SCIENTIFIC NOTATION WATERCOLOR

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Research suggests that students who learn in the arts are more likely to succeed in school because of increased engagement, motivation, and persistence (Asbury & Rich 2008; Burnaford 2007; Deasy 2002; Hetland et al. 2007).

By nearly every indicator studied, a student from a low-socioeconomic (SES) background with a high-arts educational experience significantly outperformed peers from a low-arts, low-SES background, closing (and in some cases eliminating) the gap that often appears between low-SES students and their more advantaged peers (O'Brien, 2012). Schools where teachers implement arts-integrated curriculum have been found to increase test scores, with scores increasing for every additional unit of arts integrated into the curriculum (Burnaford, Scripp, & Paradis 2012).

The purpose of this paper is to describe visual literacy and an adapted version of Visual Thinking Strategy (VTS) and its value to enhance students' understanding of scientific notation. An example of a middle school VTS, art-integrated lesson will be described as well as reflections of a secondary mathematics preservice teacher (author 1) and middle school mathematics teacher (author 2) about what they learned about students' conceptual development.

ART INTEGRATION

The John F. Kennedy Center defines arts integration as "an approach to teaching in which students construct and demonstrate understanding through an art form" (http://en.wikipedia.org/wiki/Arts_ingration.). The idea of arts-integration instruction has been part of some curriculums since progressive schooling was established in the 20th century (Purnell 2004). Arts integration, provides an avenue for students to make known their thinking more clearly than during traditional teaching (Burnaford 2007). Cognitive growth is a result of arts integration. This is because when students interact with the arts during instruction, their attention is attracted, which in turn, enhances cognitive development. "Art-centered integrated learning enables learners to see mathematics in a fuller way-to recognize the logic, imagination, and aesthetic sensibility that underlie the discipline" (Cossey & Donahue in Marshall & Donahue 2014, p. 140). Art integration provides an opportunity for students "to experience the ultimate goal of educators: to work hard and to have fun" (Dantrassy, 2012 p. 15)

When the arts are used to create a frame of reference for learning, students can make meaningful connections to one another, to themselves, to their lived world, and to other content areas (Fiske 1999; Hetland et al 2007; Stevenson & Deasy 2005). Because they become "agents of their own learning," students are often more willing to take responsibility for and give direction to their own learning experiences (Deasy & Stevenson 2005). As students experiment with different art forms and processes, they learn to take risks through exploration and to develop flexible thinking skills, envisioning from different vantage points and responding to new possibilities in the creative process (Eisner 2002; Hetland et al. 2007).

Students have the ability to express their ideas in multiple ways (Burnaford 2007; Smithrim & Upitis 2005). Arts integrated teaching also helps to turn class goals into a reality through motivational and hands-on learning experiences

(Burnaford 2007). Students may be more motivated through arts integrated teaching because they care more about the audience who will see their finished products (Rabkin & Redmon 2006). Students who learn through art-integrated instruction have been characterized by an increase in motivation to learn and many enjoyed coming to school, working hard, and being successful (Oddleifson 1994; Smithrim & Upitis 2005).

VISUAL THINKING STRATEGY

Robin Ward (2011), a mathematics educator encourages students to look at their surroundings through a mathematical lens. Likewise, asking students to look and respond to art is a excellent way to start a mathematics lesson. This is because art has the power to stop us. It is a human inclination to look. “We cannot expect students to understand that which they do not notice” (Serafini 2014, p. 32).

Abigail Housen (2001-2002), a cognitive psychologist, has researched people’s thought process when they view art. From this work, Visual Thinking Strategies (VTS) have been developed as a method facilitated by teacher-directed discussions of art images (see Yenawine 2013). It is a powerful way that teachers can use to provide students with practice of thinking skills sought by Common Core Standards (2012). Through VTS’ questioning process, students are encouraged and empowered to voice their own ideas, while respecting and learning from their classmates. The VTS method (co-developed by Abigail House and Philip Yenawine) is a copyrighted strategy that uses specific questions for discussions:

1. What is going on in this picture?
2. What do you see that makes you say that?

3. What more can we find?

Mindful and respectful of this method, the adapted version includes the types of questions in Question/Answer Relationships (QARs) advanced by Raphael (1982, 1986). In QARs, there are four levels of questions: "Right There" (factual level), "Think and Search" (inferential level), "Author and You" (the viewer needs to understand the author's/artist's message), and "Own My Own" (prior knowledge of the reader/viewer).

