USING VISUAL THINKING STRATEGIES TO IMPROVE MATHEMATICS INSTRUCTION

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ABSTRACT

The purpose of the study was to explore the use of Visual Thinking Strategies as it applied to mathematics instruction for teachers in a small, urban elementary school containing grades 1-6 in a large Midwestern metropolis. This study was implemented to address the problem of low math scores in urban schools that have students with low socioeconomic status compounded by the way math concepts are generally taught. This study was qualitative and followed the heuristic tradition of research.

The unit of analysis was the experiences of teachers with VTS, as we explored their implementation of the visual thinking strategies in the classroom gathered from open-ended surveys, observations, informal reflective conversations, in-depth interviews, and reflective journals analyzed during the illumination step of the heuristic process in a focus group discussion.

The central question that guided the study was, how can Visual Thinking Strategies (VTS) improve mathematics instruction? There were three contributing parts explored, teacher "moves," restatements of evidence regarding explicit teaching of mathematical concepts, and academic vocabulary. Five teachers in the building became co-researchers

from different grade levels, backgrounds, ages, and years of teaching experience, and who were similar in growth mindsets and established discourse procedures in their classroom.

Initial engagement started the study with surveying knowledge and interest of the teachers in VTS specifically, and math in general. Then a schedule was devised to conduct observations, including introducing the VTS protocol expectations and methods to display the art and math images.

Immersion in facilitating lessons in six classrooms first with art images and then math was reflected in conversations, journals, interviews, and living the phenomena of VTS for three months. Incubation for each participant brought personal clarity and codebooks for me. Guided by the research questions and theoretical framework of the study, the final themes I gleaned from the process include Cognitive Operations, Teacher Moves, Discourse with Vocabulary, and Visual Learning. The interpretive codes of cognition, facilitation, talking, and learning visually came from descriptive coding of the data. Illumination occurred in the focus group discussion when the participants answered the research questions.

The explication step revealed that VTS can be used to improve math instruction with collaboration to create images, such as, graphs. Students were taught the visual thinking strategies using pictures and photographs to enable them to think creatively and critically. Those same strategies helped students make sense of bar, line, circle, and picture graphs. They were able to build deeper understanding as a community from diverse individual input when teachers got students engaged and confident. Facilitators restated evidence while bumping up vocabulary from student language to make the math concepts more clear.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of Education have examined a dissertation titled "Using Visual Thinking Strategies to Improve Mathematics Instruction ," presented by Teri Campos, candidate for the Doctorate in Education Degree, and certify that in their opinion it is worthy of acceptance.

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CHAPTER 1

INTRODUCTION

Throughout my three decades in the education field, I have taught mathematics in some manner every single year. In general, my experience has been in classrooms at various elementary and middle school levels teaching mathematics as one of the core subjects. In gifted education at the elementary and middle school level, I taught advanced problem solving, traveling and winning with teams in statewide competitions. Using my mathematics expertise, I provided professional development as an instructional coach in math concepts and instructional strategies through workshops and classroom demonstrations. I have attended and presented at local and national mathematics conventions and countless math workshops. I created and scored math assessments as a Senior Leader with the Missouri Assessment Program (MAP). Mathematics is my strength and my passion.

Throughout my long personal journey of learning, teaching, and testing mathematics, I have found myself in various settings in classrooms. I have taught and coached in rural, suburban, and urban schools within a large Midwestern metropolis. However, I consider my first group of students my own five children. As the mother and first teacher of five uniquely different children, I found each child to have individual mathematical conquests and struggles. Some found the concepts easy and natural, and loved math class and their math teachers; others did not. Some grasped ideas more easily as they connected to their musicality, as all of my children learned piano and then progressed to other instruments. Two of my daughters found number concepts confusing and frustrating to the point of tears, and they avoided as many math classes as possible throughout their education, especially in college. My oldest daughter came to me as a tearful young adult asking me to teach her fractions before she took an entrance exam to get into nursing, and she was serious. In reality, she only needed a confidence building session to clear up a few misconceptions and turn the abstract into concrete, but she was convinced that she knew nothing and that the exam was going to be extremely difficult. She passed and has been a nurse ever since, and she is able to figure out fractions every day.

The experience I had at home with my children as they navigated through life using numbers and other mathematical concepts translated well into my experience as a teacher of other people's children. I find the same frustrations and successes in every classroom; some students love math, others tolerate it, and even a few hated it. I feel challenged with each encounter to help make the concepts clear, as well as to instill persistence and pride. I think it is sad there are some adults who say things like, "I was never good at math." These same people would rarely admit difficulty in reading, but proclaim deficits in math, like that is acceptable, and even excusable. I often think the children of these aforementioned adults also get a fixed mindset and believe it is okay to blame lineage as their excuse for struggling with mathematics and for having a fixed mindset or acceptance of failure.

Even teachers under my mentoring express frustration and confusion with certain mathematic concepts and therefore the methods with which to teach them. I took a job in a school that achieved less than 5% proficiency in math on the state assessment for three consecutive years. I was determined to help turn those scores around. There are several schools in urban districts like the one I work for with similar low mathematic achievement scores. There were five SIG (School Improvement Grant) schools in my own district looking for better ways to teach mathematics in order to keep or obtain state accreditation. A SIG school receives funding for both a Reading and a Math Instructional Coach. As a Math

Instructional Coach, I became part of the Leadership Team to turn around scores within three years. I began to explore Visual Thinking Strategies as one possible remedy to improve mathematics instruction and to battle fixed mindsets.

