-based tree identification lesson. In my experience, both as a botanical artist and in observing students drawing outdoors, there seems to be a greater degree of concentration and observation needed to actively draw a subject than to passively view a subject. The very act of looking closely and using one's eyes and hands to make an image of it on paper requires a level of engagement that often results in learning something new about it that may have been overlooked otherwise.

Working with both a control and experimental group of students at each school site enabled me to compare results between the two instructional methods–a passive method using primarily verbal/linguistic techniques and an active method using primarily visual/spatial techniques. A tree identification lesson developed by LEAF, Wisconsin's K-12 Forestry education program, was used for all students, and adapted for the different instruction methods. This lesson is a field enhancement in the *LEAF 7-8 Wisconsin Forestry Lesson Guide* based on a written dichotomous key and pre-drawn diagrams, and is used by teachers statewide to teach tree identification skills at the middle school level. The existing lesson and its field component was modified for the different instruction methods (passive and active), while the content of the lesson was identical for both groups. The control group learned to identify four tree species on their site using the written (text only) key, only passively viewing diagrams and specimens. The experimental group learned the same content but used an active observational drawing approach throughout the lesson. Modifications of the lesson were carefully made to ensure that both the experimental and control groups received an equal amount of instructional time, content, and student work.

Research Design

Using a quasi-experimental nonequivalent comparison group research design, the quantitative data was compared between control and experimental groups. Qualitative data was collected from the experimental group only. This research design was chosen since true random assignment of students to either the experimental or control groups was not feasible. It was necessary to work with entire classes of students as a group, yet the classroom groups were randomly assigned and there was no opportunity for self-selection by either the teachers or students.

Reducing bias. Several measures were taken in designing the research methods, to reduce the likelihood of bias. The most commonly used quasi-experimental design, the nonequivalent comparison group design, consists of giving both groups a pre-test, then the treatment, followed by a post test (Johnson and Christenson, 2014). In this study, pre- and post-assessments were given to both groups to establish the baseline of knowledge for comparison of the effect of the drawing activity on the treatment group. Administration of pre-and post-assessments to both groups served to reduce the likelihood of potential biases. In addition, the same instructor was used for all of the groups and every effort made to consistently deliver the lesson across all sites.

Assessments

In order to establish a baseline of their preexisting knowledge, as well as measure what knowledge they gained during the lesson, both groups of students were given a series of pre- and post-assessments (Table 3). The pre-assessment was given the day prior to the lesson; the post- assessments were given immediately (within 2 days) after and again four weeks after the lesson. These assessments (Appendices B and C) were based on a pre-drawn diagram in the LEAF lesson and measured their knowledge of tree and leaf structures tied to their proper terms, as well as their ability to recognize and identify tree species they observed on their site by leaf shape. In addition to these assessments, students in both the experimental and control groups completed a short Multiple Intelligences Inventory (Appendix D) to determine their dominant, or preferred, learning profile. For the experimental group, a selection of field drawings done by students were assessed using a rubric (Appendix E) that rated the amount of visual data, such as leaf shape, branching structure, or the presence of finer features such as veins, that they contained.

Table 3. Description of assessments used in study

Assessment	Description	When Given	Given By	Scoring
Assessment 1 (Research Question 1)	Line Drawing Diagram of Tree ID Terms	Pre: Prior to Lesson Post: Within 2 days Post 4: Four weeks after lesson	Classroom Teacher	0-12 Correct terms (1 point each)
Assessment 2 (Research Question 1)	Line Drawings of 4 Species on School Site	Pre, Post, Post 4	Classroom Teacher	0-4 Correct genus identification (1 point each)
Multiple Intelligences (MI) Inventory (Research Question 2)	Student self-assessment	Prior to lesson	Classroom teacher	0-15 per Intelligence, 8 Intelligences
Assessment 3 (Research Question 3)	Rubric for Student Drawings	Post	Researcher	0-3 (Scale)

In addition to these assessments, a short questionnaire was completed by students in the experimental group in which they self-assessed the levels of effectiveness, enjoyment, and observation skills they experienced through their participation in the drawing activity. Teachers' observations of student behavior and their impressions of the drawing activity were gathered, along with my own field notes and observations. Combining all these sources of information, I examined the extent of any positive impact the drawing approach had on the students' learning and retention of scientific knowledge. This established a foundation of data and observations that enabled me to determine the overall effectiveness of using drawing as a learning tool in this lesson.

Field Testing

Field test of experimental group methods. In July, 2014, I conducted a field test with a small group of five middle school students at Fox River Academy in Appleton, Wisconsin (an environmental charter school) to determine the practical effectiveness of the visual teaching methods that I would be using with the experimental group. Students were recruited by their regular classroom teacher and the class was conducted in a nearby park. For this field test, I trained the LEAF instructor to use the visual teaching methods; this included making some simplified drawings of tree and leaf structures. Having done this, I acted as an observer during the actual lesson.

The lesson, including the pre-assessments, was conducted by the LEAF instructor entirely at the outdoor site. The students made a simple drawing of each species to indicate the branching structure and did a texture rubbing of a leaf, which they then outlined to reinforce the overall leaf shape. These drawings were collected for later evaluation, and the students were given a post-test with visual outlines of the four species they just drew.

Although the small group size and the unique characteristics of the environmental charter school group (familiarity with the site, strong interest in trees, and voluntary participation in the class) differ from a regular classroom setting, I was still able to assess the logistical aspect of the lesson (i.e. timing) as well as observe any difficulties the students had with the drawing activity. Based on this, I made the following changes and adjustments:

- All pre- and post-assessments were conducted by the classroom teacher prior to the lesson, as to not overwhelm students with too many tasks in one sitting. This also enabled the LEAF instructor to devote more time to the lesson itself.
- Trees were carefully selected and pre-marked before students arrived on site.
- The field sheets for students to use would have room for only one species per page; students were confused and frustrated when the leaf was too big for the square provided.
- As well as verbally explaining the terms while drawing on the board, the instructor would write in the terms, so students could properly label their drawings. This also gives reinforcement to the link between the written term and the visual image.
- The LEAF instructor would conduct the drawing of terms and a demonstration of one species before heading out to the site to (as much as possible) eliminate variables such as weather, outside noise, and other distractions.

- It was made clear that students were to work individually, and not compare answers or collaborate.

Field testing of both control and experimental groups. Another field test was conducted with two classroom groups (one was experimental and one was control) in Iola, Wisconsin, at the start of the regular school year, in order to test my procedures and methods, including the assessments and Multiple Intelligences inventory with a group that was more similar to my sample population. It was quite obvious after this second field test that more time would be needed to properly conduct the classroom and field components of the lesson. Due to time and scheduling constraints, I decided that the initial classroom lesson and completion of the demonstration species was to be completed by the LEAF instructor on the first day. The classroom teacher would then take students out on the following day to complete the field component of the lesson, following procedures I outlined to ensure consistency.

Sample Group Selection

Participants for this study were selected from among school districts in Wisconsin that have registered school forests in the current LEAF database. To begin this process, I sent a query via email to school forest coordinators seeking middle school science or general classroom teachers who would be willing to participate in the research study with their students. Several teachers responded to this initial contact indicating their interest in the study. I then contacted these teachers through phone or email to explain more about the research, answer any questions they had, and to further determine their suitability for the study.

Experimental and control groups were selected that met the following criteria:

- Access to an outdoor learning site with several species of trees for observation.
- Adequate class size within a grade level to allow for both a control and experimental group.
- Ability to obtain district approval for the research in a timely manner.
- Logistical factors, such as distance from the LEAF office and scheduling of lessons with the LEAF instructor.

Schools that were selected for the final sample were Hurley, Northern Pines (Eagle River), Pulaski, and DC Everest. All of the groups were from seventh grade science classes, with the exception of Hurley with two sections of eighth grade students. Control and experimental groups were paired within the same school; for example two homerooms from within a seventh grade class, so that both groups had similar demographics, access to the same site, and the same levels of previous instruction. Classes were randomly assigned into two groups: one class of students served as the control group and received the tree identification lesson without the drawing component, and the other class served as the experimental group.

Procedure

The classroom lesson and field demonstration for both the control and experimental groups was delivered by a LEAF outreach staff member and forestry education specialist who had extensive experience as a high school classroom science teacher. With my background and skills as a botanical artist, I was aware of the possibility of researcher bias toward the experimental group and the drawing strategies used. To avoid this bias, yet still provide consistency, I developed and trained the LEAF instructor in simple visual drawing techniques that correlated with the Tree ID lesson, but acted only as an observer during the lesson itself. To ensure consistency, these example drawings (Appendix F) and the procedure for the visual instruction method (Appendix G) were put into a document that the instructor could refer to as needed

Throughout the following description, I refer to the “classroom teacher” as the teacher who teaches the class on a daily basis. The “LEAF instructor” refers to the K-12 forestry education specialist who delivered the Tree ID lesson. The LEAF tree ID lesson that was used in this research was conducted over two days, during two approximately 45 minute class periods for all groups. On day one, the LEAF instructor conducted the classroom part of the lesson and worked through one demonstration species with the students in the field or classroom using specimens. On day two, the classroom teacher carried out the field component of the lesson, without providing additional instruction or assistance, as the students observed the four species on their site and completed their field sheets. I served as an observer on both days.

Preparation and pre-assessments. In order to devote as much instructional time as possible for the lesson itself, the classroom teacher conducted all the pre-assessments and site preparations for the lesson. Before our arrival at the site, four species of trees were selected and marked that students would be asked to identify. At each site, every effort was made to include trees with the following basic visual characteristics:

- opposite branching pattern
- alternate branching pattern
- simple leaves
- compound leaves

The classroom teacher administered a paper pre-test of knowledge of tree identification terms and recognition of these species (Appendices B and C) to all students in both the control and experimental groups. A Multiple Intelligences inventory was also completed by each student in the class (Appendix D). This was used to identify the students' overall learning profile, based on Howard Gardner's Multiple Intelligence theory. An identification number was assigned to each student, and all data, including their learning profile, pre-and post-assessment scores, and (in the case of the experimental group) the drawings, evaluations, and answers to their self-assessment questions, was tied to that same number throughout the course of the research. The classroom teacher was given an instruction sheet by the researcher which outlined the instructional procedures for the classroom as well as the field. (Appendix H)

Classroom instructional procedure–both groups. The pre-lesson, explaining the parts of the branch and leaf, was given by the LEAF instructor in the classroom prior to going outdoors. A diagram with a key to terms needed to correctly use the LEAF key and identify species was explained to each group, using either the active visual or passive written method, prior to the on-site tree ID activity. The content of the lesson was identical for both the experimental and control groups; only the instructional delivery method differed. Students in both groups were instructed to take notes. The field component of the tree identification lesson occurred at the outdoor learning site (school forest or school grounds) where there were several species of trees. Students in both groups were given the task of identifying four pre-selected tree species on their site using the LEAF dichotomous key. Both groups were given an equal amount of time for the lesson, had the same instructor, used the same dichotomous key, and observed the same species of trees on their site.

Control group procedure. The LEAF instructor delivered the lesson to the control group using the more typical passive instructional method of lecturing with verbal and written information (Appendix I). This group was given a pre-drawn diagram based on the illustration in the LEAF tree identification lesson with blanks (Appendix J), and was asked to take written notes and fill in the terms. The LEAF instructor showed the students the same diagram on the board in a PowerPoint presentation that revealed each structure and term as she explained them. Once these were completed, the students were given the dichotomous key (Appendix K) and the field sheets (Appendix L). After dividing the students into small groups, the LEAF instructor demonstrated how to use the key by working through one demonstration species. Students in the control group followed the key step by step and copied the written descriptions that described their specimen to arrive at the correct identification.

Experimental group procedure. The experimental group received the same lesson but engaged in *active* drawing from direct observation throughout the course of the lesson. These students were given a blank piece of paper and the instructor used visual techniques to teach the lesson (e.g. drawing visual diagrams on the board while verbally explaining structure). The experimental group was encouraged to actively draw simple line diagrams along with the instructor, and label their drawing with the correct terms to create their own diagram that they could use in the field. Their completed drawings showed the tree and leaf structures and terms they would need to know to use the tree key to identify the trees in the field. As with the control group, the instructor divided the students into groups to explain the key and collectively work through one demonstration species on their field sheets (Appendix M). Students in this group were asked to draw the leaf shape, branching structure, and other details they observed. The instructor modeled some simple observational drawing techniques and reassured students that their drawings would be evaluated on the information they contained, not their artistic merit.

Field component. Due to logistical constraints, having the LEAF instructor conduct the field component of the lesson was not possible, so the classroom teacher was given instructions and completed this component during the next available class period, often the next day. I was able to act as an observer in this scenario, making note of student and teacher behaviors during the lesson. The students were told they could use their notes from the day before, along with the key, and were not to work collaboratively, as this would bias their data. Teachers were not allowed to give additional instruction and simply oversaw and directed students to the trees they were to observe.

Students in the experimental group drew the branching structure and leaves of their trees, completing one field sheet for each species. Working through the written descriptions in the key, they circled the part of their drawing that was tied to the description. For example, if their choice in the key said “opposite branching”, they circled the part of their drawing that showed the branching structure. They then wrote the name of the tree species that they arrived at in the key at the top of the drawing.

Control group students followed the same procedure, but they were asked to observe the tree and copy the written descriptions from the key that fit their tree. This created a “trail” of steps they took to arrive at the proper identification and ensured that the students in the control group also performed a comparable level of work to the drawing group.

Post-Assessments. After the tree ID activity was completed, students in both groups were given a post-test at the end of the lesson by their classroom teacher to measure any knowledge they gained. A second post-test was administered approximately 4 weeks after the lesson to measure retention of knowledge of tree species learned. Both of these assessments were the same as the pre-assessments (Assessment 1 and 2). Additionally, a random sampling of drawings from students in the experimental group was selected, by randomly blind-pulling every fifth packet, for a total of forty field sheet packets (representing 20% of the entire group); these were assessed using a rubric specifically developed for the lesson that measured the amount of information contained in them (Appendix E). A questionnaire (Appendix N), given to the experimental group only, asked students to self-assess the effectiveness of the drawing component of the lesson and how it impacted their learning experience. Teachers were also asked a few key questions on a written post-activity assessment form (Appendix O) to gather their impressions of student engagement, observation skills, and the overall usefulness of the drawing component in the tree ID lesson.

Variables

This research measured the effects of the active drawing treatment upon the students' assessment scores, involving both within and between subject variables. The continuous dependent variable was the student assessment scores, measured over time. The categorical independent within-subjects variable was the student scores with three levels; pre-, post-, and four week post, with the degree of change in scores measured between these three levels. The categorical independent between- subjects variable of the control and experimental groups was then compared to the change in assessment scores over time to determine if there were any significant effects due to the drawing method. Additionally, the categorical independent between-subjects variables of the control and experimental groups within the Multiple Intelligences (MI) categories tied to the instruction methods used in the study—Naturalist, Visual-Spatial, Logical-Mathematical, and Verbal-Linguistic—were compared to the within-subjects independent variable of the assessment scores over time.

I took into account the possibilities of other variables that could affect the outcome and took steps to control these. The lesson was administered by a LEAF staff instructor to eliminate the possible variable of classroom teacher bias. To eliminate the possibility of researcher bias due to my strong art background, I chose to act as an observer of student behaviors, such as level of engagement and observation, during the lesson. I also chose to assess the drawings for visual information contained in them according to a rubric I developed, based on a model used in a similar study (Baldwin & Crawford, 2010) in order to establish a standard of consistency when evaluating the artwork. Tree species, which were pre-selected and marked for identification, were identical between the control and experimental groups at each school site, although specific species varied from site to site. The effects of the independent variable were measured by pre-and post-tests, assessment of visual data in the student drawings, and observations of student behavior during the lesson.