THE SETTING

The middle school where this lesson took place is in an urban area in the Midwest. The student population of 300 is diverse: 65% African-American, 18% Hispanic, 10% Caucasian, and 4% mixed races. Most of the students (95%) are eligible for free or reduced lunch. Only 23% of students are proficient in mathematics based on standardized test results.

THE GRANT

As part of a grant entitled, "Thinking Like an Artist in Core Curriculum Subjects" funded by the U. S. Department of Education, pairs of secondary mathematics preservice teachers working with a middle school mathematics teacher (author 2), an art-integration consultant, and a mathematics consultant, planned art-integrated mathematics lessons each Friday for 20 weeks during the 2015-2016 school year for middle school students. For each lesson, a common core mathematics goal and a national art standard were the basis for the lesson. In this case, CCSS.MATH.CONTENT.8.EE.A.3, CCSS.MATH.CONTENT.8.EE.A.4 and VA:Cr1.1.3a "Elaborate on an imaginative idea" were the focus.

SCIENTIFIC NOTATION

Scientific notation is the way that scientists easily handle very large or small numbers. Archimedes, who was born in 287 BC and studied in the Egyptian city of Alexandria, the center of the scientific world at the time, was asked by King Gelon to calculate the number of grains in the universe. He estimated that the number was 1 followed by 63 zeroes. Of course, there is no way to make this measurement, but this story suggests the interest in enormous and tiny numbers reaches back to ancient times. Today, scientific notation is used daily by astronomers who measure distances in space to physicists who measure the speed of light, to chemists who measure atomic particles.

CONTEXT FOR THE WATERCOLOR NEBULA ART-INTEGRATED LESSON

Despite the value of scientific notation, Author 2 (Kathy, the middle school teacher) has found that this concept is difficult for students because tiny numbers or enormous numbers are hard to imagine. One sample question on a standardized test regarding scientific notation reads, "The average distance from Earth to the Moon is approximately 384,4000,000 meters. What is the average distance, in kilometers, from Earth to the Moon written in scientific notation?" Specifically, Author 2 has observed that it is difficult for her students to understand when they are taught to move the decimals to count the numbers needed for the exponent, without meaning attached. What follows here is the lesson Author 2 taught about exponents and scientific notation, as well as a previous art-integrated lesson Author 1 (Kyle, a secondary mathematics preservice teacher) taught about exponents. Then the ensuing art-integrated watercolor Nebula mathematics lesson will be described.

The purpose of the art-integrated, watercolor Nebula lesson was to offer students a topic to spark their wonder and imagination-hence their motivation-to put more time and thought into understanding this important mathematical concept.

According to Author 2, scientific notation and exponents are topics taught to eighth graders. The lesson was taught using the chapter entitled, "Growing, Growing, Growing" in the *Connected Mathematics* series (Prentice Hall, 2006) and students worked cooperatively to solve investigations. In the lesson about exponents, students were given a story problem and asked to make a table, graph, and equation to show the relationship. Scientific notation was taught as a mini-lesson in one of Author 2's learning centers. It was taught through direct instruction and an integral part of the exponent unit of study. Students were encouraged to notice patterns that were the basis of exponents. Students looked at specific examples and then were required to generalize their findings. Groups of students were enlisted to explain their thinking for each section of a problem and then to summarize the rules. The concepts of adding, subtracting, multiplying, and dividing were examined through investigations that compared equations where growth was addition in a linear equation versus multiplication in an exponential equation. Exponential decay relationship was examined through a story problem that required students to consider patterns.

Author 1 built on this lesson in a Friday art-integrated lesson entitled, "Positive Exponents in Pop Arts" (posted May 2, 2016 on riverrougearts.com). The enduring understanding goal of the lesson was for students to develop an understanding of how to apply the properties of positive integer exponents to generate equivalent numerical expressions by using visual representations. During this lesson, students applied their understanding of the properties of integer exponents to generate equivalent numerical expressions. After exploring Pop Art work by Andy Warhol that used repeating images to create a whole art piece, students applied their understanding by recreating and then developing their own designs that used repeating images to represent exponential expressions. After the students finished this activity, they analyzed their own artwork to interpret equivalent numerical expressions and to evaluate their views on the aspects of Pop Art with an exit ticket.

