

Title

The Scientific Method and the Creative Process: Implications for the K-6 Classroom

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Abstract

Science and the arts might seem very different, but the processes that both fields use are very similar. The scientific method is a way to explore a problem, form and test a hypothesis, and answer questions. The creative process creates, interprets, and expresses art. Inquiry is at the heart of both of these methods. The purpose of this article is to show how the arts and sciences can be taught together by using their similar processes which might improve student engagement. Arts-integration research from the literature is discussed. Both the scientific method and the creative process are described through examples of scientists and artists in different areas. Four, detailed learning activities are presented that demonstrate how both the scientific method and the creative process can be implemented into the classroom. Two activities are appropriate for elementary-aged children, grades K-3, while the other activities are geared for intermediate school-aged students, grades 4-6. All activities are written where either a science educator or arts educator could utilize the lessons.

Introduction

Science and the arts often seem far apart from one another, but, in reality, the method scientists use to test hypotheses is quite similar to the process an artist experiences when creating art. Bronowski (1965) stated, "There is likeness between the creative acts of the mind in art and in science" (p. 7). In science, the scientific method is used to test hypotheses, answer questions, and formulate theories. In the arts, the creative process is employed to create new works, interpret an existing work, and/or find new forms of expressing art. At the heart of both processes is inquiry. Both are most often taught separately. How might understanding the way the two processes connect, inform, and motivate students help to pursue learning in both? In her book, *Creating Meaning Through Literature and the Arts*, Cornett (2011) states, "Arts-based learning is all about creative thinking, which is all about coordinating higher order thinking processes to solve problems" (p.1). Both the scientific method and the creative process utilize creative problem solving techniques as well as facilitate higher order thinking skills. Both of these skills are vital to student success in school and in the workplace (Cornett, 2011, p. 5-6).

The purpose of this article is to demonstrate how science and the arts can be taught simultaneously by incorporating their similar approaches to increase student

engagement. The authors will investigate the scientific method and the creative process. Both processes will be defined and described in detail. Next, the authors will discuss the two processes and explore ways in which both utilize similar methods and techniques. Finally, the authors will suggest ways in which science and the arts might be joined within the K-6 classroom using the scientific method and creative process.

What Research Suggests

Learning Through the Arts (LTTA) is a longitudinal national study that began in 1999. The premise was to assign a group of schools to become LTTA schools. The researchers wrote a curriculum focused on arts integration. The experimental schools integrated arts regularly into the curriculum while the control schools continued their traditional curriculum. The researchers found that students enrolled at the experimental schools were more engaged in academic and other school activities than those in the control schools (Smithrim & Upitis, 2005). Many teachers will agree that an engaged student not only enjoys learning, but will retain more information as well. Interviews and surveys of LTTA students, teachers, parents, and administrators referred repeatedly to the “cognitive, physical, emotional, and social benefits of learning in and through the arts” (Smithrim & Upitis, 2005, p. 120). A teacher stated, “The dramatics—being able to act out the life cycles of the frog and butterfly—the children really learned those lessons—experiencing it physically made the difference” (Smithrim & Upitis, 2005, p. 120). Arts integrated activities have the ability to reach all learning modalities (aural, visual, and kinesthetic). When students are physically and mentally engaged in an activity, they are more likely to retain the information.

In 2005, Peter Gamwell conducted a research study examining how students created meaning through developmental writing and performance projects (p. 359). He believed the arts could provide “an important vehicle for students to explore their learning” (Gamwell, 2005, p. 363). To test this theory, the researcher had two main approaches: structured activities and student art projects. Students were encouraged to exhibit their understanding of academic material through various art forms (Gamwell, 2005). For example, during a structured activity, a student might create movement or dramatic interpretations of a short story or poem. The student art projects allowed the students to choose a short classical composition to interpret in any way, using “personal strengths and interests” (Gamwell, 2005, p. 364). While there was more freedom of how to create individual interpretations during the student art projects, both the student art projects and the structured activities utilized arts instruction.