Measurement

The measurement tool to assess student knowledge of tree terms and species was a two-page test with line illustrations visually depicting key parts of a tree/leaf and the leaves of four common Wisconsin tree species. Page one was a pre-drawn diagram, with a list of terms used in the LEAF Tree ID key; blanks were left on the diagram for the correct answer to be written in. The second page of the test showed leaves only of four tree species that would be identified during the lesson, with a blank provided to write in the correct species name of each, at the genus level (Appendices B and C, Assessments 1 and 2). These assessments, developed from existing LEAF curriculum materials and previously reviewed by forestry experts and LEAF staff, measured students' knowledge of concepts essential for plant identification, such as branching pattern, leaf shape and structure, venation, presence of lobes, and type of leaf margin (toothed versus smooth). Quantitative data was gathered through the scoring of these tests, with one point given for each correct answer. These tests measured the following tree identification skills:

- Term recognition: A drawing of the composite leaf from the *LEAF K-12 Forestry Guide* with a list of terms of key features measured the students' ability to tie the written term to the visual image of the tree and leaf structure (Assessment 1, possible highest score = 12).
- Pattern/shape recognition: A visual quiz of tree species measured students' visual recognition and correct identification by overall leaf shape (Assessment 2, possible highest score = 4).

Additional quantitative data was gathered that measured the following:

- Perception/observation: All drawings done by students in the treatment group were collected; a sampling of these were assessed using a rubric for the amount, degree, and complexity of the visual data contained in them (Assessment 3, scored on a scale of 1 to 3).

A Multiple Intelligences Inventory, entitled the *Getting to Know You Survey*, was given to all students prior to the lesson (Appendix D). Developed by Dr. Laura Candler, this 24 question survey was chosen for its ease of use by students and teachers. There were three easily understandable, age-appropriate questions for each intelligence category; students could rate themselves on a scale of 0-5 and total the results, with the highest possible score in each intelligence category of 15 points. Based on their answers to these questions, the intelligence(s) with the highest scores indicated their dominant learning profile.

In addition to these quantitative assessments, qualitative data was gathered from written responses of students in the experimental group on a questionnaire that measured their perceived value and usefulness of the drawing tool in the lesson. A follow up questionnaire was given to teachers who participated in the study; this gathered their observations about student behaviors, learning, engagement, concentration, and observation skills they may have noticed throughout the course of the lesson. Additional information was obtained through notes of my own and the LEAF instructor's observations.

Data Analysis

The quantitative data gathered from the pre-, post-, and four week post-assessment were analyzed using descriptive statistics and mixed-between-within subjects ANOVA, using Statistical Package for the Social Sciences (SPSS), version 21. The pre-, post- and 4 week post-assessment scores on Assessments 1 and 2 of the experimental group were compared with the control group. The within subjects factor looked at the mean student scores in both the control and experimental group over the three time periods. The between subjects factor compared the mean student scores over the three time periods between the experimental and control groups. This assessed the effect of the independent variable of the drawing method on the dependent variable of the assessment scores.

To analyze the Multiple Intelligences Inventory data, the sample population was subdivided, using an operational definition of =>9 across the eight learning profiles as a "high" rating (e.g. a score of 9 or above in visual-spatial intelligence category would be considered a "visual learner"). The student assessment scores were then analyzed across the different intelligences, again with the mixed between-within subjects ANOVA, this time comparing the within subjects factor of the mean scores on Assessments 1 and 2 across the three time periods within each intelligence (e.g. the mean scores of visual/spatial learners in both control and experimental groups). The between subjects factor compared the test scores of the experimental and control group students within that intelligence category.

Student drawings were evaluated and graded using a rubric with a scale of one to three according to the visual information they contained. Student survey answers in numerical form were evaluated by descriptive statistics. The qualitative data generated from the teacher and student questionnaires were evaluated for common themes and observations; this was used to further understand the quantitative findings of the study.

Chapter 4. Findings

In this chapter, I outline the findings of the study, beginning with a description of the participants, the student distribution among the schools, and the number of students included in the sample size of each assessment. Following each research question, I share the results of the quantitative data from Assessments 1 and 2, and the rubric scores from Assessment 3. Results of the student survey and teacher observations along with my own and the LEAF instructor observations add to the information from these results. A selection of student comments and examples of their field drawings add additional support to the findings.

Description of Participants

Participants in this study were 390 students from four school districts with registered school forests in northern Wisconsin. Schools participating in the study were Pulaski, Hurley, Northern Pines, and DC Everest (Table 4). The majority of students (n = 360) were seventh grade students (with the exception of Hurley's two eighth grade classes, n = 30) in regular education science classes. Three DC Everest science classes participated in the study, with five class sections each; these are shown as DC Everest 1, 2 and 3. The participants represented a range of student abilities found in the typical classroom setting.

Table 4. Total sample size and distribution per school

School District	Students	Percentage of Total
Northland Pines	*n*=32	8.2
Hurley	*n*=30	7.7
Pulaski	*n*=47	12.1
DC Everest 1	*n*=96	24.6
DC Everest 2	*n*=88	22.6
DC Everest 3	*n*=97	24.9
Totals	*n*=390	100

It should be noted that not all of the student participants completed the four-week post-assessment due to time constraints and teacher participation in this part of the assessment process. All students who completed Assessments 1 and 2, pre-and post-assessments (n = 390) were compared. In a separate analysis, only students who completed the entire series of Assessments 1 and 2 over three time periods were included in the final analysis of these three scores (n = 263). The results of the MI inventory (n = 390) and student survey (n=130) were not tied to these assessment scores; all students were included in this analysis.

Table 5. Distribution of sample per assessment

Assessments 1 and 2 Pre- and post- only	Assessments 1 and 2 Pre-, post-, and 4 week post	MI Inventory	Assessment 3 and Student Survey (experimental group only)
n = 390	n = 263	N = 390	N =130

Research Question Results

A mixed between-within subjects analysis of variance (ANOVA) was conducted to assess the impact of the independent variable of the drawing method on student assessment scores across three time periods. The results of this analysis of student performance in both the experimental and control groups are outlined in the following sections.

Research Question 1. To what extent does participating in a drawing activity as part of a tree identification lesson affect student *short- and long- term knowledge* of Wisconsin tree species?

Student assessment scores over two time periods. A mixed between-within analysis of variance was conducted to assess the impact of the independent variable of drawing on student scores on Assessment 1, across two time periods (pre- and post) between the control and experimental groups (Table 6). There was no significant interaction found between groups, Wilks Lambda = .997, F (1, 388) = 1.2, p = .274, partial eta squared =.003, which indicates a very small effect. There was a substantial main effect for Assessment 1, Wilks Lambda = .228, F (1, 388) = 1316.68, p = <.0005, partial eta squared =.772, with both groups showing an increase in scores on Assessment 1 across the two time periods, showing students significantly increased their knowledge of tree parts and identification. The main effect comparing scores of the two groups was not significant, F (1, 388) =1, p = .317, partial eta squared = .003, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 1 scores across the two time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no measurable effect on student learning, confirming the null hypothesis.

Table 6. Assessment 1 scores over two time periods

n = sample size, M = student mean score, SD = standard deviation

	Control			Experimental		
	n	M	SD	*n*	M	SD
Pre-Assessment 1	190	5.24	2.93	200	5.27	2.67
Post-Assessment 1	190	10.45	2.08	200	10.81	1.63

A mixed between-within analysis of variance was conducted to assess the impact of the independent variable of drawing on student scores on Assessment 2, across two time periods (pre-and post) between the control and experimental groups (Table 7). There was a significant interaction found between groups, Wilks Lambda = .984, F (1, 387) =6.3, p =.016, partial eta squared =.016, which indicates a very small effect. There was a substantial main effect for Assessment 1, Wilks Lambda = .966, F (1, 387) = 13.42, p = <.0005, partial eta squared =.034 with both groups showing an increase in scores on Assessment 2 across the two time periods. The main effect comparing scores of the two groups was significant, F (1, 387) =4.26, p = .040, partial eta squared = .01, suggesting a small but significant difference in the test scores between the control and experimental (drawing) groups. In other words, students in *both* groups gained knowledge, as shown in the Assessment 2 scores across the two time periods. When the effect was measured *between* the experimental and control groups, there was a small but statistically significant difference in the student scores. In this instance, the control group scored slightly higher on the post-assessment.

Table 7. Assessment 2 scores over two time periods

n = sample size, M = student mean score, SD = standard deviation

	Control			Experimental		
	n	M	SD	*n*	M	SD
Pre-Assessment 2	190	.85	.637	200	.82	.601
Post-Assessment 2	190	1.09	.821	200	.86	.796

Student assessment scores over three time periods. A mixed between-within analysis of variance was also conducted to assess the impact of drawing on student scores on Assessment 1, across three time periods (pre-, post, and 4 week post) between the control and experimental groups (Table 8). There was no significant interaction found between groups, Wilks Lambda = .998, F (2, 260) =.201, p =.82, partial eta squared =.002, which indicates no effect. There was a substantial main effect for Assessment 1, Wilks Lambda = .238, F (2, 260) = 415.5, p = <.0005, partial eta squared =.762, with both groups showing an increase in scores on Assessment 1 across the three time periods. The main effect comparing scores of the two groups was not significant, F (1, 261) = 1.05, p = .31, partial eta squared = .004, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 1 scores across the three time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no measurable effect on student learning, confirming the null hypothesis, although both the drawing method and the conventional method had a significant effect on student learning and retention over time.

Table 8. Assessment 1 student scores across three time periods

n = sample size, M = student mean score, SD = standard deviation

	Control			Experimental		
	n	M	SD	*n*	M	SD
Pre-Assessment 1	114	5.26	2.85	149	5.52	2.77
Post-Assessment 1	114	10.52	2.22	149	10.83	1.66
4 week Post-Assessment 1	114	9.89	2.56	149	10.03	2.50

A mixed between-within analysis of variance was conducted to assess the impact of drawing on student scores on Assessment 2, across three time periods (pre-,post, and 4 week post) between the control and experimental groups (Table 9). There was a significant interaction found between groups, Wilks Lambda = .966, F (2, 260) =4.51, p =.012, partial eta squared =.034, which indicates a small effect. This means there was some difference in scores between the students in the control and experimental groups. There was a substantial main effect for Assessment 2, Wilks Lambda = .977, F (.2, 260) = 3.1, p = .045 partial eta squared =.023, with both groups showing an increase in scores on Assessment 2 across the three time periods. The main effect comparing scores of the two groups was not significant, F (1, 261) =.668, p = .414, partial eta squared = .003, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 2 scores across the three time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no greater measurable effect on student learning, confirming the null hypothesis. The drawing method, however, did lead to a similar increase in learning and as with the control group, they retained the knowledge four weeks later.

Table 9. Assessment 2 student scores across 3 time periods

n = sample size, M = student mean score, SD = standard deviation

Control				Experimental		
	n	M	SD	*n*	M	SD
Pre-Assessment 2	114	.87	.62	149	.83	.64
Post-Assessment 2	114	1.07	.81	149	.86	.86
4 week Post-Assessment 2	114	.90	.81	149	.86	.86

Scores for both groups improved dramatically on Assessment 1, from approximately 5 terms identified correctly to ten. Assessment 2 scores showed an average of less than one out of four species correctly identified throughout the study in both groups, with the exception of the control group post-assessment mean score of 1.07.

Overall, student performance was proportionally higher on Assessment 1–the diagram of the composite leaf and the tree terminology needed for using the dichotomous key–than on Assessment 2, which tested their visual recognition of leaf shapes of the four species of trees they observed. The visual recognition and recollection of site-specific species was very low, and negligible gains were made from the pre-assessment to the post-assessments.

Research Question 2. How does participation in a drawing activity impact student learning across different learning modes, as identified in a Multiple Intelligences Inventory?

Distribution of multiple intelligences. The MI Inventory was scored using a cutoff of 9 or above on a scale of 0-15 to indicate a high degree of intelligence in a particular intelligence category. The following table shows the distribution of intelligence categories of the students in this sample, with the categories directly tied to the two instruction methods shaded (Table 10). The two categories with the highest number of students were Bodily-Kinesthetic and Naturalist, while the two lowest were Logical-Mathematical and Verbal Linguistic. Visual-Spatial, the intelligence category most tied to the experimental instruction method, contained 230 students; this was much higher than the amount of learners in the Logical-Mathematical (*n* =154) and Verbal Linguistic (*n* =134) categories that were tied to the conventional instruction method.

Table 10. Multiple Intelligences distribution of students

Multiple Intelligence (MI) category	Students
Bodily-Kinesthetic (Body)	*n* = 289
Naturalist (Nature)	*n* = 282
Interpersonal (People)	*n* = 258
Intrapersonal (Self)	*n* = 241
Visual-Spatial (Art)	*n* = 230
Musical (Music)	*n* = 229
Logical-Mathematical (Math)	*n* = 154
Verbal-Linguistic (Word)	*n* = 134

Performance of multiple intelligences on assessments. Since the observational drawing strategy was the independent variable in the study, an analysis of the intelligences that were tied to the instructional methods used for each group was conducted. These four intelligences included Logical/Mathematical, Verbal-Linguistic (conventional instruction method), Visual/Spatial and Naturalist (experimental instruction method). The mixed between-within analysis of variance was conducted with only the students whose ratings were 9 or above in these categories, to assess the effect of the variable of drawing on each intelligence.

Naturalist intelligence. To determine the effect of the visual instruction method on Naturalist learners, assessment scores of students who rated themselves above the cutoff value = > 9 on the MI inventory for this intelligence were analyzed. A mixed between-within analysis of variance was conducted to assess the impact of drawing on student scores on Assessment 1, across three time periods (pre-, post, and 4 week post) between the control and experimental groups (Table 11). There was no significant interaction found between groups, Wilks Lambda = .915, F (2, 6) =.279, p =.766, partial eta squared =.004, which indicates no effect. There was a substantial main effect for Assessment 1, Wilks Lambda = .092, F (2, 6) = 29.67, p = 001, partial eta squared =.739 with both groups showing an increase in scores on Assessment 1 across the three time periods (Table 10). The main effect comparing scores of the two groups was not significant, F (1, 196) = 1.85, p = .175, partial eta squared = .009, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 1 scores across the three time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no greater measurable effect on student learning than the conventional instruction method, confirming the null hypothesis.

A mixed between-within analysis of variance was also conducted to assess the impact of drawing on student scores on Assessment 2, across three time periods (pre- ,post, and 4 week post) between the Naturalist learners in control and experimental groups (Table 11). There was no significant interaction found between groups, Wilks Lambda = .978, F (2, 195) =2.15, p =.12, partial eta squared =.022. This means there was no measurable difference in scores over time between the students in the control and experimental groups. There was a substantial main effect for Assessment 2, Wilks Lambda = .933, F (.2, 195) = 6.95, p = .001, partial eta squared =.067, with both groups showing an increase in scores on Assessment 2 across the three time periods. The main effect comparing scores of the two groups was not significant, F (1, 196) =.006, p = .937, partial eta squared = .000, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 2 scores across the three time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no greater measurable effect on student learning, confirming the null hypothesis.

Table 11. Naturalist Intelligence Assessment Scores

Naturalist Intelligence						
	Control			Experimental		
	n	M	SD	*n*	M	SD
Pre-Assessment 1	85	5.54	2.8	113	5.66	2.85
Post-Assessment 1	85	10.46	2.44	113	10.92	1.59
4 week Post-Assessment 1	85	9.74	2.8	113	10.28	2.48
Pre-Assessment 2	85	.88	.66	113	.85	.68
Post-Assessment 2	85	1.09	.87	113	1.02	.90
4-week Post Assessment 2	85	.96	.82	113	1.10	.90

Visual-Spatial intelligence. To determine the effect of the visual instruction method on Visual-Spatial learners, assessment scores of students who rated themselves above the cutoff value = > 9 on the MI inventory for this intelligence were analyzed. A mixed between-within analysis of variance was conducted to assess the impact of drawing on student scores on Assessment 1, across three time periods (pre-, post, and 4 week post) between the control and experimental groups (Table 12). There was no significant interaction found between groups, Wilks Lambda = .999, F (2, 158) =.077, p =.925, partial eta squared =.001, which indicates a very small effect. There was a substantial main effect for Assessment 1, Wilks Lambda = .238, F (2, 158) = 252.70, p = ,0005, partial eta squared =.762, with both groups showing an increase in scores on Assessment 1 across the three time periods. The main effect comparing scores of the two groups was not significant, F (1, 159) = 1.15, p = .29, partial eta squared = .007, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 1 scores across the three time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no greater measurable effect on student learning than the conventional instruction method, confirming the null hypothesis.