THE WATERCOLOR NEBULA ART-INTEGRATED LESSON

Author 1 decided to base the lesson on large numbers such as those that describe the size of Nebula. Author 1 found artwork relating to this topic by Googling the words "Nebula" and "art" and scrolled down to "Images." Author 1 learned that some artists had used watercolor to paint Nebula; so Author 1 found watercolors by a variety of artists including Claude Monet and M. W. Turner (an African-American artist) as examples of watercolor painting techniques to show students. Author 1 then showed beautiful images of watercolor Nebula to engage students' imagination and wonder of these vast objects in the universe. The immense size of each Nebula was given. Author 1 asked the following questions when showing a power point of each Nebula:

1. What do you see? (literal level)
2. Why did the artist paint using this method? (Inferential level)
3. Why did the artist blend colors to represent a Nebula? (Understand artist

message)

4. What could we do to write a number to represent something that is so huge? (Prior knowledge-applied level).

Author 1 provided an example of how the scientific notation could be use to indicate the immense size of Nebula. Then, Author 1 informed the students that they could use watercolors to create images without distinct forms such as Nebula. After creating their paintings, students were told that they would measure the length of their image in centimeters. A single centimeter would equal one light year. Students were then to convert this number into miles, using the scale factor conversion of 1 light year = 5.88 miles. Once converted, students were to work with a partner to multiply, divide, add, and subtract, the dimensions of both their Nebula together (for practice, although astrophysicists do not actually do this). After this explanation, students were given watercolors, brushes and watercolor paper. They mixed colors and made hues to make watercolor Nebula. Students made their calculations. Volunteers shared their paintings and explained their method for finding the dimensions with the class.

ASSESSMENT

As educators, we worry about “teaching that did not stick” (Yenawine 2014, p. 2). This lesson did not have a “tag on art project” (Tunks & Moseley Grady 2003, p. 63). Art was an integral part. Assessment here afforded the authors a window into students’ understanding. Students were shown a rubric before they began to work that included consideration of their mathematics processing and their painting efforts (see **Fig. 1**). For example, a category focused on correct calculations for the operations and scientific notation; while an art category measured the design features such as multiple colors, hues, and blending.

Fig. 1. The rubric

Math Goals – Scientific Watercolor

We should be able to meet all of these statements for the activity when we are finished. If we can, then we know that we have made great artwork that depicts math!

Category	4	3	2	1
Neatness and Attractiveness	Exceptionally well designed, neat, and attractive.	Neat and relatively attractive.	Design is properly utilized, but the design does not include enough color.	Appears messy and "thrown together" in a hurry.
Scientific Notation	All calculations for the operations are correct, in scientific notation, and work was shown.	All calculations for the operations are correct and in scientific notation.	Calculations for the operations are incorrect because of computation error.	Calculations for the operations are incorrect because of incorrect measuring or not in scientific notation.
Color Variation	The design features multiple colors or hues of a color.			The design does not feature a variety of colors or hues of color.
Blending Colors	The design features a blending of colors.			The design does not feature a blending of colors or as distinct separation.

As students were painting and calculating their comments about their thinking were noted. During this lesson student learning became visible. This lesson helped to answer the question, "What is the process of learning through art viewing and painting?"

STUDENT WORK

The authors learned about students as thinkers and artists through this lesson. Author 1 noted that students' ability to represent the abstract image of light as well as the fluctuating image of water (see **Fig. 2**). In each painting, the students were able to capture these images using different color blends or light techniques. This was the idea that Author 1 wanted students to understand: to use materials to create an image that does not have distinct form. Author 1 also thought that students' use of colors showed depth (see **Fig. 3**). For example, Author 1 felt that one student's painting, went above the requirements since movement and depth was created in her work. She was able to give the Nebula shape and to create a pattern that indicated its rotation. Her technique allowed her the ability to blend colors very well and meet the artistic goal with a variety of colors and hues (see **Fig. 4**).

Fig. 2. Watercolor Nebula showing abstract light and fluctuating image of water.