Gamwell’s research “suggest[s] that arts-based learning experiences can contribute to children’s engagement in their learning, critical thinking and problem-solving skills, empathy and tolerance for others, ability to work collaboratively in groups, and self-confidence” (Gamwell, 2005, p. 363). While Gamwell considers the arts a “vehicle” for academic learning, he also believes a teacher can take an arts-based lesson and create a fully integrated lesson where students are not only learning through the art form, but learning about the art form as well.

The Scientific Method

Science is based on evidence that is observable and measurable. Scientists explore questions, test hypotheses, and make rational conclusions using the scientific method

(*Scientific Method*, 1999). The first step is to define a problem. The problem is a question to be answered. Next, the scientist forms a hypothesis—an educated prediction of the outcome. In order to make this prediction, one must conduct research to discover what is already known. Just as an artist studies subjects or thinks imaginatively about a process, a scientist has to gather information and creatively design a way to solve the problem. Bronowski (1965) describes “discoveries of science” and “works of art” as “the act of creation, in which an original thought is born” (p. 19). The third step in the scientific method is to conduct experiments and make observations. Once the scientist has conducted the experiment(s), he or she must analyze the data and formulate conclusions. The scientist then shares the results, either with other scientists in a lab, the publication of a paper, or a presentation at a conference, and receives feedback (*Scientific Method*, 1999). Much like an artist might adjust or rehearse his or her creation, the scientist then returns to the hypothesis, makes revisions, and begins the experimental process again.

Specific examples from scientific history demonstrate how scientists used the scientific method. Consider the work of Nobel Laureate Henrik Dam and his discovery of Vitamin K (ca. 1928-1935). While studying the effects of cholesterol on chicks’ diets, the chicks were hemorrhaging fatally. Dam sought to find out the cause of the problem using the scientific method. He eliminated several hypotheses through his and others’ experiments. Lack of cholesterol was ruled out as the cause, because chicks can synthesize their own cholesterol, and even the chicks given cholesterol were hemorrhaging. Dam tried giving them more fat thinking that the low amount of fat in the diet was causing the problem. Additional fats did not solve the problem. Soon, other food items were added to the diet to see if any caused the hemorrhaging to stop. It was found that green leaves and hog liver stopped the hemorrhaging. There had to be “something” in these materials that prevented the chicks from hemorrhaging. Vitamin K was isolated as the chemical needed to keep chicks from bleeding to death. After Dam published his results, others confirmed his findings and worked alongside him to discover more about this new vitamin (Dam). As often is the case with the scientific method, discoveries lead to more discoveries.

During the nineteenth century, scientists were beginning to understand chemical elements and how they could be organized. Consistent atomic weights were gathered, namely by Stanislao Cannizzaro, and new elements were being discovered. As scientists strived to discover the properties of different elements, William Prout’s idea that all elements are composites of hydrogen was being questioned (Scerri, 2006). Dimitri Mendeleev saw the problem of how to organize the chemical elements in a way that reflected their periodicity. He initially hypothesized that elements could be grouped according to how many bonds an element forms with hydrogen (Scerri, 2006). He soon discovered that, though this gave a general organization within groups of elements, it did not give a way to order the groups themselves. Mendeleev knew there had to be another property connecting all the chemical elements in a systematic way. Next, he hypothesized that the elements could be grouped horizontally according to atomic weight (much like the modern Periodic Table of Elements). Creating groups and sub-groups based upon atomic weight and elemental properties, he left “blanks” in his table where he thought an element should be located, but at this point in history, there was no known element to fit there. Mendeleev published his results (his organization of elements based upon atomic weight and properties) and predictions. He gets credit for being the “Father of the

Periodic Table” because he predicted elements that had not yet been discovered (Scerri, 2006). Mendeleev approached the problem with his initial hypothesis, but had to make reforms when his idea about elements bonding with hydrogen did not fully reveal a way to organize all of the elements. Much like an artist receives feedback from peers, Mendeleev’s creative solution of organizing by atomic weights and properties needed to be confirmed by his peers. The scientific method provided Mendeleev an approach in constructing a periodic table of elements that largely resembles our modern one.