A mixed between-within analysis of variance was also conducted to assess the impact of drawing on student scores on Assessment 2, across three time periods (pre- ,post, and 4 week post) between the Visual-Spatial learners in control and experimental groups (Table 12). There was no significant interaction found between groups, Wilks Lambda = .984, F (2, 103) =.842, p =.43, partial eta squared =.016. This means there was no measurable difference in scores over time between the students in the control and experimental groups. There was no substantial main effect for Assessment 2, Wilks Lambda = .95, F (.2, 103) = 2.28, p = .107, partial eta squared =.042, with both groups showing an increase in scores on Assessment 2 across the three time periods. The main effect comparing scores of the two groups was not significant, F (1, 104) =.112, p = .739, partial eta squared = .042, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 2 scores across the three time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no greater measurable effect on student learning, confirming the null hypothesis.

Table 12. Visual-Spatial Intelligence Assessment Scores

Visual-Spatial Intelligence						
	Control			Experimental		
	n	M	SD	*n*	M	SD
Pre-Assessment 1	64	5.58	2.82	97	5.85	2.81
Post-Assessment 1	64	10.73	1.97	97	11.01	1.47
4 week Post-Assessment 1	64	10.05	2.52	97	10.43	2.25
Pre-Assessment 2	64	.94	.64	97	.79	.69
Post-Assessment 2	64	1.11	.88	97	.96	.89
4-week Post Assessment 2	64	.97	.84	97	1.01	.88

Logical-Mathematical intelligence. To determine the effect of the visual instruction method on Logical-Mathematical learners, assessment scores of students who rated themselves above the cutoff value = > 9 on the MI inventory for this intelligence were analyzed. A mixed between-within analysis of variance was conducted to assess the impact of drawing on student scores on Assessment 1, across three time periods (pre-, post, and 4 week post) between the control and experimental groups (Table 13). There was no significant interaction found between groups, Wilks Lambda = .993, F (2, 105) =.394, p =.675, partial eta squared =.007, indicating no significant difference in scores over time between the two groups. There was a substantial main effect for Assessment 1, Wilks Lambda = .234, F (2, 105) = 172.24, p = <0005, partial eta squared =.766, with both groups showing an increase in scores on Assessment 1 across the three time periods. The main effect comparing scores of the two groups was not significant, F (1, 106) = .352, p = .55, partial eta squared = .003, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 1 scores across the three time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no greater measurable effect on student learning than the conventional instruction method, confirming the null hypothesis.

A mixed between-within analysis of variance was also conducted to assess the impact of drawing on student scores on Assessment 2, across three time periods (pre-,post, and 4 week post) between the Logical-Mathematical learners in control and experimental groups (Table 12). There was no significant interaction found between groups, Wilks Lambda = .947, F (2, 105) =2.918, p =.058, partial eta squared =.053. This means there was no measurable difference in scores over time between the students in the control and experimental groups. There was a substantial main effect for Assessment 2, Wilks Lambda = .923, F (.2, 105) = 4.39, p = .015, partial eta squared =.077, with both groups showing an increase in scores on Assessment 2 across the three time periods. The main effect comparing scores of the two groups was not significant, F (1, 106) =.704, p = .403, partial eta squared = .007, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 2 scores across the three time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no greater measurable effect on student learning, confirming the null hypothesis.

Table 13. Logical-Mathematical intelligence Assessment Scores

Logical-Mathematical Intelligence						
	Control			Experimental		
	n	M	SD	*n*	M	SD
Pre-Assessment 1	49	6.16	2.81	59	6.42	2.81
Post-Assessment 1	49	10.84	1.84	59	11.14	1.24
4 week Post-Assessment 1	49	9.74	2.8	59	10.28	2.48
Pre-Assessment 2	49	.98	.66	59	.88	.75
Post-Assessment 2	49	1.22	.92	59	.93	.94
4-week Post Assessment 2	49	1.12	.93	59	1.14	.97

Verbal-Linguistic intelligence. To determine the effect of the visual instruction method on Verbal-Linguistic learners, assessment scores of students who rated themselves above the cutoff value = > 9 on the MI inventory for this intelligence were analyzed. A mixed between-within analysis of variance was conducted to assess the impact of drawing on student scores on Assessment 1, across three time periods (pre-, post, and 4 week post) between the control and experimental groups (Table 14). There was no significant interaction found between groups, Wilks Lambda = .994, F (2, 103) =.336, p =.715, partial eta squared =.006, indicating no significant difference in scores over time between the two groups. There was a substantial main effect for Assessment 1, Wilks Lambda = .225, F (2, 103) = 177.47, p = <.0005, partial eta squared =.775, with both groups showing an increase in scores on Assessment 1 across the three time periods. The main effect comparing scores of the two groups was not significant, F (1, 104) = .559, p = .55, partial eta squared = .005, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 1 scores across the three time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no greater measurable effect on student learning than the conventional instruction method, confirming the null hypothesis.

A mixed between-within analysis of variance was also conducted to assess the impact of drawing on student scores on Assessment 2, across three time periods (pre-,post, and 4 week post) between the Verbal-Linguistic learners in the control and experimental groups (Table 14). There was no significant interaction found between groups, Wilks Lambda = .947, F (2, 105) =2.918, p =.058, partial eta squared =.053. This means there was no measurable difference in scores over time between the students in the control and experimental groups. There was a substantial main effect for Assessment 2, Wilks Lambda = .923, F (2, 105) = 4.39, p = .015, partial eta squared =.077, with both groups showing an increase in scores on Assessment 2 across the three time periods. The main effect comparing scores of the two groups was not significant, F (1, 106) =.704, p = .403, partial eta squared = .007, suggesting no significant difference in the test scores between the control and experimental (drawing) groups. In other words, while students in *both* groups gained knowledge, as shown in the Assessment 2 scores across the three time periods, when the effect was measured *between* the experimental and control groups, there was no statistically significant difference in the student scores. Therefore, the drawing method had no greater measurable effect on student learning, confirming the null hypothesis.

Table 14. Verbal-Linguistic Assessment Scores

Verbal-Linguistic Intelligence						
	Control			Experimental		
	n	M	SD	*n*	M	SD
Pre-Assessment 1	40	5.68	2.59	66	6.15	2.75
Post-Assessment 1	40	10.95	2.47	66	10.67	2.02
4 week Post-Assessment 1	40	10.45	2.47	66	10.67	2.02
Pre-Assessment 2	40	1.00	.51	66	.89	.75
Post-Assessment 2	40	1.10	.84	66	1.00	.961
4-week Post Assessment 2	40	1.08	.92	66	1.14	.94

Research Question 3. Does participation in a drawing activity affect students' *observation and perception skills* of distinguishing characteristics of tree species?

Visual assessment of drawings. A randomly selected group of 40 student field sheets, approximately 20% of the experimental group, was evaluated using a rubric for consistency (Appendix E). Drawings were scored on an overall scale of 1 to 3, and were evaluated according to the information the drawings contained rather than artistic or aesthetic merit. Drawings that scored higher included all main features, including branching structure and leaf shape, as well as minor features like venation, and were properly labeled. The following figures show an example of a drawing from each score category (Figures 1-3). All of the drawings are of the same species, and from observations of the same tree.

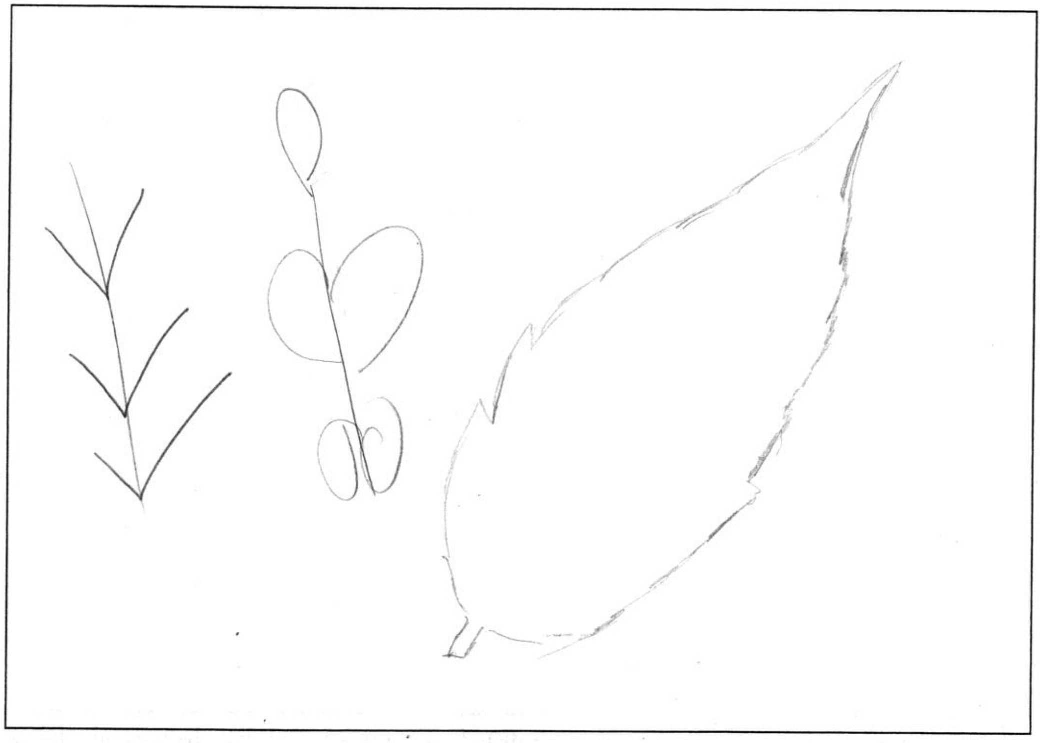


Figure 1. Score 1 student drawing of a green ash tree

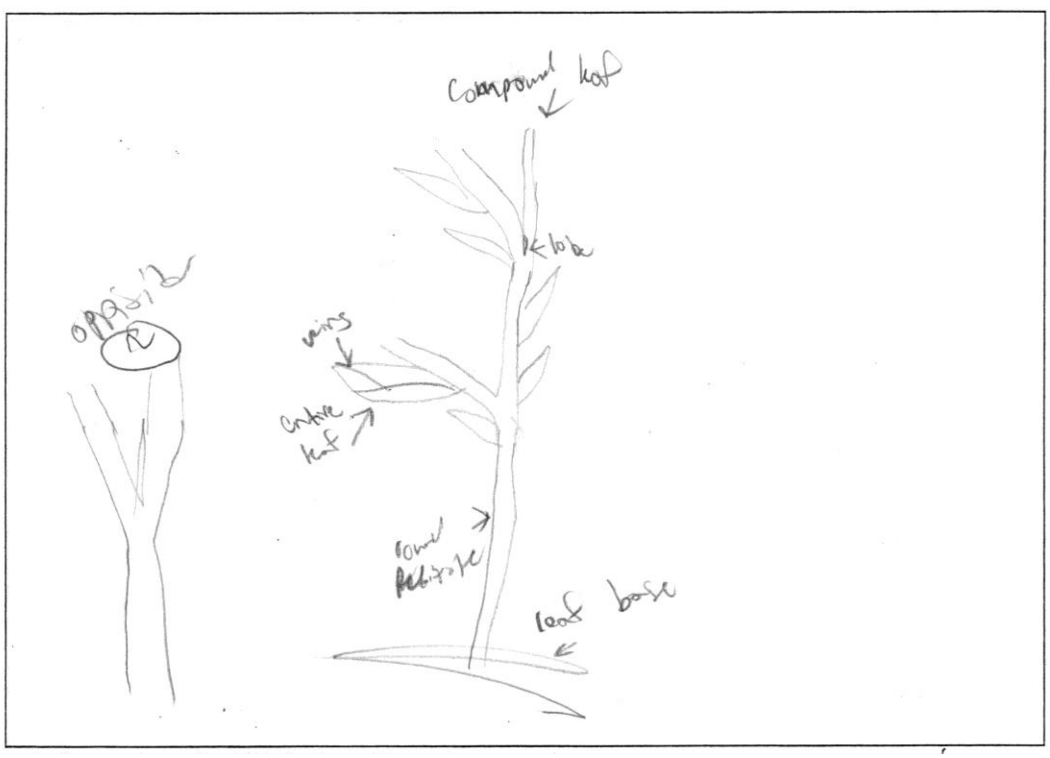


Figure 2. Score 2 student drawing of a green ash tree

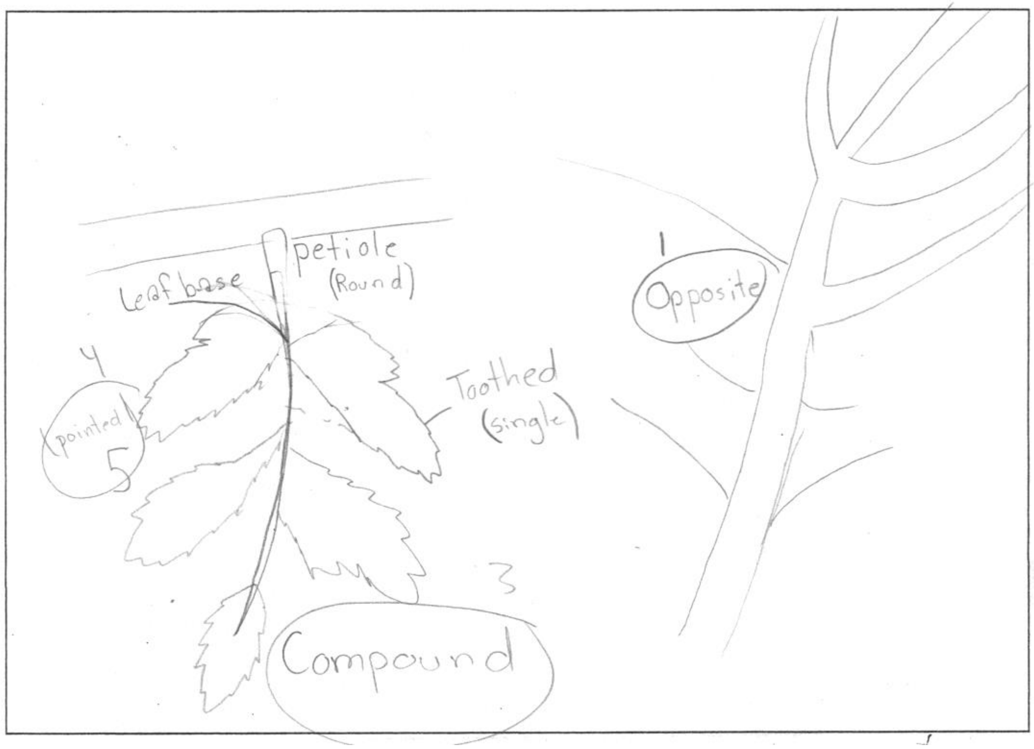


Figure 3. Score 3 student drawing of green ash tree

Of these 40 drawings, slightly more (42%) fell in the middle range (*n* =17), with some of the main and minor features drawn and labeled (Figure 5). There were eleven (28%) drawings in the lowest category (Figure 4) and twelve (30%) in the highest category (Figure 6). This distribution of scores reflected a range of student drawing abilities and observation levels across the sample. The observations of student behaviors and analysis of the selected field sheets that follow explain some of the factors that influenced observation levels reflected in these field drawings.

Incorrect identification. In addition to the rubric scores, I noticed that on many of the field sheets all of the features were very well drawn and labeled, but the species was incorrectly identified. The following example (Figure 4) shows a leaf that can be visually identified as from a red maple tree, with all of the major and minor distinguishing features indicated–including the double toothed margin, petiole shape, and the venation drawn in the correct pattern. The student obviously made one error, incorrectly identifying the branching structure as alternate when in fact maple species are opposite branching. When tying the observed/drawn information to the description in the text-based key, and then following the steps in their logical progression, the student made the wrong identification by missing this one crucial step. This was common in several of the student drawings I reviewed.