Problem Statement

The problem of persistently low mathematic scores of many free and reduced lunch students in urban schools is perhaps, compounded by the manner in which math concepts are taught. Approximately one-third of fourth grade children from low socio-economic households do not reach basic achievement levels in mathematics as defined by the National Assessment of Educational Progress (Lee, Grigg, & Dion, 2007). This statistic has remained significantly unchanged from 2005 to 2011 (U.S. Department of Education, 2011). Schools that score in the lowest five percent on state assessments in mathematics and reading for two years in a row are placed on a Tier I list. This status places the school or school district in jeopardy of being restructured unless there is a turnaround and scores improve within the next three years (U.S. Department of Education, 2010). As previously stated, these schools are eligible for School Improvement Grants that provide funding for a Math Instructional Coach.

Morgan, Farkas, Hillemeier, and Maczuga (2014) used data from The Early Childhood Longitudinal Study Birth 2001 that utilized the Kindergarten 1998-99 Cohorts to examine children's mathematic difficulties with a sample size of over 900 students, ages four and five, that scored in the bottom 25th percentile. A second study followed of the students in grades three, five, and eight. Using logistic regression, the study examined many factors that are common in urban schools and present in my own school; among these, socioeconomic status (SES), preschool attendance, and learning difficulties that may be related to persistent mathematics difficulties. Researchers found a strong relationship between low SES and children's risk of persistent math difficulties. The study further concluded that Head Start and other preschool caregivers significantly reduced persistent math difficulties for children ages four and five, but the effect was not maintained at the later grades of three, five, and eight. This conclusion justifies the need for support throughout elementary and high school for those struggling with math. The study also validated previous findings that vocabulary and reading difficulty can predict persistent math difficulties (Morgan et al., 2014).

The State Assessment Program math scores in 2013 showed decline as the percentage of students statewide who passed math fell to 53.9% from 55.5% in 2012, according to the State Department of Elementary and Secondary Education. This data also show the achievement gap persists with passing rates of white students at 59.2% and black students at 30.2%. According to results from the 2014 assessment, the statewide average rate of proficiency fell in English Language Arts (ELA), Mathematics, and Science (Sarah, 2014). This past year, 2017 was a little better than 2016, but a trend is not evident because the assessment itself changed, and testing requires three years of data to establish a trend. The 2017 data shows an average of 48% of students in third through sixth grade in the state achieving proficient and advanced scores in math. My urban school district had only 24% scoring proficient or advanced, with my school scoring only 14% in proficient and advanced in tested grade levels.

Sirin's 2005 meta-analytic review of literature, a replication of a study conducted fifteen years earlier, was designed to assess the magnitude of the effect of socioeconomic status (SES) on academic achievement. Findings suggested that students from lower SES had lower academic achievement (especially in mathematics). The study reviewed journal articles published 1990-2000 that comprised data from 101,157 students from 6,671 schools and 128 school districts and from 74 independent samples. The studies selected by Sirin were those reported in qualitative data, had an SES measure, included students K-12, and were located in the United States. A limitation of the findings was the correlation to SES, as it is currently defined. The gathered statistics found achievement diminished but not correlated to SES because economic status is a multi-dimensional construct formerly based on parent income, parent education, and parent occupation ten years ago; whereas now, neighborhood socioeconomic status is considered as well. Free and reduced lunch status comprise current data, but racial and cultural backgrounds are critical factors. In urban neighborhoods, SES was found to have a correlation to achievement. Diverse racial and cultural backgrounds were prevalent in urban areas due to three main factors. Children with diverse backgrounds are more likely to (a) live in low-income households or in a single parent family, (b) have parents likely to have less education, and (c) attend under-funded schools (Sirin, 2005). My study, conducted in an urban neighborhood school, follows this trend in data in regards to our students and their families.

Low standardized achievement scores continue to be a problem for math teachers and school leaders, as attempted reforms have not yielded any significant positive results (School Improvement Grants, 2011). The problems for students that continue as a result of the limited proficiency in math include the lack of opportunities to attend college or other post-secondary opportunities, lessened chances of procuring a job in any STEM field (Fielder, 2012), and facing challenges with budgets, income taxes, and many other math related life skills as they matriculate through life.

Sean Reardon (2013), a Stanford University sociologist, who reviewed NAEP data, asserted that there is also an achievement gap between students of different income levels. He examined the impact of the problem in a different way, viewing income disparities as opportunity gaps. While the scores increased at the national level for fourth grade from 2009 to 2011, the achievement gap between black and white students did not narrow (Reardon, 2013).

The National Center for Education Statistics, the National Assessment of Educational Progress, and the National Mathematical Advisory Panel all collect, analyze, and report data yearly. There is an achievement gap between white students and those of color, which has persisted with only slight improvement over the past thirty years (Reardon, 2013). Reardon asserted, “We have moved from a society in the 1950s and 1960s, in which race was more consequential than family income, to one today in which family income appears more determinative of educational success than race” (2013, p. 11). This gap is often referred to as the opportunity gap because it exists regardless of race or ethnicity.

> The new gap means that too many poor, urban and rural students of color lack the education necessary to obtain jobs that can support a family in an information economy in which low-end jobs are disappearing. This hurts the U.S. economically, deepens social divisions, and endangers our democratic society. (Reardon, 2013, p. 14)

While Reardon expressed the impact on students as extending beyond the attainment of employment and economic benefits, he pointed to the need to protect our democracy with an educated citizenry. Thus, the impact of the problem is dire, especially among marginalized students.

Compounding the problem may be ineffective math instruction. I agree with Lisa Delpit (2012), that many teachers make the mistake of nurturing by lowering expectations.

In her article, "Multiplication Is for White People: Raising the Expectations for Other People's Children," she contends that teachers should be warm, but demanding. I have seen effective teachers modeling what Delpit describes. These "warm demanders" recognize the obstacles in their students' lives but still expect a lot from them because they believe in them, which in turn helps students believe in themselves.