Dam and Mendeleev faced different problems that required different approaches toward solution. While Dam ran experiments to figure out why the chicks were hemorrhaging, Mendeleev proposed a plan that not only explained proper element organization, but he also made predictions. Though Mendeleev did not conduct experiments in a lab, when he proposed the existence of elements that had not yet been discovered, he was experimenting with a new plan of element organization. Would these unknown elements be discovered? Would they have the atomic weights and properties that he had proposed? Bronowski (1958) discusses the idea that in science it is not until after a new organization system is confirmed that it can be labeled as a “success.” It was not until after Mendeleev’s publication of his new plan that he was proven correct by other scientific discoveries. Though these two approaches of Dam and Mendeleev were different, they both required creative thinking and problem solving. The scientific method outlines a basic plan for scientists to follow when answering a question: define the problem; form a hypothesis; experiment and make observations; analyze data and make conclusions; and publish, receive feedback, and revise as needed.

Proceeding through the steps of the scientific method may take a matter of minutes or of years, based on the problem being explored. An individual does not have to be a scientist to use the scientific method. The method just described is used everyday to answer a variety of questions, even simple ones: How can I improve my car’s gas mileage? What would be the best material to use in building a birdhouse? Individuals ask and answer questions, using the scientific method for common everyday problems.

The Creative Process

The creative process is similar to the scientific method just described. An artist has an idea or problem he or she wishes to solve and express. Providing a concrete definition is difficult as artists and performers have varying processes in creating art and differing mediums through which the “solution” is expressed. While the scientist begins by writing hypotheses, the artist hypothesizes through his or her initial creation, experimenting with the chosen medium and gathering research to enhance understanding of the problem or question. Once the artist has completed the initial creation, he or she will revise, rehearse, and make adjustments as necessary. For example, a composer will add and take away harmonies until he or she has achieved the desired sound. Next, the artist shares his or her artwork and receives feedback, much like the conclusion of a scientific experiment. When progressing through the scientific method, individuals examine their results, make adjustments and conduct the experiment again. An artist’s process is very similar. For example, a new musical theater production may have new music deleted and/or added, based on the audience reaction during a preview performance. The preview performances are their “results,” and the changes made to the

script or musical score are made to improve the quality of the show. The theater company will rehearse (experiment), then perform the musical again with the hope of an improved audience reaction.

Consider how the creative process is used as actors prepare to create a character onstage. Each individual actor's interpretation of the character will differ, but each will basically follow the same creative process. The Stanislavski System guides an actor into the "character's complete world" (Barton, 2003, p. 112). First, the actor must ask the questions: Who is this character? How do the characters they fit into the play? An actor researches the play—the plot, time period, location, culture, etc. Next the actor researches the historical or contemporary context that surrounds the play. The actor is much like an anthropologist. He or she must study the world of the play and the individual character that interacts with that world and the people/society within it. After research and observation, the actor is ready to play and experiment with the role.

According to the Stanislavski System, an actor must understand the "strong motives [that] drive the character" and interpret these intentions into physical actions (Barton, 2003, p. 113). This step takes place during rehearsals. Guided by the director, the actor is free to explore and embody the character. The conclusion is the performance. No two performances are the same; each individual creates a unique interpretation of the character. The actor continually reflects and improves throughout rehearsal, and, once the production is open, each performance. A scientist does the same by analyzing results and tweaking an experiment. Moore (1965) writes,

The Stanislavski System is the science of theater art. As science it does not stand still; being a science, it has unlimited possibilities for experiment and discoveries. Elements of the System have continually evolved and been tested, as new chemicals are tested in a laboratory. (p. 7-8)

Just as problem solving in science requires multiple revisions and inventive thinking, the theater arts compel the artist to continually make adjustments in order to create one's art.