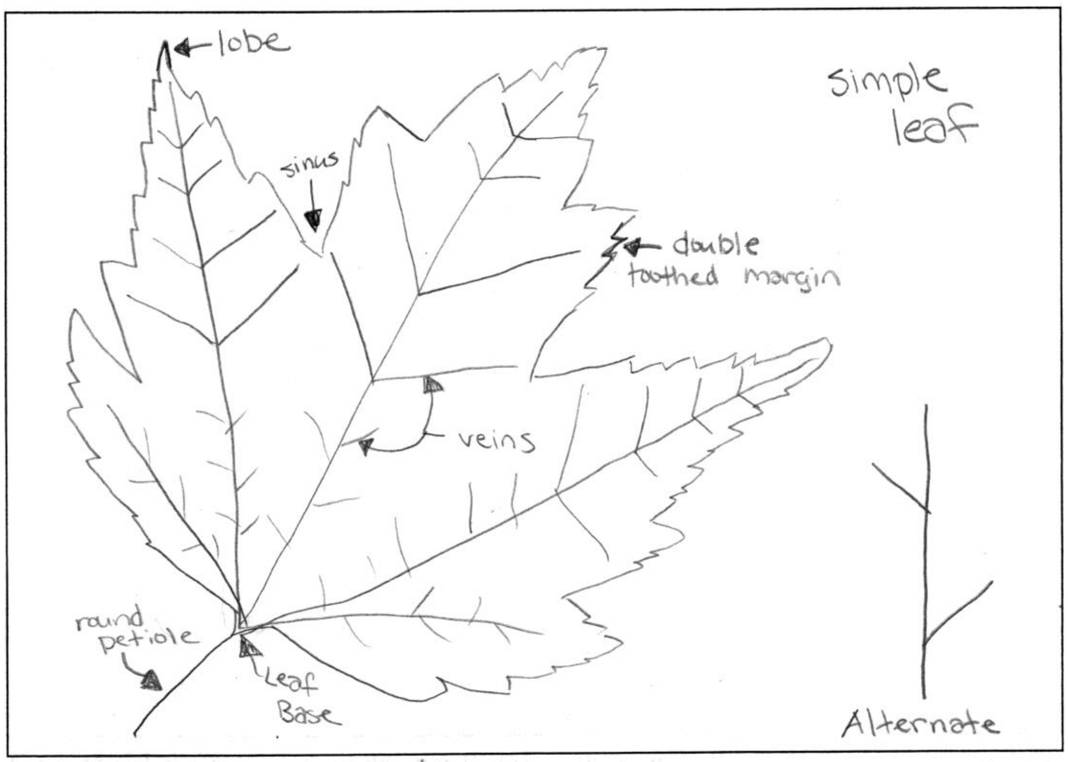
EXPERIMENTAL GROUP–Drawing Field Sheet

Student #

C TREE # 3 Species Red Oak

Observe the tree and draw the structures you need to know to identify it.
Draw and label:

- Branching structure (opposite or alternate)
- Petiole and how it is attached to the branch. Note the petiole shape (round or flat)
- Leaf base
- Draw outline of the leaf and label it (simple or compound)
- For compound leaves, note number of leaflets and shape (round/pointed)
- Note presence of lobes and sinuses
- Looking closely at the leaf margin, draw it and label the leaf margin as entire or toothed (fine, coarse, single or double)



Circle the labeled parts in your drawing that show the steps in the tree key to that you took to get to the correct species.
Write in the number of each step you took from the key next to the circled and labeled term.

Figure 4. Drawing with incorrect identification

Inconsistency. Another finding was that the demonstration species drawings done as a group in the classroom were of much better quality than those done independently in the field. The difference between the two was in some cases quite marked, as shown in the following two examples (Figures 5 and 6). These were done by the same student; the field drawing was done the following day after the classroom demonstration.

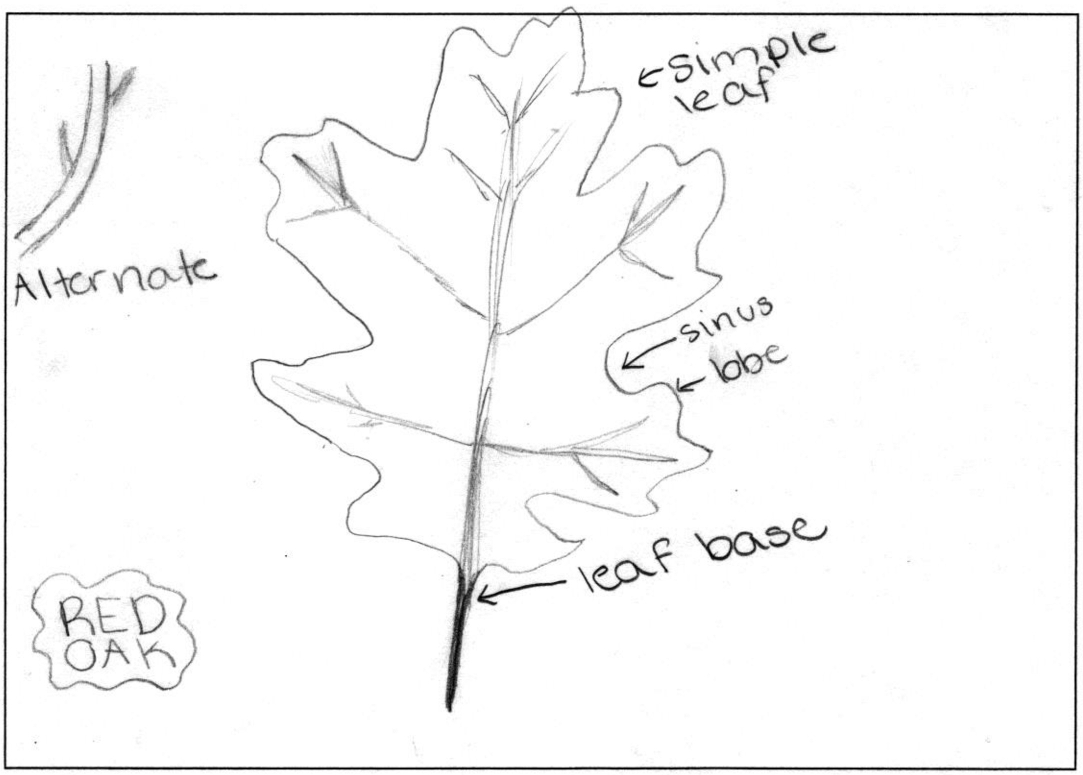


Figure 5. Demonstration species drawing

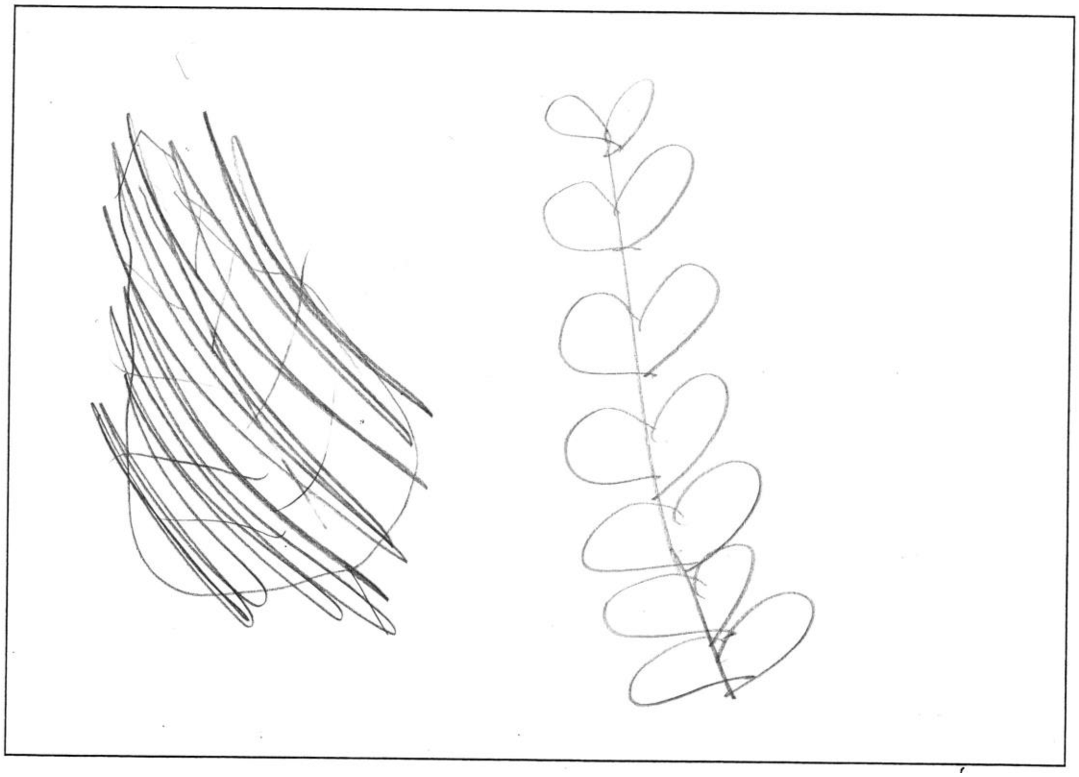


Figure 6. Field drawing done by same student

Multiple intelligences. I found several examples of drawings that were very meticulously drawn, all features labeled, and with the species correctly identified. I had expected that these drawings would have been produced by students who ranked themselves as a Visual-Spatial learner on the Multiple Intelligences inventory. In several cases, these were done by students who ranked themselves *lower* on this intelligence category than others. This example (Figure 10) was done by a student who ranked themselves highest in Naturalist, Verbal-Linguistic, and Bodily-Kinesthetic intelligences; they ranked Visual-Spatial intelligence as the second lowest category (a rating of only 6 points).

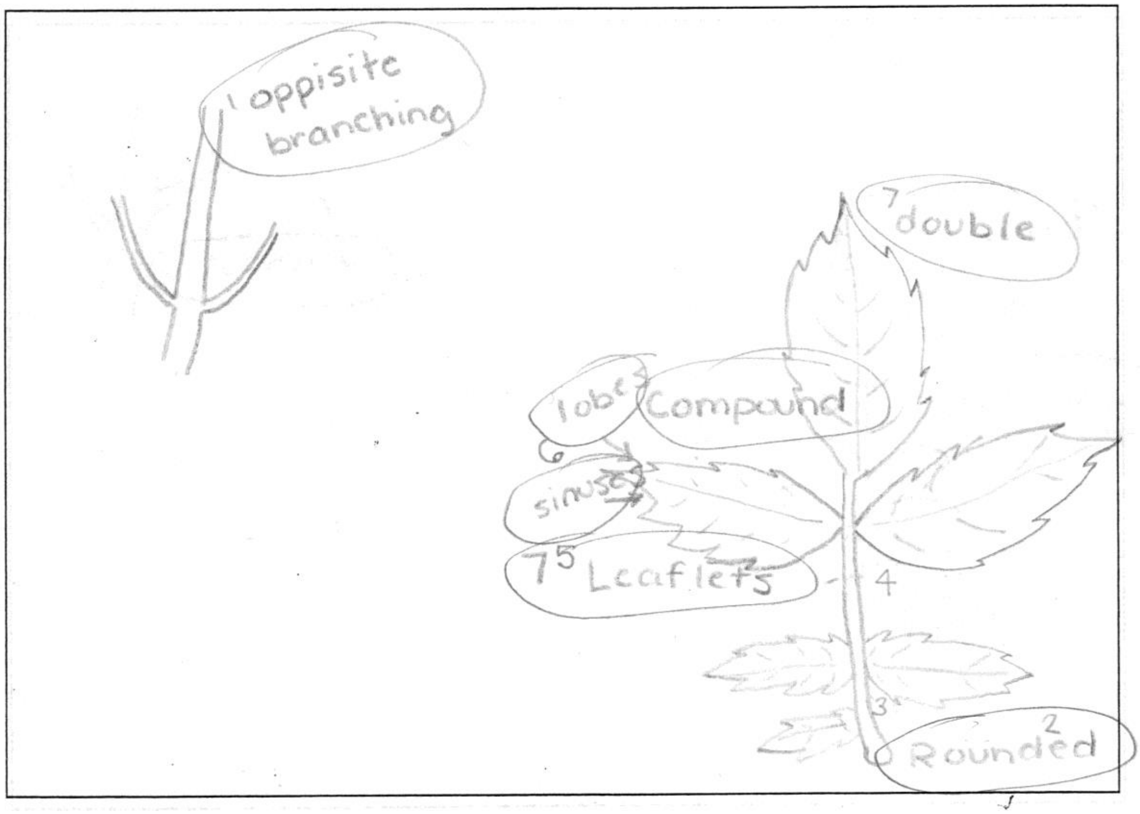


Figure 7. Verbal-linguistic student drawing. This figure shows a drawing done by a student with a *low* visual-spatial intelligence and *high* verbal-linguistic score.

This student's scores on Assessment 1 jumped from 3 on the pre-test (below the mean score) to 12 on both the post- and four week post-test (above the mean score). The student also reported that they found the drawing strategy helpful and enjoyable, and it somewhat increased their observation skills.

Experimental group student surveys. Students in the experimental group filled out a paper survey at the conclusion of the activity to assess their thoughts on the effectiveness of the drawing strategy (Table 15). Student perceptions of the drawing strategy were important to know in order to understand possible implications of the results and make recommendations for future research. These questions were scored on a scale of 1 to 3, with 1= no, 2= somewhat, and 3= yes. On all three of these questions, the majority of students answered that the drawing activity was somewhat to definitely helpful, enjoyable, and aided their observation skills.

Table 15. Experimental group student survey

Question n =130	Yes	Somewhat	No
1. Do you feel like drawing helped you learn tree ID?	n = 66 (51%)	n = 53 (41%)	n =11 (8%)
2. Did you enjoy the drawing part of the lesson?	n = 57 (44%)	n = 52 (40%)	n = 21 (16%)
3. Did you feel like drawing helped you observe the trees better?	n= 63 (48%)	n = 41 (16%)	n = 26 (20%)

Question 1 asked students whether they felt drawing helped them learn tree identification; 91.6% percent of the students responded that it was somewhat to definitely helpful. The following comments further support and expand on this finding.

"When I draw things it helps me focus on it more"

"Because it made learning tree ID more fun and I remember the fun stuff more"

"Because I could actually see the lesson drawn out"

"It helped me because before I never could ID trees"

"I feel like drawing helped because it was easier to understand and remember the leaf parts"

Although the majority of students felt drawing helped them learn, some (11 out of 130) clearly did not. These students found the drawing process cumbersome, difficult, or "boring"– as one student commented, "It was time consuming and required to [sic] much details."

Question two asked students whether they enjoyed drawing in this lesson. The answers they gave to this question seemed tied to their answer to the first question. Most students who felt that it helped them learn reported that they liked to draw and enjoyed it. Students who felt that drawing was not or only somewhat helpful reported they disliked drawing and felt they were not skilled at it. Students' perception of whether they were good at drawing seemed tied to their enjoyment level in most cases, both positive and negative. Typical positive responses (e.g."I love to draw") were common, along with more detailed comments such as:

"I enjoy drawing and it made the lesson more engaging/fun"

"I enjoyed drawing because I like to draw and learn. Learning and drawing together is so much fun."

Typical negative responses were numerous as well (e.g. "I hate to draw"), along with many negative comments about their own ability level (e.g. "I am bad at drawing") Some comments combined the two, such as "Because I am not good at drawing so I dislike it a lot." Other comments were more specific:

"It would be easier if I knew how to draw."

"No, because I feel like I didn't have enough guidance."

"It was hard to draw the exact tree shape."

"It was boring and took too much time."

While some students did not particularly *enjoy* or feel they were good at drawing, they still felt like it was a valuable learning tool, reflected in comments such as:

"I love drawing even though I am a really bad drawer. So this helped my

drawing and science skills"

" I don't really like to draw, but I do like to learn and this was a learning process."

" It was ok because it helped my mind but I hate to draw."

Some students indicated they enjoyed drawing because they appreciated using a different or novel instructional strategy in their science class. As one student commented,

"It was better than a lot of boring talking."

One student in particular appreciated the drawing activity, commenting:

"I got to draw in class."

On Question 3, students' answers about their level of observation indicated that in many cases (80%), they saw a greater amount of detail when they drew. Comments such as these showed that some students not only noticed more minor features of the leaf, but also noticed their own behaviors while drawing.