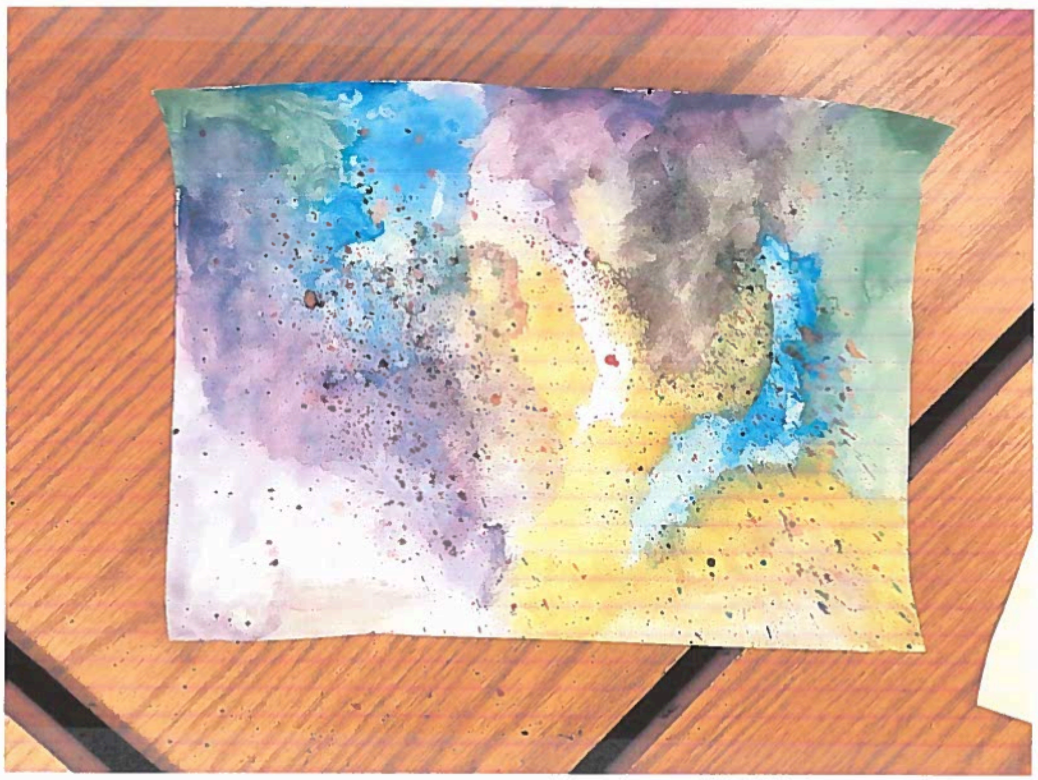


Fig. 3. Watercolor Nebula with colors that show depth.

Fig. 4. Watercolor Nebula with watercolor that shows movement and depth.

Author 2 (Kathy, the middle school mathematics teacher) reported that when students were asked to repeat their calculations several weeks later after the watercolor Nebula art-integrated lesson, they were able to write numbers in scientific notation and to convert them to standard form. However, they had to be reminded how to add, subtract, multiply, and divide scientific notation. Students used their tablets to look up how to do this (see **Figs. 5 and 6**).

Fig. 5. An example of a student's scientific notation calculations.