The Achievement Gap Initiative (AGI) at Harvard (2017) found that improving classroom instruction is one key to closing the gap. The AGI is a university-wide effort that began in 2006 and continues today, employing staff, graduate student research assistants, fellows, project consultants, and other affiliated faculty. The AGI has the slogan, "toward excellence with equity," with the mission to bridge research with practice by framing issues, conducting research, and disseminating high quality research to schools, teachers, parents, and other stakeholders in order to show the urgency and the possibilities of progress in closing the achievement gap. The AGI project list for 2014-2015 included ongoing national studies on instructional quality, parenting, school culture, and community support through collective impact efforts, which have a cradle-to-career focus.

Two Achievement Gap Initiative projects support my concerns with mathematics: one in parenting and the other in instruction. Mentioned in the five fundamental behaviors of parenting is the use of number games and rhythms to lay foundations for numeracy. Early concepts of mathematic concepts include matching, sorting, cardinality, comparing, and ordering. Parents should encourage activities that incorporate these skills beginning at birth. Research shows that the amount of "number talk" that occurs between parents and their children is a predictor of emerging math abilities in school (Levine, Gunderson, & Huttenlocher, 2011). The other project, the Tripod Project, was on instruction. The three fundamental things, or tripod, an effective teacher must possess are content knowledge, pedagogic skills, and relationship skills. I believe that Visual Thinking Strategies can increase a teacher's pedagogic skills and create a classroom culture that builds relationships.

Instruction, in general, is a concern in urban education. I believe, as Geneva Gay (2010) does, that teachers should be culturally responsive inside a classroom. Since I am not African American, but 75% of my students are, I must make a conscious effort to address issues such as racism and powerlessness, and encourage the study of a variety of ethnic individuals and groups. Using art as the medium to teach the VTS protocol allows a culturally responsive teacher to find images that represent a wide variety of age, gender, place, social class, and diversity. The discourse in VTS could help create a classroom climate that is conducive to learning for ethnically diverse students if the teacher is a partner in learning with respect, honor, and a growth mindset. VTS could teach mathematic concepts and values simultaneously.

In 2008, The National Mathematical Advisory Panel (National Mathematics Advisory Panel, 2008) made several recommendations related to mathematics teaching in its report. The panel, chaired by Larry Faulkner, President of the Houston Endowment and President Emeritus of the University of Texas at Austin, was comprised of 24 members. Panelists represented a variety of foundations, universities, professional organizations such as the National Council of Teachers of Mathematics (NCTM), researchers, mathematics award winners, psychology professors, educational consultants, and a principal whose school had made remarkable gains in math and reading. The panel published a pamphlet of their recommendations and a 72-page final report. One suggestion was the implementation of curriculum that contained a growth mindset toward mathematical knowledge by encouraging the active participation of all. The panel also concluded that math should involve testing ideas and sharing those ideas verbally.

Members stated that most class instruction is from textbooks, workbooks, and worksheets that involved a lot of drill and practice. They recommended that instead, teachers of mathematics should have classrooms that model problem-solving behavior whenever possible. Teachers should explore and experiment along with students during any problem-solving activity. Mathematics teachers should create a classroom atmosphere in which all students feel comfortable trying out ideas and invite students to explain their thinking at each stage of their solution. Visual Thinking Strategies also advocates a risk-free classroom atmosphere and open discourse, which was the suggestion of this education panel (National Mathematics Advisory Panel, 2008).

Conceptual math activities emphasize the application of a conceptual framework in order to organize foundational, factual knowledge and foster more complex math concepts and analytic and reasoning skills (National Academies of Science, Engineering, and Medicine, 2005). Empirical studies reviewed in the literature about the "opportunity to learn" reveal that instructional content lacks equality. Some national studies also have shown that instructional processes are not equal (Bachman, Votruba-Drzal, El Nokali, & Castle Heatly, 2015). Desimone and Long (2010), using a multilevel growth model, analyzed whether teacher quality influenced the achievement gap between black and white and high and low SES students in the early grades. The researchers defined teacher quality using the following criteria: degree in mathematics, experience, certification, math courses taken, and professional development. They defined opportunity to learn as the amount of time spent on mathematic instruction and the amount of that time as conceptual, basic procedural, and/or advanced procedural. Desimone and Long found that schools tend to "exacerbate instead of mitigate the achievement gap" because low-achieving students who were placed with teachers who used basic procedural skills remained low achieving. When students were given the opportunity to learn more advanced procedural and conceptual skills, it improved their skills. The most detrimental practice was frequent test taking, and the most beneficial practice was increasing math instruction time, especially in geometry and measurement. Desimone and Long (2010) concluded that 100 minutes spent daily with mathematics instruction closed the gap by ten percent. They also found that low achieving students tend to get the weakest teachers, who spent less time on math instruction when really just the opposite needs to happen. Visual Thinking Strategies implemented in classrooms would increase math time and thus the opportunity to learn. VTS is conceptual rather than procedural when applied to math graphics.

Large national studies of instruction have shown associations between instructional content and standardized math achievement, but a current review shows that literature lacks instructional process measures, such as meaningful mathematical discussions and building connections between mathematical representations. However, the National Council of Teachers of Mathematics in 2014 stated that effective mathematics pedagogy should pay attention to instructional process characteristics with both direct instructions and classroom discourse. They made suggestions to guide the training and professional development of math educators with these recommendations in mind (Bachman et al., 2015). I observe much classroom mathematics instruction and concur with Means and Knapp (1991) that disadvantaged students receive less instruction in higher-order skills, such as mathematical reasoning. In their article, "Cognitive Approaches to Teaching Advanced Skills to

Educationally Disadvantaged Students" they asserted that schools often focus on the basics to the exclusion of reasoning skills. I agree that this is often the case. Many teachers think that basic computation is a hurdle that must be passed first before more complex math can be introduced, which means more emphasis is placed on structured drill and practice and leaving little time for higher-order thinking. The authors further described current classrooms that have the teacher as the transmitter of knowledge and the students as the passive receivers of this knowledge. Cognitive psychologists believe children come to school with knowledge and through dialogue; a teacher can build on that knowledge. Means and Knapp (1991) made several suggestions that could be met by implementing Visual Thinking Strategies. One suggestion was to encourage multiple approaches to academic tasks, such as problem solving. Another suggestion entailed providing scaffolding to accomplish complex tasks. Finally, they said teachers should make dialogue the central medium for teaching and learning. VTS with its classroom discussions would combine all these suggestions.