" I just looked more closely at the tree's features so I could make a more detailed drawing."

"It was kind of like going inside of a leaf on a tour."

"I noticed how many times the veins would branch out and how coarse the teeth on the leaf were."

"I noticed more closely that the leaves are very busy with all the stuff they have to do for the tree."

"I noticed the little hairs on the black oak."

"I noticed how complex a leaf can be. If you don't draw what you see, you won't catch important details."

Some cases emerged where the answers to the series of questions taken together as a whole pointed to interesting results. For example, this student who rated himself or herself strongly as a Verbal-Linguistic learner on the MI inventory did not enjoy drawing, but realized that it helped them as a learning tool.

Question 1. "It helped me learn better because I knew the information roughly in my head, but when I drew it, I had a real image in my head as well."

Question 2. "I don't really enjoy drawing, but it wasn't really horrible and was a little cool tracing leafs [sic] with a lot of detail."

Question 3. "Yes, drawing helped me observe better because I could see on my paper why it was simple or compound and what detail it included."

Additional Findings

Teacher Survey In addition to the quantitative assessments and student survey data, teacher observations and their perceptions of the drawing strategy were gathered in a post survey questionnaire. All of the nine participating teachers in the study, including the field testing and pilot study teachers, had an overall positive impression of the drawing method; their responses to the following three survey questions added a layer of insight to the data I collected. Most of the teachers felt that the drawing activity definitely increased student's engagement, focus and observation levels, but there was not a consensus among them as to whether this resulted in an increase of knowledge or retention. Below are the questions and a few of their representative responses.

1. In what ways do you feel that the added drawing component in the LEAF tree ID lesson impacted your students' learning?

   "Students that drew had to slow down and pay closer attention to what they were

doing. There did not seem to be an increase in retention or knowledge of information in the drawing group."

"Students seemed to focus their attention more on the structures when they had to draw them. Therefore, those students seemed to gain and retain the knowledge more than the students not drawing."

"*I feel that the drawing component allowed the students to observe the tree structure better. I don't know if it helped with the species identification, but we would have needed to spend more time on using the tree key for that."*

2. Did you observe any differences in the level of student engagement and concentration in the tree ID activity with the added drawing element?

   If yes, please describe:

   "I thought that the students who were drawing were more engaged both in the classroom portion of the lab as well as the outside portion. They seemed to be more on task and more focused on the parts of the tree."

   "The level of student engagement seemed about the same for both groups, but in different ways. I noticed that those who drew their notes tended to refer back to them less than the non-drawing group. They seemed to remember the leaf structures easier."

   "Yes, students who drew were definitely more focused and engaged in both the instruction and the keying of trees."

3. What evidence, if any, did you see of increased observation skills in students who participated in the drawing component?

"I observed that the students who were drawing spent much more time looking at the leaves trees [sic] when trying to key them out. Those students seemed to be more methodical when using the keys."

LEAF Instructor observations. The LEAF instructor, who has substantial classroom experience as a high school science teacher, also observed that the overall engagement level of students in the experimental group was higher and that "students were much more focused in the notes section when they were drawing and labeling vs. just labeling a diagram." As an instructor, she felt the visual instruction method was also a more engaging way to teach, compared to conventional methods:

"As the facilitator, it was more engaging to draw notes along with the students and I felt like the content was delivered in a more fluid and understandable way instead of just pointing to the screen, mentioning the term, and then defining it."

Researcher observations. Acting as an observer, and not providing any instruction in either drawing or tree identification, enabled me to observe both the instructional delivery method and the student behaviors during the classroom and field components. I made notes of behaviors in both the control and experimental groups. While I concur with the classroom teachers' and LEAF instructor's observations, I noticed some additional behavioral differences between the experimental and control groups.

One unanticipated behavior that I observed was that students tended to ask their classmates questions, and work as a group rather than individually. This was much more prevalent in the control group. Often, this resulted in wrong answers being shared amongst many students. Although I emphasized to students that their work was not graded and that for my research purposes they could not collaborate and share answers, the behavior persisted. The drive at this developmental stage to confer with peers is strong, and students' social behavior in the field sometimes seemed to interfere with their attention level in the lesson.

One obvious difference between the control and experimental groups was that the students who drew tended to work much more individually. Since they had to draw the tree parts rather than just circle the answers, fill in a blank, or copy a description from the key, asking their neighbor for the answer was not a feasible option. In many cases, even though it may not have resulted in the correct species identification, students in the experimental group were at least observing and recording their own direct visual data based on their own observations, rather than the answers from someone else.

Students also had great difficulty understanding and using the dichotomous key, even with instruction. Often, terms and descriptions on the key were hard for them to understand and apply to live specimens in the field. One of the most confusing tasks was deciding whether a tree had opposite or alternate branching patterns. It was also difficult for them to compare descriptions such as "papery bark" or "bark not papery" when they did not have a visual example of each to look at, or had prior experience observing trees. Choosing between whether a leaf was "three times" or "less than three times as long" was difficult without a measuring device. Numerous student comments such as "the tree key was confusing with all the numbers" confirmed my observations.

Conclusion

The results of the mean scores of Assessment 1, the fill in the blank diagram which tested students' knowledge of tree identification terms, showed no statistically significant difference in scores on pre-, post-, and four week post-tests between the control and experimental groups. The results of the mean scores of Assessment 2, the fill in the blank test with images of the four species on their site that students observed, did show some very small significant difference in scores in the analysis of the entire group (n=390) over two time periods (pre- and post- assessments, no four week post- tests). Additionally, there was no statistically significant effect of the drawing method when these assessment scores were compared across the spectrum of intelligences. This confirmed the null hypothesis. Results of Assessment 3 showed that the students' field sheets did contain evidence that they were actively observing and drawing the trees, in many cases labeling terms and identifying structures and features correctly, although the species was not always correctly identified. The results of the student survey indicated that the majority of students found the drawing activity was helpful, enjoyable, and aided their observation skills.

Additional findings from the student drawings and survey responses point to the perceived value and potential improvements in both the drawing method and the overall tree identification lesson. This was substantiated by both the teacher observations and LEAF instructor comments, as well as my own observations. Combining these results of all of the different sources of data, the following chapter outlines my implications and recommendations stemming from this study.

Chapter 5. Discussion and Recommendations

Even though the pre and post assessment scores did not show a measurable increase in student leaning with the drawing method, numerous observations and student positive student questionnaire responses warrant a closer look at the drawing tool and its ultimate value. Certainly, the students who drew did as well as the students who used the traditional text-based method, and there were other immeasurable benefits to the instructional strategy that are worth examining. There were several limitations in this study that may have affected its ability to fully and accurately assess the effect of this learning tool. Taking steps to remedy these limitations in future research studies may yield more precise results. In this chapter, a discussion of these factors along with my recommendations for lesson implementation and further research are outlined.

Throughout the course of this study, from its inception, design, implementation, and finally to the analysis of the findings, I gained many new understandings about the difference between theory and practice in both the field and classroom settings. I was able to identify several areas where the study and its methods could have been altered and refined to improve its ability to hone in on the variable of drawing.

Discussion

Research question 1. The findings from Assessment 1 and 2 answered the question "to what extent does participating in a drawing activity as part of a tree identification lesson affect student *short- and long- term knowledge* of Wisconsin tree species?" The assessments, timing of the treatment, and the lesson itself may have had limitations that prevented a clear analysis of its effect.

Assessments. The LEAF lesson-based assessments that were adapted for this study may not have been the best tools for capturing the students' level of knowledge about tree parts and leaf characteristics. With their menu of fill in the blank responses, one teacher felt that many of her students were "good guessers" on the pre-test and their answers did not reflect their actual knowledge level. In my observations where I saw the pre-assessments administered, students were very uncomfortable not knowing the correct answer--even in situations where they had not been exposed to content before and were told it was acceptable to leave it blank and "not know". This ran so counter to their usual experience that there was a fair amount of answer sharing between students on the assessments. Although students were never given the correct answers, using the same diagram for all three assessment periods may also have created situations where students learned the terms by repeated exposure to the same test rather than knowledge gained in the lesson.

Curriculum-based assessments, grounded in existing class content, may have captured the effect of the different learning strategies more accurately. For instance, an illustrated lab notebook or field notebook, graded periodically over the course of the semester, may give a more comprehensive understanding of overall student performance. (Baldwin & Crawford, 2011)

Duration of the study. This study evaluated student learning in one very small snapshot of one tree ID lesson conducted over two 45-minute class periods. This was a very short period of time, within which a fair amount of unfamiliar instructional content was delivered. This small window of instructional time was chosen due to two factors– the amount of time teachers could accommodate for the lesson outside of their regular curriculum, and the logistical needs of myself and the LEAF instructor. Two class periods were the limit of what was practically feasible, not what was ideal for optimum student learning. Other similar studies that evaluated art-based strategies and drawing as a learning tool were conducted over a longer period of time, such as a term or entire semester (Landin, 2011; Levine, 2007). A longer term approach may have yielded a more accurate picture of the impacts the drawing strategy had.

A longer term study could have allowed students to become more familiar with the tree identification lesson itself and more comfortable with drawing in a science context. Many students expressed frustration with the amount of time allowed for the lesson, commenting, "we had only one day to learn about the whole thing and it got very confusing" and "maybe use the whole week and not two days." One DC Everest teacher commented, "I feel that the drawing component allowed the students to observe the tree structure better. I don't know if it helped with the species identification, but *we would have needed to spend more time on using the tree key for that*" (emphasis added). Expanding the time period would have allowed for repeated exposure to the content within the context of the existing classroom structure, rather than just one lesson in an isolated subject area.

LEAF tree identification lesson. Although this lesson is a good resource for tree identification, students found using the key somewhat difficult. This lesson, as it appears in the LEAF K-12 forestry education guide, was not developed to use with an active visual teaching method, so tying the existing written descriptions to a visual teaching method was at times awkward. In order to arrive at the correct identification of the tree at hand, students in both the experimental and control groups still had to use the written key. As one teacher earlier pointed out, using the key would take time and practice. This may account for the very low assessment scores on Assessment 2, the visual recognition of four site-specific species. If students did not correctly navigate the key and know the terms (some of which were not covered in the pre-lesson) their identification was incorrect. There was no way for students to independently check their answers, such as with a picture in a guidebook.

Curriculum integration. In most cases, the lesson and the assessments used in this study were created out of context of the students' regular curriculum. Although some of the schools (Northland Pines, Hurley, and Pulaski) were planning a tree identification unit, the materials and methods they normally used for this lesson were altered to fit the confines of the research. This created a less natural learning environment. The LEAF lesson was chosen because it was an already developed and tested resource, representative of the way tree identification is commonly taught, not because dichotomous keys are necessarily the best or only way for students to learn to identify trees. Teachers in the study who were experienced in teaching this skill normally devoted many class periods to covering the content, and used lessons that build upon students' prior knowledge. This approach is in keeping with theories of brain-based learning and memory formation (Jensen, 2008). Developing a lesson that worked in harmony with these theories (e.g., building on prior knowledge), could have created a more optimal learning experience. The LEAF Instructor in this study felt that it would be useful to "continue a study like this with other science content areas that are more directly related to their learning instead of just one lesson."

Sample group size. The size of the sample group was quite large (*n* = 390). I originally chose to work with such a large sample to ensure that the results would be more valid and applicable to other situations. The large sample size provided many control and experimental groups, representing a diverse group of learners. While these were desirable outcomes of this choice, the overly large size and geographical distance between the schools was somewhat cumbersome. Doing repeated assessments, follow-up surveys, and site preparation was left to the classroom teachers, which may have inadvertently affected results. Not all follow up surveys were administered on the day immediately following the lesson, but during the next class period. In a few cases, the four-week post assessments were not administered at all by the classroom teacher. This ultimately affected the number of students who could be counted in the quantitative assessment data.

The study gathered mostly quantitative data, through Assessments 1 and 2 (fill in the blank diagrams) and Assessment 3 (drawing rubric). This numeric data was fairly efficient to analyze. The qualitative data, which was gathered through handwritten teacher and student surveys, was more informative and supportive of the value of the drawing tool than I had anticipated. I had only expected the student and teacher comments to be used as anecdotal support for the quantitative findings. Knowing this, it may have been more helpful to gather qualitative data through a more comprehensive survey with targeted questions that more closely examined such factors as student attitudes and confidence toward drawing.

Research question 2. The results of the Multiple Intelligences (MI) inventory answered the question of "how does participation in a drawing activity impact student learning across different learning modes, as identified in a Multiple Intelligences Inventory?" While this was an interesting way to look at student performance on the assessments, the self-scored inventory showed some limitations in its ability to accurately define students by intelligence types.

Multiple intelligences inventory. The Multiple Intelligence (MI) Inventory test that I chose for this study revealed some unforeseen limitations. I chose to use the *Getting to Know You Survey* (Appendix I) developed by Dr. Laura Candler, primarily for its age-appropriateness, convenience and ease of use. While the information from this self-assessment inventory was helpful in identifying a student's perceived strengths and weaknesses, the chief limitation was in its scoring method. In theory, students could rate themselves equally in several different intelligences (as many students did), and there was no way to capture their dominant intelligence or learning style. This made it very difficult to identify the Visual-Spatial learners whom I specifically wanted to evaluate. A different survey that asked more questions and had been more rigorously tested, such as the 54-question *Teele Inventory of Multiple Intelligences* (Teele, 1995), may have taken students a bit more time to complete, but would likely have yielded more precise results.

The results of the Multiple Intelligences Inventory did reveal that many more students self-identified as Naturalist and Visual/Spatial learners than Logical/Mathematical and Verbal Linguistic learners. This would seem to indicate that the teaching methods tied to the visual instruction strategy would better reach the makeup of learners in this group. In fact, the dominant instruction methods –Verbal/Linguistic and Logical/Mathematical—were rated the two lowest among the eight categories. This poses the question of whether the instruction methods we commonly used in the classroom are worth re-examining.

Research question 3. The rubric scores of the student field drawings, along with the observations and self-assessments from the teacher and student surveys, answered the question of "how does participation in a drawing activity affect students' observation and perception skills of distinguishing characteristics of tree species?" Some patterns and common characteristics were found in the student drawings that suggest students were using effective observation and perception skills; this was corroborated by their survey answers and teacher comments. Although the drawings and survey showed evidence of this, this did not translate into higher assessment scores in the experimental group, which may have been due to other factors.

Field drawings. My assessment of the student drawings revealed some interesting findings. The majority of drawings received a rubric score of 2 or 3, which indicates that most students were observing and recording visual information about the trees they were looking at. Most of these drawings contained at least some identifiable major and minor features of the tree; this could only be obtained by direct observation, not by guessing or copying another student's answers. Obviously producing these drawings required the students to look closely at the tree specimen; the information contained in their drawings is proof that they saw the features indicated. The problem seemed to lie in the ability to identify and distinguish between tree species, as written in the text-based key.

Evidence of difficulty making the identification through the text, was obvious in drawings such as the red oak (Figure 9). Although this is a very nicely drawn specimen, it was wrongly identified as a red oak. This species was obviously a red maple. The major difference between the oak and maple genus is that maples are opposite branching, while oaks are alternate branching. Since the student did not correctly observe and identify the branching structure, the whole identification process was then adversely affected. It is quite easy to make this error, as there is quite a bit of visual variation in branching patterns on the same tree. On an opposite branching tree, such as this maple, a branch may have fallen off or been removed, giving the illusion of alternate branching. Students were not guided through this identification process of using the key; they were just taught the basic principles of how the key worked and the terms used. The fact that there were a great deal of misidentified trees that were clearly visually identifiable from the drawings seems to indicate that the difficulty lay more in the use of the dichotomous key than the actual observation skills of the students.

Differences in demonstration drawings and independent field drawings. Overall, the quality of the student drawings done as demonstrations were better than the drawings done individually in the field. This was likely due to the fact that the demonstration species was drawn from specimens in class, and the students were guided step by step, while the instructor modelled how the drawings should be made. The field drawings were, in many cases, much more haphazardly executed. This may be attributed to the differences inherent between the two environments. In the field, students were much more distractible, since they were in an unfamiliar environment with wind, noise, and other students to compete with their attention. In the classroom, it was likely easier to focus on the specimen at hand, since that was the only branch available. These had been pre-selected to clearly show such features as typical branching structure for the genus, as well as typical leaf shape. Outdoors, there are many different branches and leaves to choose from, making it more difficult to choose and hone in on distinguishing characteristics. It is common for students to behave differently in the outdoor setting—especially if they are not accustomed to doing labs outdoors—this showed in the difference in the quality of many of the drawings.