Another example comes from music. When Beethoven composed music, he did not simply create a composition, perform it and leave it alone. He wrestled with his compositions. Among the vast musical output during his lifetime, Beethoven wrote only one opera, *Fidelio*. After its premiere, Beethoven reworked it, discarded some music and added new music. For Beethoven, his compositions were constant works in progress, but his problem was composing an opera to suit his personal compositional standards. He experimented with his composition with the hope that performance would yield the results he hoped. With each premiere of the opera, Beethoven revised his opera until he felt the creative process was complete.

Both the scientific method and creative process are cyclical and similar to each other. There is a question or problem, followed by hypotheses, and then experiments are conducted in an effort to answer or express an understanding of the problem or question. The researcher, or artist/performer, then analyzes the results, which leads to more questions bringing the artist or scientist back to the beginning of the cycle.

As we can see, the two processes of inquiry have much in common. Throughout both processes, the artist and the scientist must embrace the possibility, as Eisner (2002) suggests, that outcome variability is acceptable, that there is "more than one solution to a

problem” (p. 196). In order to stay open to possibilities, imagination is critical. The idea of using one’s imagination to approach a problem is important to teach in the science classroom. Eisner states, “. . . this is what scientists and artists do; they perceive what is, but imagine what might be, and then use their knowledge, their technical skills, and their sensibilities to pursue what they have imagined” (Eisner, 2002, p. 199). Not only does teaching students to think creatively help to engage them in the academic classroom, it also can serve them well in their future careers. According to the Partnership for 21st Century Skills, “Many of the fastest-growing jobs and emerging industries rely on workers’ creative capacity—the ability to think unconventionally, question the herd, imagine new scenarios and produce astonishing work” (2008). Providing students opportunities for creative thinking and problem solving is essential to students’ long-term success.

Suggestions for the Classroom

The next section provides learning activities (kindergarten through intermediate grades) that utilize both the creative process and the scientific method. Teaching arts integrated activities often requires additional preparation time for the classroom teacher but the benefits of arts integrated instruction are worth the time investment. According to Rabkin and Redmond,

Students invest emotionally in arts-integrated classrooms. Their thinking capacities grow; they work more diligently, and learn from each other. In arts-integrated rooms, students often work in groups and turn classrooms into learning communities. (2005)

Arts integration in the science classroom can easily occur in all grades, but the authors have selected activities for elementary and intermediate grades in order to narrow the article’s focus.

Kindergarten-3rd Grade

Activity 1: How Plants Grow

In her book, *Artful Teaching*, Patty Yancey (2010) describes a science and dance lesson she taught for kindergarten that utilizes the scientific method (p. 143-44). The students planted a seed and recorded its growth in a daily art journal. After several observations, the teacher asked students to close their eyes and envision the seed growing and changing. The students were coached to begin moving slowly to explore the space around them. They opened their eyes to see the different forms their classmates had taken. Finally, the teacher led a discussion about the students’ movement decisions. In a later lesson, Yancey divided the students into small groups and assigned each group a different environmental condition (varying climates, rocky soil, etc.), and the groups began to move in time to represent their specific growing conditions—eight counts to grow from a seed to a plant, eight counts frozen in place, and eight counts to melt to the ground. The next step was to put these 24 counts to music appropriate for the performance (Yancey, 2010). For example, *Vers La Vie Nouvelle* by Nadia Boulanger begins softly and gradually grows in volume and intensity.

Yancey’s lesson example can be expanded to include more of the scientific

method. For example, the teacher can have students create predictions (hypotheses) about what will happen with their seed (e.g. height, growth rate, appearance, etc.), then have them compare the actual results to their original hypotheses.