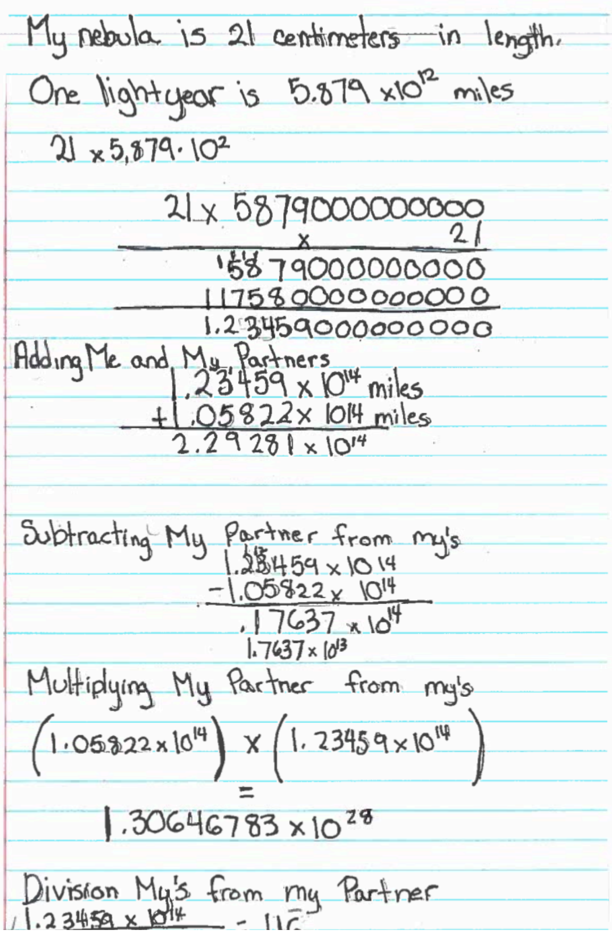
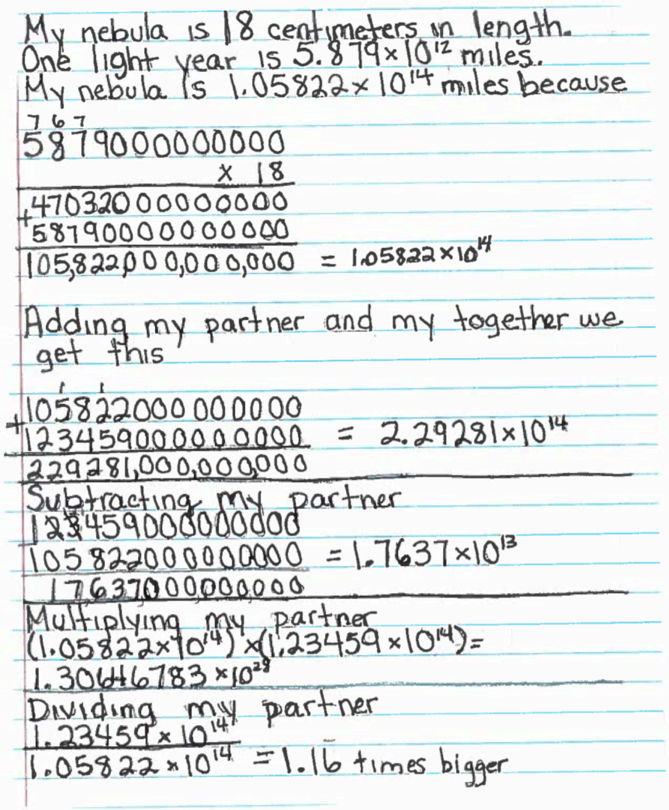

My nebula is 21 centimeters in length.
One lightyear is 5.879×10^{12} miles
$21 \times 5{,}879 \cdot 10^{2}$
21×5879000000000
$\times \quad 21$
5879000000000
117580000000000
1.23459000000000
Adding Me and My Partners
1.23459×10^{14} miles
$+1.05822 \times 10^{14}$ miles
2.29281×10^{14}
Subtracting My Partner from my's
1.23459×10^{14}
-1.05822×10^{14}
$.17637 \times 10^{14}$
1.7637×10^{13}
Multiplying My Partner from my's
$(1.05822 \times 10^{14}) \times (1.23459 \times 10^{14})$
$=$
$1.30646783 \times 10^{28}$
Division My's from my Partner
1.23459×10^{14} - 1.16

Fig. 6. Another example of a student's scientific notation calculations.



My nebula is 18 centimeters in length.
One light year is 5.879×10^{12} miles.
My nebula is 1.05822×10^{14} miles because

767
5879000000000
× 18
47032000000000
+5879000000000
105,822000,000,000 = 1.05822×10^{14}

Adding my partner and my together we get this

105822000000000
+123459000000000 = 2.29281×10^{14}
229281,000,000,000

Subtracting my partner
123459000000000
105822000000000 = 1.7637×10^{13}
17637000000000

Multiplying my partner
$(1.05822 \times 10^{14}) \times (1.23459 \times 10^{14}) =$
$1.30646783 \times 10^{28}$

Dividing my partner
$\frac{1.23459 \times 10^{14}}{1.05822 \times 10^{14}} = 1.16$ times bigger