Another factor that seemed to influence the field drawings was the social nature of middle schoolers. Understandably, being in an unfamiliar outdoor setting and working in groups led to more sharing of information and talking among the students than in the classroom. This interfered with the actual time spent on drawing the trees. Since there was a limited amount of time for each tree species, many of the field sheets were incomplete or not completed to the best of a student's ability. Allowing for students to work in groups and collaborate might have seemed like a more natural way to run the lesson, but that was not preferred in a research situation where individual results were being collected.

It was obvious, looking at the incomplete field sheets, and from some of the student comments reported in Chapter 4, that many students felt like there was not enough time devoted to using the drawing strategy. This could be remedied by reducing the amount of species from four to one or two, and allowing students to do more completed in depth drawings. This way, the drawing strategy could still be used in a conventional 45 minute class period.

Student survey answers. Clearly, many of the students felt that the drawing activity had value for them, as evidenced by their responses to the survey questions. That so many of them felt this helped them learn is important to note, for perceptions and attitudes toward learning affect how a method is received and how knowledge is ultimately gained. The majority of students enjoyed the drawing activity as well, and seemed to pay attention to this more novel approach. Put simply, if the students are having an enjoyable experience that they see value in, they will be more likely to learn and retain information. In terms of memory formation, we know that positive emotional experiences and experiences that take place in novel settings can impact long term retention of information (Jensen, 2008). While this was not reflected immediately in the student assessment scores compared to the control group, implementation of this strategy over time may yield measurable results.

It was most interesting to see some of the series of responses, such as the one discussed in Chapter 4 (p. 69) where students acknowledged that, although they did not particularly enjoy drawing or feel they were good at it, it helped them learn. This is very insightful and speaks to the potential effectiveness drawing could have even for those learners who do not view themselves as artistic. This finding is supported by the drawings that were evaluated and found to be of very high quality, yet were drawn by students who did not identify as a visual/spatial learner on the Multiple Intelligences Inventory.

There may have been a couple of factors that affected this. One may be that the student's perception of their drawing ability is opposed to their actual ability level. Often high achievers have perfectionist tendencies, or an expectation of excellence, therefore they may self-rate themselves lower than others. In reading the student responses, that those who reported they did not find drawing helpful and did not enjoy it either, often commented that they were "not good at it". The other factor that could account for this disparity is the type of simplified drawing techniques that were modeled in the classroom and field. The artistic merit of the student drawings was de-emphasized, which may have caused some of the students who did not think of themselves as “artists” to feel less pressured to perform. Feeling more relaxed, they may have produced better work.

Looking at the evidence present in these drawings is in itself visual data, the kind of direct aesthetic response that scientists and naturalists such as von Humboldt and Thoreau gathered in their first steps of scientific inquiry. If this drawing technique can foster that inquiry process and build observation skills, especially when (in the case of this study) it results in assessment scores that are at least as good as more conventional methods, there is merit to consider it as another learning tool that may have benefits for more types of learners than we would first assume.

Additional Findings

In addition to the findings that were tied to the three research questions, some additional findings on the overall study are important to discuss here. The teacher questionnaire gave valuable insight to their attitudes toward the visual instruction methods in science classes, and informed some possible practical implications of the study. Knowing their impressions was very important in forming recommendations based on this research, for no matter how effective a teaching method may be in a research situation, it must be well received by educators to have practical value in the field and classroom.

Judging by the teachers’ comments, it was clear that they all saw value and practical applications for using drawing in their science classes. All of the teachers in the study remarked, both in their responses to questions and in conversations with myself and the LEAF instructor, that they saw a marked difference in student engagement levels when the visual instruction method was used. This may be due to the novelty factor of the lesson itself rather than the overall appeal of drawing as a learning tool, but this is something that only more long term use of drawing within the context of the regular science class would reveal. That the lesson was given by someone other than the regular classroom teacher might also have affected the engagement level, but since the same instructor was used for both groups, observations of the difference in students' attention levels between the control and experimental groups seem valid.

The LEAF instructor's comment that the lesson was easy and more pleasurable to teach using the visual method seems to indicate a different sort of value in this approach. Certainly it would seem that student learning is affected by the teacher's attitude and demeanor, therefore if the teacher feels good about teaching in this manner, perhaps there is merit in using drawing. The teachers involved in the study did express that they might not feel as confident using drawing in their classes, since many of them lacked an art background or training. This is probably true for most science teachers, since visual arts are not necessarily part of their educational requirements for a teaching degree. Providing some instruction to teachers seems necessary for drawing to be used to its full potential in the field and classroom.

In addition, instruction for students seems to be imperative for drawing to be used successfully as a learning tool. This was indicated in prior research (Landin, 2011) and echoed in student responses. The kind of drawing that is needed in science classes is perceptual drawing, based on the ability to draw accurately what the eye observes. One DC Everest teacher, who uses drawing in a unit about plant growth, expressed that the unit is often hard for students, since they must accurately draw the stages of growth in the plant in their lab books. Many art educators agree that drawing is a skill that can be developed, just like reading, playing an instrument, or learning to play a sport (Edwards, 1999). The enjoyment factor for students using this technique may increase with more practical instruction and practice, since the frustration level students experience while trying to draw accurately would likely decrease.

Recommendations

Based on this study and the discussion of its findings, there is clearly room for further research that can continue to clarify the relationship and potential value of art based strategies in the science classroom. Positive reaction to the instruction method and reported gains in student learning, engagement, and observation are justification in themselves to consider implementing a visual strategy in the LEAF tree identification lesson and modifying it for ease of use. The following outlines my recommendations for research and implementation.

Future research needs. Earlier studies that explore the use of drawing as a learning tool in science laid the groundwork for this research (Landin, 2011, Baldwin &Crawford, 2010). This study attempted to fill a gap in the existing research by its use of quantitative assessments that measured the effect of the drawing strategy on a large number of K-12 students. Refinement of the study design, research methods, and implementation strategies used in this research will aid in creating future studies to better understand and articulate the effects of observational drawing as a learning tool.

Curriculum connections. A study that is rooted in the existing curriculum would likely yield clearer results. The visual instruction method could be integrated throughout the content of the class, and student learning assessed with existing evaluation tools. This could even possibly yield data from student performance in prior years, or with identical content in other sections of the class. As part of the curriculum, the drawing strategy could be implemented for a much longer term and its effects more clearly seen.

Drawing instruction. It is essential in designing any study that is attempting to assess drawing as a learning tool to provide some instruction in drawing. In one study (Landin, 2011) that produced measurably significant gains in student knowledge, drawing instruction was provided in a short tutorial at the beginning of the course. Even this minimal level of instruction produced a 6 point gain in test scores of the drawing students over their writing peers in the introductory biology lab. In another study, students were provided instruction through an ongoing collaboration between a botany and art professor (Baldwin & Crawford, 2011). Students in this class self-reported learning more than they otherwise would have. The researchers assert that "incorporating drawing into a science laboratory is more successful when students' drawing skills are actively mentored" (Baldwin & Crawford, 2011, p. 22). Collaborations between K-12 art and science teachers might produce similar results.

These studies had small sample sizes of one class over the course of a semester, with the instructors as researchers, and no control group. The Landin study had a sample size of 30 students (Landin, 2011), while the Baldwin and Crawford study had 41 students. Expanding the scope of these studies and taking more rigorous measures to avoid researcher bias would be helpful in establishing the legitimacy of drawing as a valuable instructional strategy. I recommend conducting future research with a stronger study design–including pre- and post-assessments and control groups–that provide integrated drawing instruction, and with a larger sample size than was used in the aforementioned studies.

Development of tree identification curriculum. Given the difficulties that many students experienced in using the LEAF tree identification key, an assessment and possible modification of this resource seems in order. The lesson used in this study was not developed with a visual teaching method in mind; co-development of the written text and drawing activity is essential for the two to work well together. This was done recently, in collaboration between a forestry educator and illustrator for the *Winter Tree Identification Key*, a supplemental resource available to educators through the LEAF K-12 forestry education program. Field testing of this new resource, with its illustrations of twigs and bud structures for each species, has gotten many positive reviews from educators. A similar version-- with illustrations that explain each step in the key--could also be developed for the conventional tree identification lesson. Simple field illustration techniques could also be introduced as part of the lesson. Implementing the visual strategy through observational drawing exercises done in the field would then be a more natural fit, and the curriculum could be used in collaborations between art and science teachers.

Develop opportunities for art and science integration. Since art instruction has been shown to be important in order for drawing to be an effective learning tool in science (Landin 2011), it would follow that successful integration of art and science depends on the availability of quality instruction in both subject areas. Unfortunately, in many school districts, instructional time for art has been reduced, art teacher positions have been eliminated, and overall support for art is secondary to core academic subjects.

While changing the climate of support for art programs in general requires a many-pronged approach that is beyond the objectives of this study, the positive reaction of science teachers to this instruction method and using drawing as a learning tool indicates potential for collaboration between art and science teachers. Art educators in our schools fill a unique niche in this endeavor, as experts in teaching the very skills that are beneficial in science classes.

To accomplish this cross-curricular integration, projects that combine the standards of both subjects around a common content area could be developed. A recent survey of art teachers for the LEAF K-12 school forestry program indicated that there was a strong interest in this area. Driven by this interest, art lessons that teach drawing skills and expand on science concepts could be co-developed collaboratively by teachers of both subject areas. For example, a tree identification unit in science could be paired with a project in art where students learn field drawing techniques of a tree, or use leaves as a design element. In this way, similar content is taught in different subject areas to enhance the value of art while enlivening the content of science. Far from being an extra-curricular outlier, art can become an integrated component of students' overall learning experience. Perhaps this integration could lead to a better overall perception of the value and importance of art-based strategies, and a strong level of support for art classes in our schools.

Conclusion

This study is not by any means the final word on whether drawing is a valuable learning tool in science, but rather it holds open the door for further investigation and experimentation. Ultimately, if additional research in this area can point to measurable impacts on student learning, it is beneficial to both the fields of art and science and even more importantly, art and science education. We also cannot dismiss the immeasurable capacity of the art-based approach discussed here to impact student learning. Drawing is more than a pretty distraction. It is a way to directly engage with the natural world, to see the world through our own eyes. It is a tool of inquiry and discovery for everyone seeking to understand the natural world.

Since the time when Charles Darwin drew his tree of life sketch, our scientific knowledge of the world and how it works has exploded exponentially, yet the underlying principles of the scientific method remain the same. These principles rest on fundamental observation skills that span many disciplines and do not waver with the educational trends of the times. Great scientific discoveries do not happen by magic, nor are they nurtured by rote learning. To foster the kind of curiosity, inquiry, and excitement for learning that will lead to future scientific discoveries, we need to find ways to excite and engage students in discovering the world around them. The next DaVinci or Darwin may very well be sitting in a classroom today…drawing in class.

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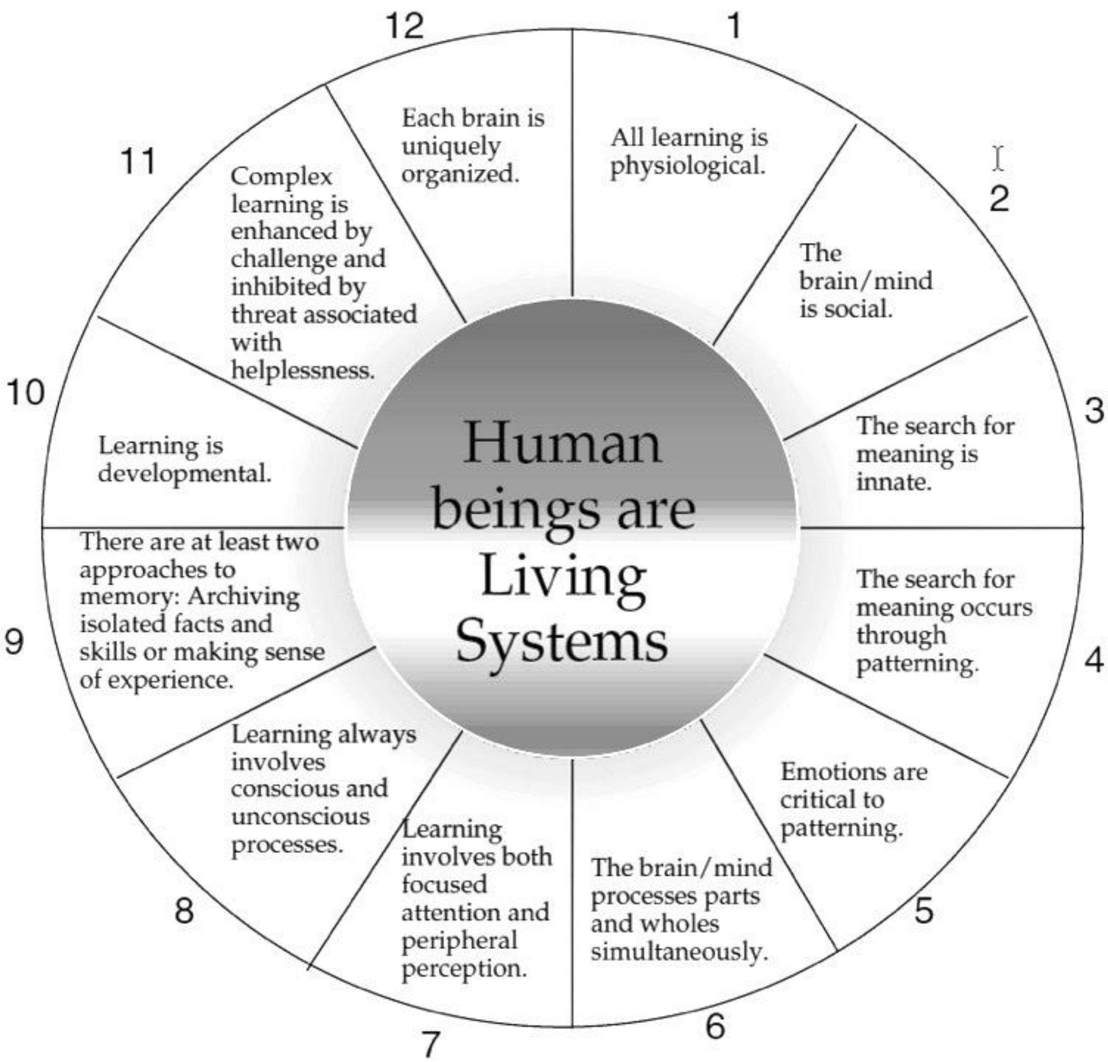
Appendix A-Twelve Principles of Brain-Based Learning