To create opportunities for higher order thinking, the teacher can ask students to listen to excerpts from each of the four movements in Antonio Vivaldi's *The Four Seasons*. After each musical excerpt, students can describe what type of climate and/or soil condition the movement might represent. This allows students to use higher order thinking as they describe the mood of a song and describe why they believe it represents a specific growing condition. Students are encouraged to use known scientific and musical terminology to describe their interpretation of each musical movement.

The student will learn about the process of a seed becoming a plant and how environmental conditions affect its growth while learning the basics of dance performance. This lesson allows for teaching young students about plant growth using the scientific method and the creative process to interpret their results. Students are also learning about beat, tempo, and musical expression through the lesson's movement activity.

Activity 2: Carnivores, Herbivores, and Omnivores

The following activity will integrate creative drama concepts in a lesson about the distinction among carnivores, herbivores, and omnivore animals. The teacher first provides pictures of several different animals within each group (carnivore, herbivore, omnivore) and asks students to compare and contrast the animals' physical traits. After the teacher presents the definition of each group, he or she asks students to predict which animals fit into each category. (For example, a student might place the lion in the carnivore category because of its sharp teeth.) Next, the teacher has students brainstorm about the characteristics of each eating group after the lesson is introduced. Students can cite animal examples of each type to further illustrate carnivores, herbivores, and omnivores. With the help of the teacher, students can categorize various animals by habitat type (for example: jungle, ocean, desert, etc.). Each category should have several carnivores, herbivores, and omnivores. The teacher then plays an adaptation of Viola Spolin's theater game titled "New York (Lemonade)" (Spolin, 1986). The teacher divides the class into two groups that stand in parallel lines across from each other. The first team decides on an animal from one of the habitat categories and begins to walk toward the second team while the following dialog takes place:

Team 1: Here we come.

Team 2: Where From?

Team 1: (Chooses one of the habitat type)

Team 2: What's for dinner?

Team 1: Something splendid!

Team 2: Give us some!

Team 1 gets as close to Team 2 as desired and acts out the chosen animal while team 2 tries to identify the animal and whether it is a carnivore, herbivore, or omnivore. Once identified, Team 1 runs to home base and those captured by Team 2 join their team. After an equal number of turns by each team, the team with the larger number of students wins.

This theater game reinforces the scientific learning as well as make students aware of the “possibilities of nonverbal communication,” an important aspect of theater training (Spolin, 1986, p. 94).

At the end of the unit, the teacher can have students create their own animals and decide what category they fall into based on physical features. These activities use creative drama and visual art as a vehicle for remembering and understanding the definitions of carnivore, herbivore, and omnivore. While this activity does not directly utilize the scientific method, it does utilize higher order thinking through predictions based on prior knowledge as well as encourages student inquiry.

Intermediate Grades (4-6)

Activity 1: Bonding Between Elements

The basic concepts of metals, nonmetals, and bonding among elements can be taught to students using a simple activity involving the Periodic Table of Elements. The teacher explains the two main categories of elements: metals and nonmetals. Students quickly brainstorm about certain known characteristics of metals and nonmetals (e.g. shiny vs. dull, “clangy” sound vs. muted sound, conductive vs. nonconductive). The left side of the Periodic Table lists the metals while the nonmetals are found on the right side. Students can construct an experiment that observes the various sounds created by various metals and nonmetals. They can observe what sounds are made and compare them to unpitched percussion instruments, such as the cowbell and triangle (metals), and the wood block and clave (nonmetal). The teacher might consider having the class create a composition using the sounds found in the metals and nonmetals studied.