The Common Core State Standards has similar wording regarding mathematics, stating that the goal is to prepare students for college and the workplace of the 21st century. Common Core State Standards require students to think critically, problem solve, reason, listen, speak, and write at higher levels than ever before (Porter, McMaken, Hwang, & Yang, 2011) in order to be college and career ready upon high school graduation. A lesson in Visual Thinking Strategies calls for students to listen to one another's input, speak about their own ideas, and to think critically by providing evidence for the conception of their ideas.

In December of 2012, the Obama Administration announced the Cross-Agency Priority (CAP) goal of increasing the number of graduates of science, technology, engineering, and math (STEM) degrees to one million over the next decade. The Department of Commerce estimates that STEM occupations will create 2.6 million jobs by 2020. Those degrees and jobs will require people who are proficient in mathematics, so the new CAP goal included five focus efforts. One of the efforts was addressing the mathematics preparation gap that students face when they arrive at college, using evidence-based practices that generate improved results (Fielder, 2012). Increasing mathematics achievement through Visual Thinking Strategies will help to achieve this goal.

Purpose and Research Questions

The purpose of this heuristic descriptive study was to explore of the use of Visual Thinking Strategies (VTS) as it applies to mathematics instruction for teachers in small, urban elementary schools in grades 1-6, in a large Midwestern city. Heuristic inquiry fit this study because the researcher was the primary instrument of this type of qualitative research. I, as the primary instrument, facilitated VTS lessons to initiate the phenomenon. Heuristic inquiry falls under the phenomenology umbrella because it involves researchers living the experience of a phenomenon (Patton, 2015). VTS is the phenomenon that I shared with other teachers in my building. We shared an experience and then analyzed the interpretations of each co-participant to build an understanding. I focused on the descriptions of what each teacher-participant experienced through reflective conversations, in-depth interviews, and a focus group discussion. Heuristic inquiry is different from phenomenology in three ways: the researcher has a personal connection instead of detachment; it leads to personal meaning rather than describing a structure of the experience; and since the researcher is the primary instrument in the research, the approach challenges objectivity (Patton, 2015).

At this stage in the research of visual thinking strategies, when used in studying art, (Housen, 2005) asks three main questions:

- What is going on in this picture/graphic?
- What do you see that makes you say that?
- What more can you find?

At first the facilitator, who is also the researcher, asks the questions. Through questioning and dialogue, the class builds a community understanding. The facilitator points out the items in the picture or graphic mentioned as participants discuss the evidence they believe supports their assertions, then nonjudgmentally summarizes their input of the visuals while bumping up (restating student language into academic language) their vocabulary. Facilitators also guide the construction of meaning by allowing the group to explore multiple possibilities. I want to explore how teachers can apply visual thinking strategies to academics (Yenawine, 2013) such as mathematics utilizing graphs, charts, and diagrams to better instruct and deepen understanding. Eventually, it is my hope that students may practice the strategies independently as they apply VTS when they encounter math graphics and attempt problem solving.

The unit of analysis was the experiences of teachers with VTS, as I explored their implementation of the visual thinking strategies in the classroom gathered from open-ended surveys, observations, reflections, and in-depth interviews and then analyzed them during the illumination step of the heuristic process. During the reflection time after a VTS lesson, I worked with teachers to analyze how the three fundamental VTS questions could elicit mathematical understandings from the students as a group. As the facilitator of the process, I hoped to illuminate how VTS factored into the instructional decision-making process throughout the lesson.

One of the characteristics of a Visual Thinking Strategy discussion is that it involves group collaboration and is a community building exercise. Students learn to agree and disagree with polite and scholarly discourse (Yenawine, 2013). The collaboration efforts include preparing images for each lesson with the math concepts in mind and then reflecting whether that was accomplished, and if so, to what extent. A focus of the reflection time with the teachers was to see how incorporating math vocabulary during lesson facilitation can help students acquire academic math vocabulary.

Preliminary Research Questions

The following central question and sub-questions guided this study:

Central Question: How can Visual Thinking Strategies improve mathematics instruction?

a. How do teachers apply the three main questions of VTS with teacher “moves”?
b. What do teachers do to reinforce restatements of evidence regarding explicit teaching of mathematical concepts?
c. What are teachers’ perceptions of the facilitation of group discourse related to the reinforcement of academic vocabulary?

It is important to note that teacher “moves” in this study are defined as the instructional strategies and decisions teachers make that either aid or inhibit mathematical conceptual understanding.

Theoretical Framework

Maxwell (2013) defined the theoretical framework as the conceptual framework of the research that shows what theories, beliefs and prior research findings will guide and inform the current study. In defining key concepts of the framework, the researcher frames the phenomenon, preliminary studies, and personal experience. Creswell (2013) viewed theoretical frameworks as a phase when the researcher explains a set of beliefs that guide their actions. As the researcher, I have a set of beliefs that guide my actions as a mathematics teacher, which then affect how I conduct my research. Creswell asserted that a qualitative researcher embraces different realities than those of the individuals studied. I also have a different reality than those reading the study, so the framework is designed to narrow the scope and provide a foundation literature base to the study. The framework attempts to get us all on the same page.