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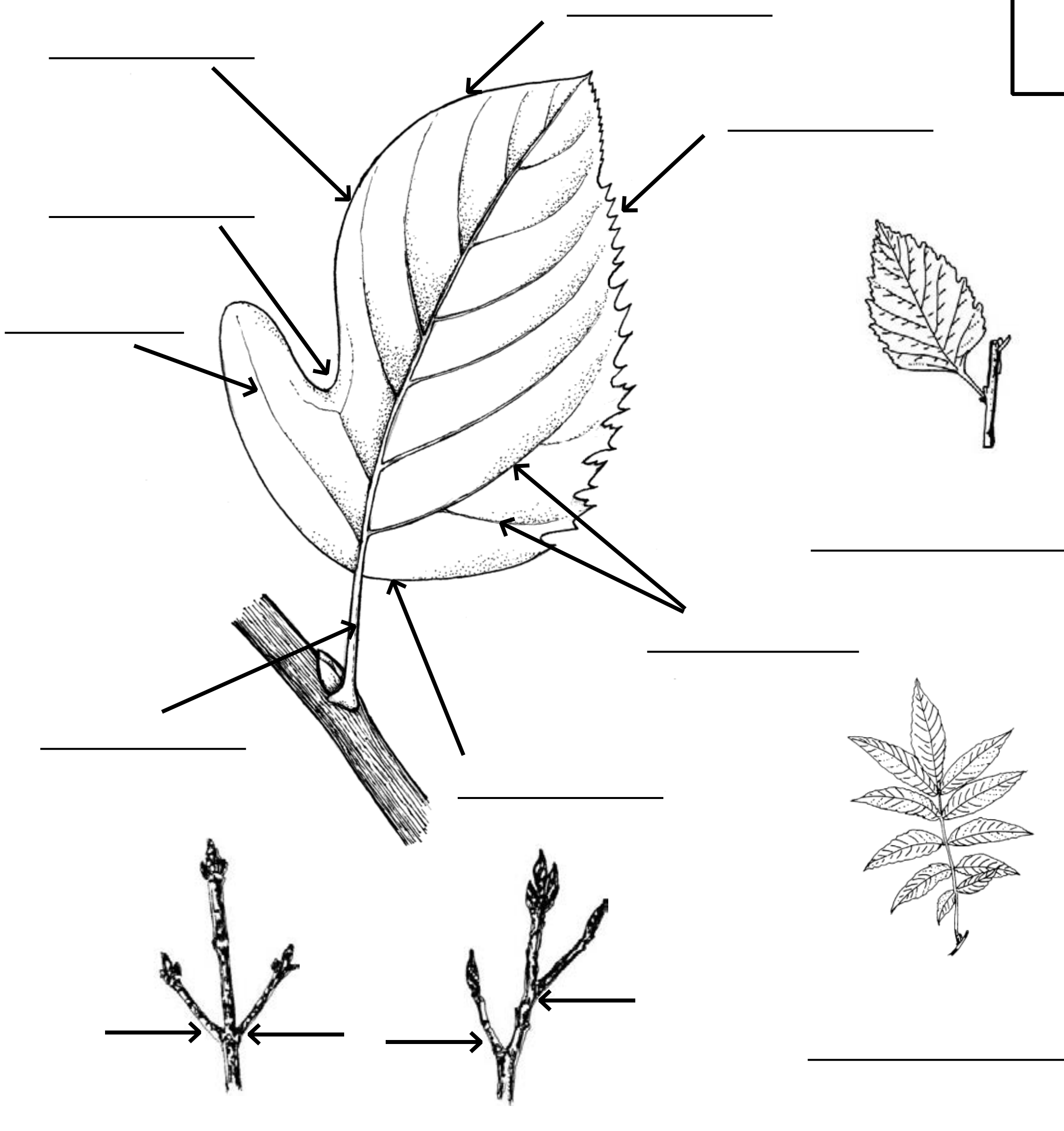
Appendix B-Assessment 1

Assessment # 1 Parts of a Leaf: Terms (linking term to image) For Experimental and Control Groups

Student #

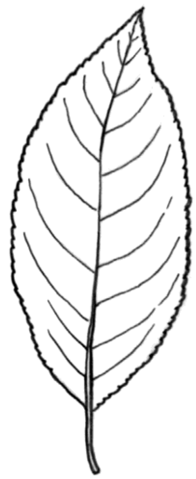


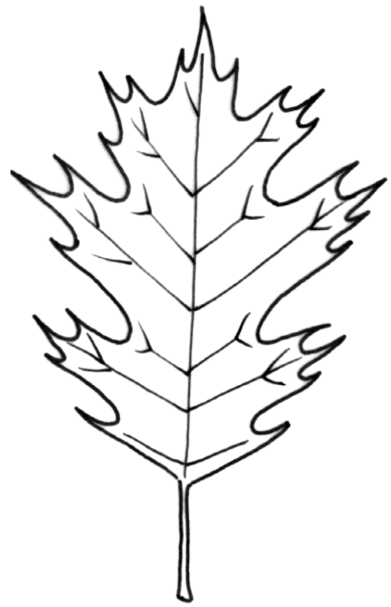
LEAF MARGIN	LEAF BASE	SIMPLE LEAF
SINUS	ENTIRE Leaf Margin	COMPOUND LEAF
LOBE	TOOTHED Leaf Margin	OPPOSITE
PETIOLE	VEINS	ALTERNATE

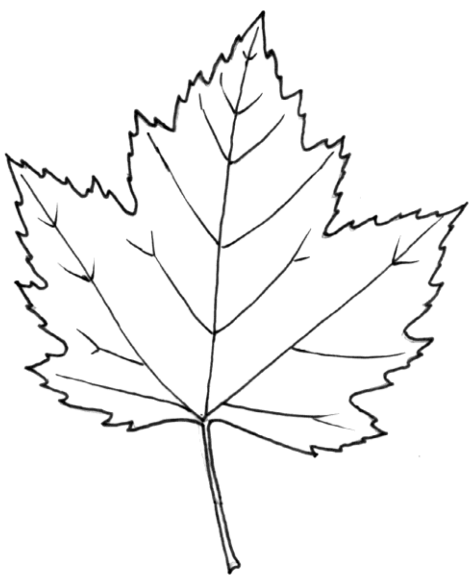
Appendix C-Assessment 2

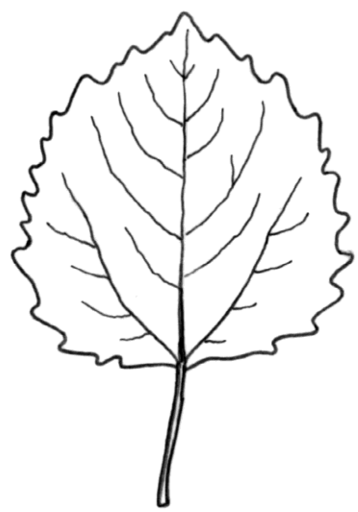
Student #

Assessment #2 Visual Recall of Species Learned - Northland Pines   For Experimental and Control Groups









Appendix D-Multiple Intelligences Survey

Name ______________________________

Getting To Know You Survey

Directions:
Fold the paper on the dark vertical line so that the eight columns on the right are folded back. Then read each statement below. Rate each statement from 0 to 5 according to how well the description fits you (0 = Not at All to 5 = Very True) Next unfold the paper and transfer each number over to the outlined block on the same row. Finally, add the numbers in each column to find the total score for each multiple intelligence area. The highest possible score in one area is 15. How many ways are you smart?

Which of the following are true about you?	0-5	Naturalist	Mathematical-Logical	Verbal-Linguistic	Musical-Rhythmic	Visual-Spatial	Bodily-Kinesthetic	Interpersonal	Intrapersonal
I enjoy singing and I sing well.									
I love crossword puzzles and other word games.									
I like spending time by myself.									
Charts, maps, and graphic organizers help me learn.									
I learn best when I can talk over a new idea.									
I enjoy art, photography, or doing craft projects.									
I often listen to music in my free time.									
I get along well with different types of people.									
I often think about my goals and dreams for the future.									
I enjoy studying about the earth and nature.									
I enjoy caring for pets and other animals.									
I love projects that involve acting or moving.									
Written assignments are usually easy for me.									
I can learn new math ideas easily.									
I play a musical instrument (or would like to).									
I am good at physical activities like sports or dancing.									
I like to play games involving numbers and logic.									
My best way to learn is by doing hands-on activities.									
I love painting, drawing, or designing on the computer.									
I often help others without being asked.									
I enjoy being outside in all types of weather.									
I love the challenge of solving a difficult math problem.									
Having quiet time to think over ideas is important to me.									
I read for pleasure every day.									
Totals ➔									
		Nature	Math	Word	Music	Art	Body	People	Self

Appendix E-Drawing Assessment Rubric

Assessment #3 Experimental Group Only

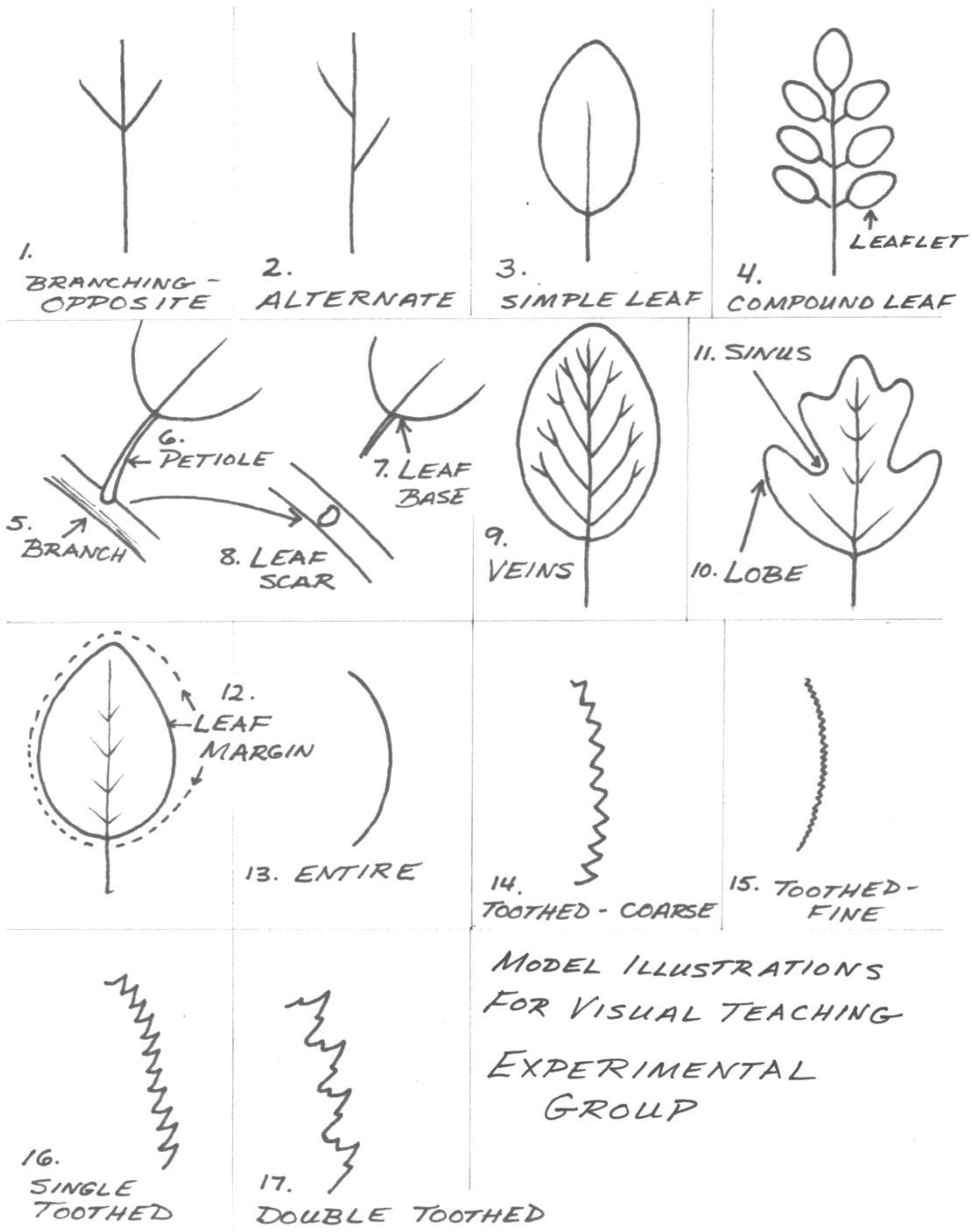
LEAF Tree ID Drawing Assessment Rubric

3	2	1
Species is clearly identifiable from drawing (genus and species)	Species partially identifiable (i.e., genus only)	Species not identifiable from drawing
All main structures are correctly labelled	Three or more structures correctly labeled	One or no structures labelled
Outline of leaf shape evident	Outline of leaf shape present but ambiguous	No identifiable leaf outline
Branching pattern clearly indicated	Branches drawn but no pattern indicated	No branching structure drawn
Compound/Simple leaf clearly indicated	Compound /Simple leaf suggested	No Compound/Simple leaf type drawn
Minor features evident (i.e. veins, petiole shape, leaf margins)	Minor features indicated but unidentifiable	No minor features indicated

SCORE_______________

COMMENTS:

Appendix F - Sample Drawings for Visual Instruction Method



Appendix G – Visual Instruction Method: Experimental Group Procedure

EXPERIMENTAL GROUP

"Assessing Drawing as a Learning Tool in Science -- Field Methods and Assessment Tools

Procedure: Teaching LEAF Tree ID Lesson with Visual Techniques

Janet Moore, UWSP Master's Student and Gretchen Marshall, LEAF K-12 Forestry Education Staff

PRIOR TO LESSON

Classroom Teacher:

1. Assign each student in BOTH Control and experimental group a number to be used throughout the study. All consent forms, pre-and post-assessments, and drawings should be marked with the student number.

2. Send home and collect Parent Consent and Student Assent forms. Sign teacher consent form. Give to researcher.

3. Administer paper copy of Multiple Intelligences Inventory, check student's self-scoring. Keep this information confidential until after the lesson is given.

3. Give pre-assessments of tree term diagram and pictures of 4 species we'll be identifying. (Assessments 1 and 2) Explain to students that they do NOT need to know the correct answers, but it is to find out what they know already.

4. Pre-select 4 tree species to be identified on site (to be done during pre-visit with researcher)

5. Administer post-assessment quiz at conclusion of lesson and 4

weeks after the lesson. LEAF Instructor-Procedure

In the classroom:

1. LEAF Instructor will briefly explain how a dichotomous key works, using the activity from *the LEAF Field Enhancement 1, Tree ID activity*. In this

activity, students practice using a dichotomous key by observing features in each other (such as eye color, hair color, etc.) . (5-10 minutes)

2. Explain to students that trees also have features that distinguish one from another, and she is going to teach them different terms they will need to know to use the dichotomous key and correctly identify species.
3. Using a blank white board or tablet, the LEAF Instructor will draw the visual illustrations of terms used on the Tree ID diagram and in the key. The Instructor will verbally describe what she is drawing, as well as label the terms clearly as they are drawn. . Students will be instructed to draw along with her, and label their drawings with the terms, in order to make a diagram they can take out in the field and use.
4. Terms will be drawn in this order:
    1. Opposite Branching
    2. Alternate Branching
    3. Simple Leaf
    4. Compound Leaf...(point out leaflet)
    5. Branch
    6. Petiole (draw attached to branch)
    7. Leaf Base
    8. Leaf Scar
    9. Veins
    10. Lobe
    11. Sinus
    12. Leaf Margins (circle around leaf to indicate margin as edge of leaf)

    13-17. Leaf Margin Types (Entire, Coarse Toothed, Fine Toothed, Single Toothed, Double Toothed)

When students have their diagrams drawn and labeled, hand out the worksheets and clipboards for drawing the four pre-selected species in the field. Explain they will do their drawings on these sheets and that we'll collect them at the end...drawings won't be judged on "artistic merit" but just on what information is shown.

In the field:

Explain and **demonstrate** the following drawing procedure. Be sure to emphasize this is NOT meant to be highly detailed art, but rather a quick line sketch/diagram of what they observe (see examples)

1. Following the written dichotomous key, and observing your tree, draw the features you need to know to identify your tree.
2. Draw and label the branching structure (opposite/alternate)
3. Draw and label the petiole and how it is attached to the branch. Note the petiole shape (round, flat)
4. Draw the outline of the leaf, and label it (simple/compound)
5. Note presence of lobes
7. Looking closely at the leaf margin, draw it and label the leaf margin as entire, toothed (smooth, coarse, single or double)
8. For compound leaves, note number of leaflets and shape (round/pointed).

At this point in the drawing, all features need for identification of the correct species should be shown, and the correct answer can be filled in.

Appendix H – Classroom Teacher Protocol

Janet Moore--UWSP "Assessing Drawing as a Learning Tool in Science"

Protocol for Classroom Teachers: LEAF Tree ID Field Work

Day One:

LEAF Instructor will deliver lessons to both groups, including the following:

1. EXPLANATION OF TERMS (Classroom)
   - Control Group (non---drawing)–A Powerpoint will be used to show images from the LEAF lesson guide; students will take written notes during the lecture and write the answers in the blank diagram they use in the field.
   - Experimental Group (drawing)–Instructor will draw and label terms on the board, and students will take notes by drawing/labeling the terms along with her to make their own diagram to use in the field.