Next, the teacher passes out a card to each student. Each card will have an element on one side. Students will classify themselves as a metal or a nonmetal by using a Periodic Table and stand on the left (metal) or right (nonmetal) side of the room. A good illustration would be to have more “metal” students; it is a good way to illustrate that there are more metals on the Periodic Table. Each student will have an unpitched percussion instrument (metal or nonmetal). On the other side of the card, a compound should be listed that has the element in it. For example, if the card has “sodium (Na)” on one side of the card, the other side could have “sodium chloride (NaCl)” on the other side. Another example is “oxygen (O)” on one side, then “carbon dioxide (CO₂)” on the other side. Each student can find his or her partner(s). Through observation of what types of elements are bonding together, some basic rules about bonding can be hypothesized by the students. Some “rules” that students can observe through this activity: 1) Metals and nonmetals can bond to each other; 2) Nonmetals can bond together; 3) Metals never (rarely) bond together. Once students have found their partners to create their compounds, they will play with various combinations of sounds and rhythms produced by their instruments and create a rhythmic pattern that will represent their compound’s name. For example, the sodium chloride (NaCl) group will find one sodium (metal) and one chlorine (nonmetal) to form their group. Students will use their instruments (one metal and one nonmetal) to create a rhythmic pattern to represent their compound. Figure 1.1. provides an example of a rhythmic pattern using the sodium chloride compound.



Figure 1.1. Sodium Chloride rhythmic pattern example

Just as students use steps from the scientific method to make observations regarding their Periodic Table elements, they will proceed through parts of the creative process to compose a rhythmic pattern that is representative of their assigned compound element. This activity encourages student engagement. Students think about what they already know about metals and nonmetals and build upon that knowledge through observations and collaboration. Once students make some inferences about bonding among elements, they use their imaginations in creating the musical pattern to help remember the various compounds.

Activity 2: Solubility and Miscibility

In Kohl and Potter's *Science Arts: Discovering Science Through Art Experiences*, they describe several visual art activities that illustrate solubility and miscibility principles (Kohl & Potter, 1993). These activities can be implemented with the scientific method and help students through the creative process. Beginning with paint mixed with water and paint with oil, the teacher instructs students to paint using the water paint first. Then students observe what happens when oil paint spots are dropped on top of the water paint (Kohl & Potter, 1993). The teacher can introduce the terms, "solubility" (ability of a substance to dissolve in another substance), "density" (ratio of mass to volume of a substance), and "miscibility" (ability of substances to mix together). Water and oil are immiscible, because oil and water are insoluble. Since, water paint is denser, it stays on the bottom when oil paint is dropped on top of water paint (Kohl & Potter, 1993). Next, students can observe what happens when food coloring is added to layers of oil and water in one container. Because food coloring will push through the oil layer until it diffuses throughout the water layer, the miscibility concept is illustrated (Kohl & Potter, 1993). Water and food coloring are miscible while oil and food coloring are immiscible. Using these illustrated concepts, students working in groups can then make observations about what happens when oil, water, soap or detergent (e.g. dishwashing liquid), food coloring, and milk are added to each other in different combinations (Kohl & Potter, 1993.) The teacher can encourage students to manipulate the materials as needed (e.g. shaking the container) and to create some various works of art. Students can form hypotheses in explaining some of their observations. Then they can design an experiment to confirm or disprove them. For example, one group might hypothesize that detergent is miscible with water and immiscible with oil. The students can then observe what happens when detergent is added to oil and mixed together. Since detergent and oil are actually miscible, they will stay mixed and not form separate layers. Finally, students can share their findings and their created art with each other. The teacher can lead the class in summarizing the lessons learned. Some major points that can result from the students experimenting and teacher-led discussion include: 1) If soap is shaken with oil and water, small oil globules will be suspended in the water. This is called an emulsion. "The soap has simply broken the oil into smaller balls of oil which are suspended throughout the

water but are still separate from the water (Kohl & Potter, p. 36). 2) Milk is another example of an emulsion; its ingredients, water and fat, do not mix. 3) Detergent is a surfactant, because it can mix with both water and oil. (4) “When detergent is dropped into milk, one end of the detergent molecule attaches to fat in the milk and the other end of the detergent molecule attaches to the water which causes a boiling effect” (Kohl & Potter, 1993, p. 98). This “boiling effect” is apparent when detergent is dropped onto the food coloring drops that are sitting on top of the milk.