The problem of persistent low mathematics scores of low-income students compounded by the way math concepts are generally taught, was addressed in this study. As a School Improvement Grant Mathematics Instructional Coach, I provided professional development in math concepts and instructional strategies. Over the past 30 years, I have attended local and national mathematics conventions and math workshops. I have had a long personal journey as I have learned mathematical concepts and how to best teach them to various age and ability groups in urban classrooms located within a Midwestern metropolis.

My passion for math and my experience in the field of Visual Thinking Strategies created a curiosity for applying the method in mathematical instruction, leading me to select heuristic inquiry as the theoretical tradition for my study. I began using VTS as a coach and felt the excitement of teachers I coached using VTS in their classrooms. When the art museum facilitators started Visual Thinking Strategies in our building with images they brought to our school, everyone was excited. The students participated, and discourses revealed vivid imaginations and critical thinking skills. The museum mentors tied the art talks to writing and found with a pre- and posttesting that students did increase their number of observations and their ability to cite evidence. After ten visits, the museum experts stopped coming, and the expectation was VTS would continue, with the classroom teachers taking over the facilitator role. Perhaps those observation skills would be applied to other core subjects. Some teachers tried it with varying degrees of success, but the excitement waned.

I had very limited success in my first attempts to tie the lessons learned to math graphics when I demonstrated mathematics lessons the rest of the year. I could envision future possibilities; and as the facilitator, I often felt validated with the classroom discourse. I did not think that I influenced the classroom culture as much as the classroom teacher could, so my impact was minimal. I went back into the classroom after four years as a math coach and have successfully used Visual Thinking Strategies in my classroom. I found success in my classroom with my students, and I now want to expand its application and incorporate the approach in mathematics instruction.

I brought some assumptions to this qualitative study. First, I believe people process differently through visual stimuli. One theory that supports this assumption is that people have more than one type of intelligence according to Howard Gardner (1983, 1999). The theory of multiple intelligence categorizes intelligence into different realms. According to Gardner's *Intelligence Reframed* (1999), there are eight intelligences, and visual intelligence is one only of them. Students who can activate verbal/linguistic and visual/spatial intelligences along with their mathematical/logical intelligence tend to make sense of math in more than one way. Facilitating a strategy to make up possible stories behind the picture in art could be applicable to mathematical pictures or graphics and eventually other types of problems to make the abstraction of numbers more concrete.

Another theory that has a visual category is learning styles. The three types of learning styles or modalities (Fleming & Baume, 2006) are visual, auditory, and kinesthetic (Kolb, 1984). Visual learners think in pictures, and VTS engages the visual modality, not just the auditory modality, as some current math instruction does. One vehicle to make students more visually aware is to practice looking at visually stimulating works of art. Visual representations have been used to successfully model mathematics in other types of popular math programs (Schaffhouser, 2013; Tang, 2003), and visual thinking strategies can be an extension of any type of program already in place if facilitated with classroom discourse to get students talking about the mathematics they see and using evidence to back up their assertions.

Further, I assume that just as a math talk or Number Talk is designed to elicit specific mathematics strategies that focus on number relationships and number theory (Parrish, 2014), so can a VTS lesson. VTS can be one more tool that an innovative teacher may use in order to improve math instruction. My goal is to combine VTS and mathematics by offering the visual stimuli and then facilitating classroom discussions to guide participants in understanding a mathematical concept more fully. One final assumption is that visual representations illustrating math concepts can be found and/or created to use with VTS in order to reach more students of different ages and abilities.

The topics included in the theoretical framework are: Multiple Modalities, Visual Intelligence, and Thinking. Multiple Modalities are important because they show how teaching with more than one modality allows teachers to reach more students, thus increasing learning and cognitive ability. Visual Intelligence is part of multiple intelligence theory and acknowledges that children bring many different types of intelligence into the classroom. VTS can utilize not only visual/spatial intelligence, but also linguistic intelligence to talk about math, ultimately increasing mathematics intelligence. Finally, I include Art integration as a way of increasing critical thinking skills. The VTS process begins at this point—looking at art—which informs my study. The strategy used with art gets students analyzing pictures, thinking, and making up many possible stories. I think that training students to look at pictures closely and then making up stories, is applicable to mathematic images as well.

Multiple Modalities

A theory that supports VTS as the visual stimulus for mathematics instruction is that there are modalities with which learners may function: visual, auditory, and kinesthetic (Fleming & Baume, 2006). Teachers who engage as many students as possible find instructional strategies to incorporate multiple modalities for each lesson. That means visual learners learn best with their eyes, auditory learners with their ears, and kinesthetic learners through movement (Kolb, 1984). Math lessons delivered through direction, explanation, lecture, and discussion are auditory methods. Mathematics delivered with anything seen, such as numbers, graphs, and abstract symbols, are visual methods. Mathematics delivered through a kinesthetic means utilizes manipulatives and other hands-on devices to make the abstract more concrete with movement.

Each different type of learner has their strengths and weaknesses in the classroom. Auditory-sequential learners are left hemispheric, think in words, have a good sense of time, are systematic learners, follow directions, are organized, memorize linear instructions, and progress from easy to difficult material. Visual-spatial learners are right-hemispheric, think in pictures, relate to space not time, are whole concept learners, read maps well, have unique methods of organization, learn best by seeing relationships or patterns, and can learn complex concepts more easily than simple ones (Burnaford, Aprill, & Weiss, 2001). VTS involves both hemispheres of the brain, since it involves looking at visual mathematics and then talking and listening to others.

Too often when demonstrating a math algorithm, the steps lose their meaning while the visual learner is trying to picture things in their head for one step and the teacher has gone on to the next (Rapp, 2009). VTS addresses this problem with the initial "think time." The one- to two-minute think time in the VTS protocol may allow the visual learner to formulate the pictures and stories before constructing meaning. Being able to do something such as computation is not evidence of understanding. It may have been a good guess or done by rote. Truly understanding a concept is not just getting the right answer, but also knowing how and why, and then being able to transfer that knowledge to different problems (Wiggins & McTighe, 2006). Transferring is what Bloom (1956) meant by application. When students can transfer knowledge of a mathematical concept to different problems and in different situations, they have attained a higher depth of knowledge through application. An over-reliance on auditory-sequential teaching methods cause blocks for visual-spatial learners, both academically and emotionally in math (Silverman, 2002).