2. DEMONSTRATION (Field)
   - Control Group–Using a tree that is not a species selected for ID, the instructor will guide students through the field sheet and and dichotomous key. Answers will be circled/written.
   - Experimental Group–Field sheet will be explained; parts of the tree species will be drawn to illustrate the type of drawing expected, as well the information that should be included for proper ID. Answers will be drawn/circled and labeled.
   - Both groups will write the path of steps it took to arrive at the right answer.

At this point, students will have a completed diagram with terms, know how a dichotomous key works, and have an example from the demonstration tree showing how to complete their Field sheet.

3. PRACTICE
   - Students will be directed to their first tree (Field Sheet, Species #1), to be done independently.
   -

Day 2:

1. FIELD WORK

Using the instruction and examples already provided by the LEAF instructor, the classroom teacher will take students out to the site to identify the 3 remaining species and complete the Field Sheet.

IMPORTANT! In order to maintain accuracy, please follow these guidelines:

- Students should be directed to go to their tree and observe it closely to complete their filed sheet.

- For *both* Control and Experimental groups, no further instruction/review should be given by the classroom teacher!

- Students are to work independently; sharing answers and collaborating among students corrupts data.

- Teachers should NOT help, guide, correct, or affirm students' progress or answers. Doing so will give inaccurate information on how the *teaching method* works.

- A time limit should be set for each tree (approximately 10 minutes)

- For both groups, the researcher (Janet Moore) will act only as an observer and will not provide any instruction or guidance to students during the lesson.

2. CONCLUSION

- All field sheets and tree term diagrams should have the student number written on it, then collected by the researcher.

- Post assessments will be given by the teacher and collected.

- The classroom teacher and students in the Experimental group will be given a few questions to capture their thoughts on the drawing part of lesson and any observations they had. These will be collected by the researcher.

Appendix I – Written Instruction Method: Control Group Procedure

CONTROL GROUP

"Assessing Drawing as a Learning Tool in Science -- Field Methods and Assessment Tools

Procedure: Teaching LEAF Tree ID Lesson- Oral/Written Teaching Method

Janet Moore, UWSP Master's Student and Gretchen Marshall, LEAF K-12 Forestry Education Staff

PRIOR TO LESSON

Classroom Teacher

1. Assign each student in BOTH control and experimental group a number to be used throughout the study. All consent forms, pre-and post-assessments, and drawings should be marked with the student number.

2. Send home and collect Parent Consent and Student Assent forms. Sign teacher consent form. Give to researcher.

3. Administer paper copy of Multiple Intelligences Inventory, check student's self-scoring. Keep this information confidential until after the lesson is given.

3. Give pre-assessments of tree term diagram and pictures of 4 species we'll be identifying. (Assessments 1 and 2) Explain to students that they do NOT need to know the correct answers, but it is to find out what they know already.

4. Pre-select 4 tree species to be identified on site (to be done during pre-visit with researcher)

5. Administer post-assessment quiz at conclusion of lesson and 4 weeks after the lesson.

LEAF Instructor-Procedure

In the classroom:

1. LEAF Instructor will briefly explain how a dichotomous key works, using the activity from *the LEAF Field Enhancement 1, Tree ID activity*. In this activity, students practice using a dichotomous key by observing features in each other (such as eye color, hair color, etc.) . (5-10 minutes)
2. Explain to students that trees also have features that distinguish one from another, and she is going to teach them different terms they will need to know to use the dichotomous key and correctly identify species.

3. Using a Powerpoint presentation, the LEAF Instructor will show the students images of the diagram they just saw for the pre-assessment. With a blank copy, they will be instructed to take written notes as they follow along with the lecture and label their diagram with the proper terms.

4. Terms will be explained in this order, using close-ups and enlarged images of the terms used throughout the lecture.

    1. Opposite Branching
    2. Alternate Branching
    3. Simple Leaf
    4. Compound Leaf...(point out leaflet)
    5. Branch
    6. Petiole (draw attached to branch)
    7. Leaf Base
    8. Leaf Scar
    9. Veins
    10. Lobe
    11. Sinus
    12. Leaf Margins (circle around leaf to indicate margin as edge of leaf)

    13-17. Leaf Margin Types (Entire, Coarse Toothed, Fine Toothed, Single Toothed, Double Toothed)

When students have their diagrams labeled, hand out the Field Sheets for identification of four pre-selected species in the field. Explain for each tree species they will fill in information about what they observe for each tree to arrive at the correct identification.

In the field:

Explain and **demonstrate** the following procedure. Throughout the process, circle the answers to questions on the key that you followed. Write the path you took to arrive at the answer you chose. (See Field Sheet)

1. Using the written dichotomous key and observing each tree, fill in the following information:
2. Branching structure (opposite/alternate)
3. Petiole shape (round, flat)
4. Identify the leaf type (simple/compound)
5. Note presence of lobes
7. Looking closely at the leaf margin, identify the leaf margin as entire, toothed (smooth, coarse, single or double)
8. For compound leaves, note number of leaflets and shape (round/pointed).

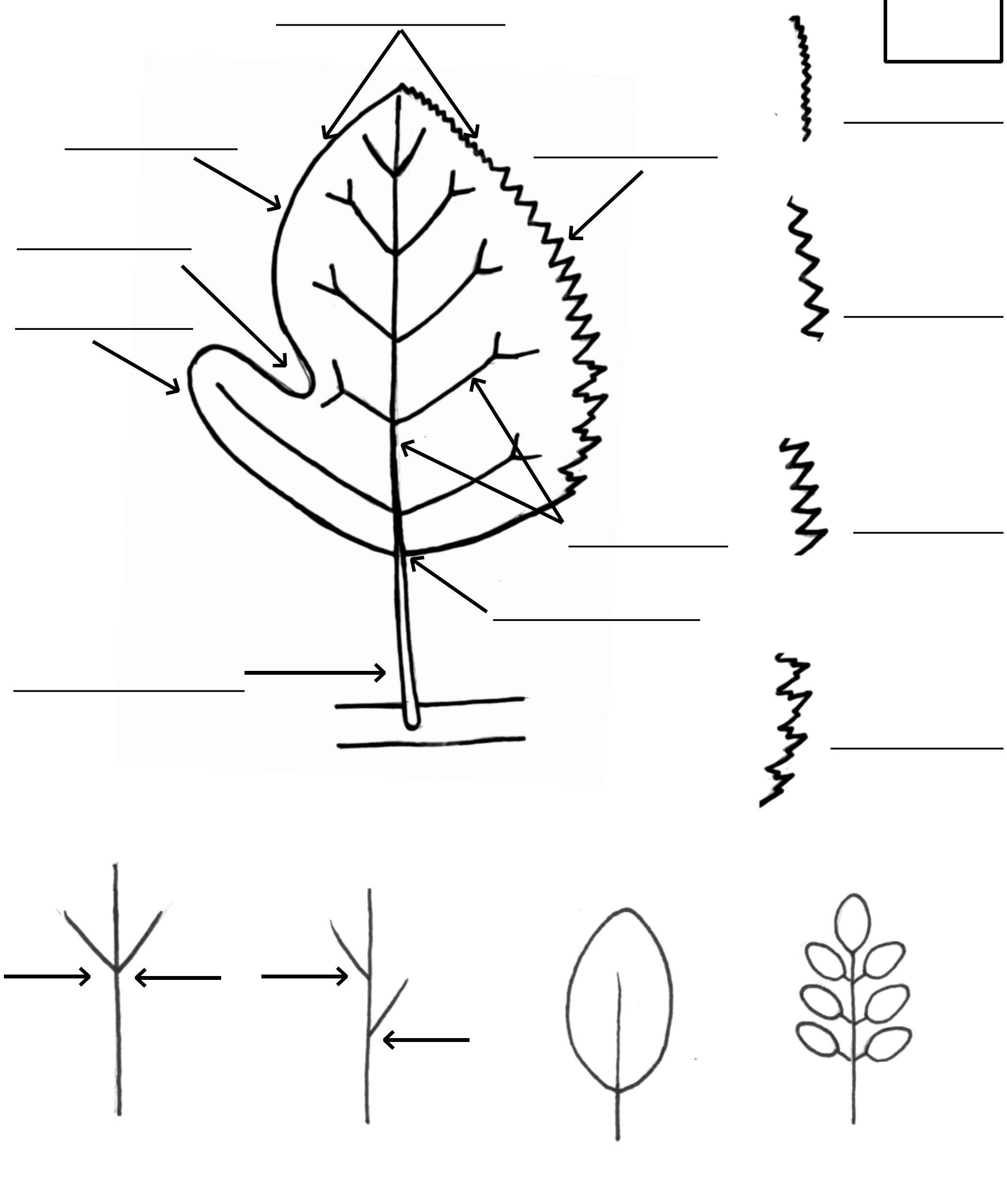
At this point, all features need for identification of the correct species should be filled in and the correct can be filled in.

Repeat for the 3 other trees, as time allows. Each species should take 5-10 minutes. Time getting from one tree to the next, and actual time spent on identification and observing may vary so the instructor should note students' progress carefully and adjust.

Appendix J – Control Group Diagram

Field Diagram: Parts of a Leaf and Terms   For Control Group

Student #



Appendix K – LEAF Tree Identification Key

4B

TREE IDENTIFICATION KEY
BROADLEAF KEY

1. Opposite branching (2)
1. Alternate branching (4)
   2. Compound leaves (3)
   2. Simple leaves: Maple species (see a-c below)
      a. Leaf margin entire, 5 lobes .... **Sugar Maple *(Acer saccharum)***
      b. Leaf margin double-toothed, 3 to 5 lobes .... **Red Maple *(Acer rubrum)***
      c. Leaf margin single-toothed, 3 to 5 lobes, lobes separated by deep, angular openings.............................. **Silver Maple *(Acer saccharinum)***

3. 3 (rarely 5) leaflets .... **Box Elder *(Acer negundo)***
3. 5 to 11 leaflets: Ash species (see a-c below)
   a. 7 to 13 leaflets, leaflets do not have petiole .... **Black Ash *(Fraxinus nigra)***
   b. 5 to 9 leaflets, leaflets have petiole, smile-shaped leaf scar extending up sides of new bud...... **White Ash *(Fraxinus americana)***
   c. 7 to 9 leaflets, leaflets have petiole, leaf scar ends at base of new bud... **Green Ash *(Fraxinus pennsylvanica)***

   4. Compound leaves (5)
   4. Simple leaves (8)

5. 7 or fewer (usually 5) leaflets, egg-shaped nut...................... **Shagbark Hickory *(Carya ovata)***
5. 7 or more leaflets (6)
   6. Leaflets rounded.. **Black Locust *(Robinia pseudoacacia)***
   6. Leaflets pointed (7)

7. Leaf 6 to 8 inches long... **Mountain Ash *(Sorbus americana)***
7. Leaf 8 to 24 inches long... **Black Walnut *(Juglans nigra)***
   8. Leaves not lobed (9)
   8. Leaves lobed: Oak species (see a-f below)
      a. Rounded lobes, 5 to 9 deep even lobes and sinuses, leaves hairless... **White Oak *(Quercus alba)***
      b. Rounded lobes, pair of deep sinuses near middle of leaf, hairy underside of leaves .... **Bur Oak *(Quercus macrocarpa)***
      c. Rounded lobes, leaf narrow at base and broad near middle, hairy underside of leaves .... **Swamp White Oak *(Quercus bicolor)***
      d. Pointed lobes, sinuses extend halfway to mid-vein, leaves hairless, dull green.. **Red Oak *(Quercus rubra)***
      e. Pointed lobes, deep sinuses extend 3/4 of the way to mid-vein, leaves hairless, bright green and shiny ..... **Northern Pin Oak *(Quercus ellipsoidalis)***
      f. Pointed lobes, deep sinuses, young leaves hairy underneath, dark green and shiny, leathery.......................... **Black Oak *(Quercus velutina)***

4C

TREE IDENTIFICATION KEY
BROADLEAF KEY

9. Bark not papery (10)
9. Bark papery: Birch species (see a-c below)

a. Leaf margin single-toothed, white peeling bark.. **White Birch *(Betula papyrifera)***
b. Leaf margin double-toothed, dull green leaves, yellow or bronzed bark .... **Yellow Birch *(Betula alleghaniensis)***
c. Leaf margin double-toothed, shiny green leaves, reddish-brown to silvery-gray bark .... **River Birch *(Betula nigra)***

10. Leaf petioles flat (11)
10. Leaf petiole round (12)
11. Leaf triangular-shaped with coarse teeth ....**Eastern Cottonwood *(Populus deltoides)***
11. Leaf oval: Aspen species (see a-b below)

a. Leaves have small, fine teeth less than 1/16 inch.. **Trembling Aspen *(Populus tremuloides)***
b. Leaves have large teeth........... **Big-toothed Aspen *(Populus grandidentata)***

12. Leaves nearly as wide as long (13)
12. Leaves longer than wide (14)
13. Leaf margin finely toothed.......................................**Balsam Poplar *(Populus balsamifera)***
13. Leaf margin coarsely toothed..**Basswood *(Tilia americana)***
14. Leaf less than 3 times as long as wide (15)
14. Leaf at least 3 times as long as wide........................**Willow species (Common species include Weeping Willow and Black Willow)**
15. Leaf veins thin and branch often (16)
15. Leaf veins thick and run from center to edge of leaf without branching (17)
16. Fine blunt teeth, leaves 2 to 6 inches long, bark dark .... **Black Cherry *(Prunus serotina)***
16. Sharp pointed teeth, leaves 2 to 4 inches long and hairy, leaf base asymmetrical ....**Hackberry *(Celtis occidentalis)***
17. Leaf shiny and leathery (thick), coarse sharp teeth................... **Beech *(Fagus grandifolia)***
17. Leaf dull and rough (18)
18. Most leaf bases even, seed in elongated clusters .... **Ironwood *(Ostrya virginiana)***
18. Leaf base uneven, seeds flat and papery......................**Elm species (Common species include American Elm, Rock Elm, and Slippery Elm)**

Appendix L – Control Group Field Sheet

CONTROL GROUP–Field Sheet

Student #

DEMONSTRATION TREE Species___________________________

Observe and circle the the answers that describe your tree:

- Branching Pattern—Opposite or Alternate?
- Petiole Shape—Round or Flat?
- Leaf Type—Simple or Compound?

(If compound, number of leaflets__________ Shape (round or pointed)

- Leaf shape—Lobed or Unlobed?
- Leaf Margin—Entire or Toothed?

(If toothed, describe: (fine, coarse, single, or double)

Write out and number the steps in the path you took to identify your tree species :

Appendix M -- Experimental Group Field Sheet

EXPERIMENTAL GROUP–Drawing Field Sheet

Student #

DEMONSTRATION TREE Species________________________

Observe the tree and draw the structures you need to know to identify it.
Draw and label:

- Branching structure (opposite or alternate)
- Petiole and how it is attached to the branch. Note the petiole shape (round or flat)
- Leaf base
- Draw outline of the leaf and label it (simple or compound)
- For compound leaves, note number of leaflets and shape (round/pointed).
- Note presence of lobes and sinuses
- Looking closely at the leaf margin, draw it and label the leaf margin as entire or toothed (fine, coarse, single or double)

Circle the labeled parts in your drawing that show the steps in the tree key to that you took to get to the correct species.
Write in the number of each step you took from the key next to the circled and labeled term.

Appendix N – Student Survey: Experimental Group Questions

Student Number_______________

Experimental Group Questions

Do you feel like drawing helped you learn tree ID?

___Yes ___Somewhat ____No

Why or why not?

Did you enjoy the drawing part of this lesson?

___Yes ___Somewhat ____No

Why or why not?

Do you think drawing helped you to observe the trees more closely?

____Yes ____Somewhat ____No

If yes, what did you notice?

Other comments:

Appendix O – Teacher Survey Questions

Qualitative Questions for Teachers

1. In what ways do you feel that the drawing component in the LEAF tree ID lesson impacted your students' knowledge of tree structure and species?

2. Did you observe any differences in the level of student engagement and concentration in the tree ID activity with the added drawing element? If yes, please describe:

3. What evidence, if any, did you see of increased observation and perception skills in students who participated in the drawing component?