REFLECTIONS ABOUT THE LESSON

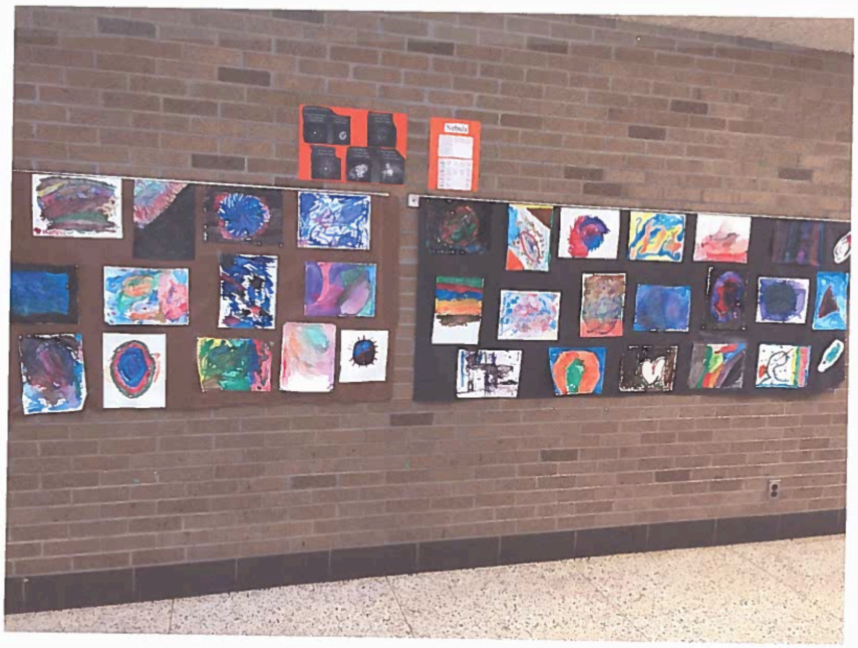
Author 1 believes that the benefits of the lesson were both mathematical and artistic. This is because it gave students a visual example of the need for scientific notation and validated why they were learning this topic. Author 1 says, "I remember students connected their understanding to work they had previously done with me about the rules of exponents, in determining how large something was and writing it in scientific notation."

Author 2 has found that students have struggled with this mathematical concept and wondered how art could help these students. This author learned that by combining mathematics, science, and art, students were more interested and motivated to learn about this topic. When asked about the lesson, one student said that, "it was awesome because we got to be creative and learn about math." Another student thought, "it was fun to put colors together and make something new. " Author 2 thought that this art-integrated lesson made scientific notation more interesting; therefore it motivated students to persevere through their difficulties and complete the task. Viewing art and painting helped students to reveal what they had learned about scientific notation. This was the case, because students had the opportunity to create their own image and to measure it; thus there was ownership in their mathematical processing.

Author 3 (Peggy, a project co-director) observed the watercolor Nebula lesson sitting at a table with two students. She noticed that student hands flew up when Author 1 showed the power point of artwork and asked questions. Students wanted to share what they thought. Students enjoyed the painting and mixing the colors. They were all engaged. Some came up with dazzling and beautiful hues.

The authors recommend that this lesson take more than one class period. They found it helpful to have a strategy for quickly removing cups of water and cleaning up. They suggest having a place to display paintings (see **Fig. 7**). This lesson took place in the mathematics classroom because not all eighth graders took art. The authors borrowed the watercolors from the art teacher and recommend that mathematics and art teachers collaborate and visit each other's classrooms to consider possible connections between what they teach. This is because collaborative efforts among classroom teachers and arts specialists contribute have been found to increased teacher satisfaction, interest, and success, and lead to the development of a sense of community of practice in the school (Burton et al. 1999; Deasy & Stevenson 2005; Werner & Freeman 2001).

Fig. 7. A wall of watercolor Nebula.



IN CONCLUSION

Mathematics teachers might wonder “Why teach art when my students need to know how to do mathematics?” Dantrassy (2012) advises that the art-integration may take time for its positive influence to positively affect student performance.

For those students who struggle in mathematics, art might be part of the answer to gain their interest and promote their understanding. Thomas Lawson, dean of the School of Art at Cal Arts has said, "We are looking for the kind of kids who didn't quite fit in at high school" (cited in Thornton 2008, p. 63). Eisner, an acclaimed art educator and researcher believed, "Academic schooling would do well to look more like the processes the arts celebrates. In the current educational policy climate we have it upside down. The arts are not marginal niceties; they should be regulative ideas for all we do" (p. 8). VTS and art integrated lessons are a worthwhile approach to teaching and learning that promotes current initiatives in education that prioritize conceptual and procedural skills but will advance education's transformation (Marshall 2014). No subject stands alone. Traditionally, art classes and core subjects in schools are often physically separated within the school (Purnell 2004). However, the authors encourage middle school mathematics teachers to take advantage of the synergy possible through arts integration.

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