Visual Intelligence

One theory that supports the use of VTS as a visual stimulus for mathematics instruction is the theory of multiple intelligences, developed by Howard Gardner, Ph.D., Professor of Education at Harvard University in 1983. Gardner's work in psychology, human cognition, brain damage, and potential, led to the development of the initial six intelligences (Gardner, 1983). Gardner (1983) defined intelligence as a set of skills that make it possible for a person to solve problems in life by selecting from or creating potential solutions, both of which involve gathering new knowledge. His theory explained the different combinations of the intelligences used to empower students and advised teachers not to limit them. With the Multiple Intelligence Theory, he suggested matching teaching to ways students learn, encouraging students to stretch their abilities, develop all their intelligences, and honor diversity (Gardner, 1999). His study has stood the test of time and expanded to include more intelligence categories; Gardner reframed the multiple intelligences for the 21st century in 1999 and asserted that educators who teach a topic in more than one way can reach more students and understandings in more intelligences. Thirty years after his original theory, he reframed and added other intelligences (Gardner, 2011). Based on the multiple intelligence theory, students may be stronger in different types of intelligence such as mathematical, visual, or verbal intelligences. Using visual or verbal intelligence to connect math concepts may help students who are stronger in those areas and build understanding and meaning in different ways. These intelligences are described more fully in the literature review.

Katai, Juhasz, and Adorjani (2008) published Making Math Real: Connecting Research to Practice – A Comprehensive Multisensory Structured Methodology in

Mathematics K-12 Workshop to review the work of Giedd, Sowell, Deheane, Butterworth, Geary and others in the areas of neuroscience and cognitive science. They also reviewed the work of Miller, Mercer, Tomey, Marolda, and Orton-Gillingham, analyzing the connections to the cognitive benefits of multi-sensory structured methods. They concluded that the more senses involved in the learning process, the more information is retained. The students showed more gains in information when topics taught used the sense domain, which they thought was their strongest. Multiple sense delivery of information created more pathways for locating the stored information and distributed the loading of information as well. Strengths of individual learners can be used to their advantage. In reviewing this research on the role of our senses in education, I concluded as the researchers (Katai et al., 2008) did that combining senses creates a more efficient learning process. Since VTS lessons involve the whole class, there are many different intelligences and different modality preferences. Utilizing visual stimuli and verbal reflection to find a pathway to understand the mathematics will meet the needs of more learners and therefore create a more efficient learning process for mathematics instruction.

My concurrence with multiple intelligence theory drives my passion to help students whose strengths are visually or verbal to improve in their mathematic intelligence when activating their personal strengths. Gardner's work remains widely consulted in educational settings.

Thinking

We take for granted all that happens in a matter of seconds between our eyes and our brains, changing the raw data perceived through the sense of sight into concepts and generalizations. Our thoughts influence what we see, and what we see influences our thoughts (Arnheim, 1984). The ability to see involves millions of nerve fibers on each retina connected to an area where several billion neurons process that information. The information is then passed to another area of the brain, where several billion more neurons process it at a more complex level. All this happens in a matter of seconds. With VTS, a student may learn to take a little more time to process visual information and gain a deeper understanding of the mathematic concepts. All dimensions of abstract reasoning rely on perception, especially visual. All thinking is sorting and classifying what we see, or perceive to see, and comparing it to what our brain expects (Marzano, Pickering, & Pollock, 2011). This scientific phenomenon is intriguing to me, and I believe we can use this to create better math learners as we help students make sense of math when they process visual data into stories based on evidence they see.

Yet another theory that supports VTS is that a foundation of school success is academic language and literacy in English. The definition of literacy is expanding to include many modalities. Readers today need to be able to navigate the various parts of the text contributed by the writer, illustrator, publisher, and/or graphic designer simultaneously (Serafini, 2012). Through the VTS program, students create possible stories or narratives about art images together as a class. Even in math, students must be able to read, write, speak, and listen. English language learners (ELL) are one of the fastest growing subgroups in school populations. According to Echevarria, Vogt, and Short (2013), it is a goal when teaching ELL students to allow each student opportunities to read, write, speak, and listen every day. The problem of teaching diverse learners exists in most classrooms across America, and we are all language learners. The relationship between literacy proficiency and academic achievement grows at each grade level (Echevarria et al., 2013). The facilitator during a VTS session bumps up the vocabulary when retelling the observations made by students. Expecting all students to share in the discourse encourages reluctant speakers by providing them stems such as, "I agree with ______ because I also see a ______________" or "I disagree with __________ because I think ___________ when I see ____________________." Interaction with others is important and increases motivation and comprehension. I believe all students benefit from guided practice before they move on to independent work.

Another theory that supports the visual aspect of using VTS to think in math is the idea that looking at art to practice observing will increase both observation and critical thinking skills. Art integrated into other subject areas to increase an understanding of the world around us, has been the work of Project Zero through Harvard Graduate School of Education for the past fifty years. Nelson Goodman established Project Zero in 1967 to focus on learning in and through the arts. Artwork can be the starting point for teaching lessons, building blocks for further understanding, and serve as bridges between old and new information (Poldberg, Guy, & Andrzejczak, 2013). Some students could benefit from a non-text entry point into the curriculum, especially English language learners. Non-linguistic representation has proven to assist English language learners in expressing their ideas (Marzano et al., 2011) and engage students throughout the learning process. I believe art images and images directly related to math curriculum and math vocabulary have the potential to make connections for learners more meaningful. As they say, "A picture is worth a thousand words."