Students will create visual works of art while following the scientific method. As they are engaged in the activity of creating artwork, they can observe the behaviors of liquids and begin forming explanations. Students use their imagination and work as a team during the experimenting and drawing conclusions sections of the lesson.

Conclusion

Utilizing arts integration techniques in the science classroom can benefit the students in learning both artistic and scientific concepts, because there is overlap between the creative process and the scientific method. Eisner (2002) states, “Artistic activity is a form of inquiry that depends on qualitative forms of intelligence” (p. 232). Bringing the scientific method alive through a creative process illustrates how real-world problem solving is done. Eisner cites that intrinsic satisfaction matters and being flexible in one’s work is important (p. 202, 205). Not only can students learn certain musical and scientific knowledge, but they can learn important life lessons as well. According to Rabkin and Redmond,

When the arts are an interdisciplinary partner with other subjects, they generate conditions that cognitive scientists and education researchers say are ideal for learning. The curriculum becomes more hands-on and project-based. It offers students authentic and challenging intellectual work. Learning in all subjects becomes visible through the arts, and student work becomes the basis of thoughtful assessment (2005).

Though an educator might feel out of his or her comfort zone when teaching outside of the specialized field, using the scientific method and creative process together is worthwhile. The authors encourage science teachers and music, drama, or visual arts teachers to collaborate and create a fully integrated lesson that can be both engaging to the student as well as demonstrative of both processes.

References

- Barton, R. (2003). *Acting onstage and off*, 3rd ed. Belmont, CA: Wadsworth/Thomson Learning.
- Bronowski, J. (1965). *Science and human values*, 2nd ed. New York, NY: Harper & Row Publishers.
- Bronowski, J. (1958). *The common sense of science*. Cambridge, Massachusetts: Harvard University Press.
- Cornett, C. (2011). *Creating meaning through literature and the arts: Arts integration for classroom teachers*, 4th ed. Boston, MA: Pearson Education, Inc.
- Dam, H. (n.d.). *The discovery of vitamin K, its biological functions and therapeutical application*. Retrieved November 4, 2011 http://www.nobelprize.org/nobel_prizes/medicine/laureates/1943/dam-lecture.html#
- Eisner, E. W. (2002). *The arts and the creation of mind*. New Haven & London: Yale University Press.
- Gamwell, P. (2005). Intermediate students' experiences with an arts-based unit: An action research. *Canadian Journal of Education*. 28/3, 359-83.
- Kohl, M. & Potter, J. (1993). *Science arts: Discovering science through art experiences*. Bellingham, WA: Bright Ring Publishing.
- Moore, S. (1965). *The Stanislavski system*. New York: The Viking Press.
- Partnership for 21st Century Skills. (2008). *21st Century skills, education, and competitiveness: A resource and policy guide*. Retrieved February 2, 2013 http://www.p21.org/storage/documents/21st_century_skills_education_and_competitiveness_guide.pdf.
- Rabkin, N., & Redmond, R. (2005). Arts education: Not all is created equal. *Education Week*, 24(31), 46-47.

Scerri, E. R. (2006). *The periodic table: its story and its significance*. New York, NY: Oxford University Press.

Scientific Method. Films Media Group, 1999. *Films On Demand*. Flash, <http://digital.films.com.ezproxy2.library.arizona.edu/PortalPlaylists.aspx?aid=9778&xtid=8428>. (accessed October, 26 2010).

Smithrim, K. & Upitis, R. (2005). "Learning through the arts: lessons of engagement," *Canadian Journal of Education*, 28(1), 109-127.

Spolin, V. (1986). *Theater games for the classroom: A teacher's handbook*. Evanston, IL: Northwestern University Press.

Yancey, P. (2010). Learning and teaching dance in the elementary classroom. In David M. Donahue and Jennifer Stuart (Ed.), *Artful teaching: integrating the arts for understanding across the curriculum, K-8* (pp. 138-147). New York: Teachers College.