Art used in the teaching of mathematics may seem like a stretch for some, but art has been used in studies as a way for children to make sense of their world and process abstract ideas (Poldberg et al., 2013). Art integration in past work helped students internalize concepts, process information, visualize, and develop the ability to think metaphorically.

Bowen, Greene, and Kisida (2013) conducted a randomized controlled trial study with 3,811 students assigned by lottery to participate in a school visit program at a museum; the study showed a causal connection between an arts experience and critical thinking skills, especially for disadvantaged groups of students. The test group was given information about three art pieces with a packet and a five-minute video prior to their visit to the museum. A follow-up survey with a prompt to write an essay about one of the pieces found students in the test group grew in critical thinking skills of observation, interpretation, association, comparison, flexible thinking and evidence as coded blindly with a rubric. These researchers combined art and writing similar to the way I combined art and mathematics in this study. Much of math is visual representation, such as graphs, geometry, money, measurement, and mapping, but even concepts such as fact families could be represented with pictures or shapes instead of numbers. For this reason, I wanted to explore the possibilities through VTS.

Overview of Methodology

Interest in ways to teach mathematics more effectively to more students inspired my search for alternative methods. When my building started a pilot program with the art gallery to teach Visual Thinking Strategies,, I saw firsthand what a profound experience the students had after the initial lessons with different art mediums and a writing follow-up. It was exciting to see even reluctant learners participating in the group process to construct meaning. I want to explore making the visual image in the VTS technique one of math content, such as graphs, tables, patterns, or geometric shapes.

I chose the heuristic descriptive research design to capture the personal experiences of myself as a math teacher and five co-participant teachers who experienced a shared phenomenon. Heuristic inquiry is a form of phenomenological inquiry that emphasizes the personal experience and insights of the researcher (Patton, 2015). I wanted to understand more about how to apply Visual Thinking Strategies in the mathematics curriculum. Regarding a phenomenon of interest, VTS, I wanted to explore, "What is my experience of this phenomenon and the essential experience of others who also experience this phenomenon intensely?" (Patton, 2015). Heuristic inquiry refers to a process of an internal search through which one discovers the nature and meaning of an experience and develops methods and procedures for further investigation and analysis. Heuristic inquiry is open-ended with only the initial question as the guide. "What works?" becomes the focus, and anything that makes sense is then tested. This trial-and-error process, this discovery of what works, is heuristic. Applying VTS in the different strands of mathematics was a trial-and-error process to find whether it would increase student participation and understanding of math concepts according to the teachers' implementation.

I chose heuristic inquiry as the method for this research because it is process-oriented, which appealed to me since I am very process-oriented. Heuristic methodology concentrates on events and aspects of the experience and not results, which allows the researcher to live the phenomenon and be passionate about the subject matter. I am passionate about mathematics and how it is taught to elementary children. I am the type of teacher who self-reflects before, during, and after a lesson, so "living with" the phenomenon appealed to me, and would feel natural and not forced. Heuristic inquiry provides structure to explore meaning of a lived experience. After a lengthy career in education, I have tacit knowledge about math and instruction, which is a part of the heuristic method. This method design chose me more than I chose it, because of the word “intensity” (Patton, 2015). I felt intensely excited to study how VTS may improve mathematics instruction, which may be one contributing factor of the problem of low math achievement by low SES students. The setting was one small urban elementary school with grades K-6 in a large Midwestern city, given the pseudonym, Smart School, with a majority African American population of students, but mostly White teachers (see Table 1 for demographics of the school).

Table 1

Demographics of School Setting

Population	African American	White	Hispanic	Asian	Other
Students = 231	75%	6%	13%	1%	5%
Teachers = 19	25%	65%	5%	5%	
Free and reduced lunch	100%	100%	100%	100%	100%

VTS had been introduced at this school several years before by art gallery trainers and had been implemented to varying degrees. Several of the trained teachers retired or changed assignments within the district since that time. One advantage of working in the building as a classroom teacher is being able to get a more holistic perspective to capture the context within which people interact with the phenomenon of VTS (Creswell, 2013). Another advantage is that firsthand experience allowed me as an inquirer to be open, discovery oriented, and inductive, three key attributes that lend themselves to both scientific and heuristic inquiry. During direct observations, I saw things that may seem routine to another classroom teacher, but really are unique. Another advantage was the chance to uncover things people may have been unwilling or unable to provide on sensitive topics or was beyond their perceptions, such as the possibility of mathematic misconceptions perpetuated by ineffective instruction. As with many qualitative designs, data collected through multiple sources allow for crystallization. I collected data through observed VTS sessions, field notes, surveys, conversational reflections, in-depth interviews, a focus group discussion, and my journal reflections. Crystallization replaces the idea of triangulation in qualitative research for validity because a triangle is a "rigid, fixed, two-dimensional object," whereas a crystal "combines symmetry and substance with an infinite variety of shapes, substances, transmutations, multidimensionality, and angles of approach" (Richardson, 1994, p. 92). The field notes, in combination with my journal, allowed me to capture the accuracy, authenticity, and reliability of the observations (Patton, 2015). In the validation phase, depictions shared with the co-participants in a focus group helped confirm my interpretations and offered them a chance to add anything they thought was missing.

Significance of the Study

Since language learners should read, write, speak and listen to language daily (Echevarria et al., 2013), VTS lends itself to speaking and listening whereas other mathematic problem-solving strategies focus on reading and writing to model the solutions. Most teachers have English language learners in their classrooms, and this research will be of significance to them as they explore ways to improve their math instructional practice. Making meaning together by observing carefully, deciphering patterns, clarifying, supporting opinions and generating ideas in a Visual Thinking Strategy lesson addresses Common Core State Standards (National Governors Association, 2010). The sharing of ideas in the VTS lesson fulfills the components of speaking and listening daily and expands the mathematic academic vocabulary of participating students.

There are empirical studies on using visual thinking strategies in schools as applied in art, but few of these studies pertain to mathematics instruction. One study published in *Phi Delta Kappan* found that the energy that occurs between creativity and critical thinking allows powerful learning to occur during a VTS session (Moeller, Cutler, Fiedler, & Weir, 2013). Thinking is a lifelong skill that most teachers aspire to pass on to their charges. One study suggested that critical thinking may be transferrable to mathematic graphics (Franco & Unrath, 2014), but because there were gaps in the literature, they could not support that claim. Educational leaders who are attempting to improve math achievement will have an interest in the outcome of this study. This study will add to current knowledge on mathematics instruction.

Additionally, literature exists on how integrating art improves motivation, engagement, and achievement in other academics, such as writing and science (Goodman, 2017; Winner, 2007), but there are few studies that pertain to mathematics. This study will add to the knowledge about integrating art into core subjects. Hence, findings will be significant to educational leaders looking for ways to improve math scores, math instruction, and engaging all learners in a classroom. I expect that mathematics teachers will find this study useful because they are constantly looking for innovative ways to improve the understanding of math concepts, especially those who already incorporate math talks or Number Talks (Parrish, 2014) in their repertoire of daily lessons. This study will be significant to the field of visual thinking strategies that currently is used to improve evidence-based observations in communication arts (Cappello & Walker, 2016). It has not been tried in other core subject areas.

Further, with the growth of STEM-related careers, those that currently exist and future careers, there are fewer people in the United States to fill them. The federal government has set a goal to improve math and science education at all levels to meet the demand (Fielder, 2012). This study to improve math instruction is very timely as it pertains to the STEM movement. STEM includes the studies of science, technology, engineering, and math. Students who feel more confident in language and previously avoided math classes out of fear or confusion may, through VTS, find a way to connect their math brain with their language brain. I have had the exact opposite experience, as I have had to learn to connect my language brain to my math brain to describe this study.

Conclusion

As mentioned before, Common Core State Standards (National Governors Association, 2010), require students to think critically, problem solve, reason, listen, speak, and write at higher levels than ever before (Porter et al., 2011). VTS may be another tool to accomplish this higher level of critical thinking in mathematics as students speak about mathematics and listen to one another's ideas. This outcome could result from instructional protocols practiced in a VTS lesson with a math-related picture or graphic on which to focus.

The problems of an achievement/opportunity gap in mathematics (Levine, 2012; Traverine, 2012) and the continued overuse of drill and practice math instruction needs to be addressed. One purpose of this heuristic inquiry is to find out if experiences with teachers support the use of Visual Thinking Strategies applied in mathematics. The significance of the study is to include the use of VTS to improve mathematics instruction and, in turn, math achievement scores to close the achievement/opportunity gap. In order to find out if VTS is a worthwhile endeavor, I explored the experiences of teaching and learning mathematics with VTS as a new tool that incorporated verbal and visual intelligences with mathematical intelligence (Gardner, 1983).

Chapter 1 of this study addressed the problem that led to the development of the research inquiry. I also outlined the purpose, research questions, theoretical framework, overview of the methodology, and the significance of the study. Chapter 2 expands on the theoretical framework and introduces additional literature related to the study. Chapter 3 presents an expanded discussion of the proposed methodology. Chapter 4 presents the findings of the study, and Chapter 5 discusses the implications of the findings, recommendations, and future research for consideration.

CHAPTER 2

LITERATURE REVIEW

The problem of low mathematics scores of many free and reduced lunch students in urban schools persists (Morgan et al., 2014; Sirin, 2005), which may be compounded by the manner in which mathematic concepts are generally taught. Approximately one-third of fourth grade children from low socio-economic households do not reach basic achievement levels in mathematics as defined by the National Assessment of Educational Progress (Lee et al., 2007). This statistic remained significantly unchanged from 2005 to 2011 according to the National Center for Education Statistics (U.S. Department of Education, 2011).

The Achievement Gap Initiative at Harvard (2017) found that improving classroom instruction is one key to closing the gap. As summarized in Chapter 1, the National Mathematical Advisory Panel of the U.S. House of Representatives Committee on Education and Labor (2008) made several recommendations in its report. They found that most class instruction is from textbooks, workbooks, and worksheets, which involved a lot of drill and practice. Instead, teachers of mathematics should have classrooms that model problem-solving behavior whenever possible and help all students feel more comfortable with math by exploring and experimenting along with students (National Mathematics Advisory Panel, 2008). Ferguson and Stellar (2010) supported the proposition that better instructional practices aid in reducing the achievement gap.

The National Mathematical Advisory Panel (2008) also suggested the implementation of curriculum that contains a growth mindset toward mathematical knowledge by encouraging the active participation of all. The Common Core State Standards state the goal of mathematics instruction should be to prepare students for college and the workplace of the 21st century. Common Core State Standards require students to think critically, problem solve, reason, listen, speak, and write at higher levels than ever before (Porter et al., 2011). The Department of Commerce estimates that STEM occupations will create 2.6 million jobs by 2020. Those degrees and jobs will require people who are proficient in mathematics. It is my belief that elementary teachers of mathematics should be the first to address the mathematics preparation gap that students face when they arrive at college (Fielder, 2012).

To develop the review of the literature, I searched the databases available on-line through my university including MOBIUS, The Public Library of Science, JSTOR, and Google Scholar. I read studies to learn more about the history of visual thinking and the protocol of Visual Thinking Strategies. When considering VTS as a vehicle to improve mathematics instruction, and thus to improve mathematics achievement, the two parts of VTS that I thought needed to be reviewed as foundational were vision and thinking. In connection with vision, literature on visual intelligence (Gardner, 1983, 1999, 2011), visual modality (Kolb, 1984), and current visual modeling practices, such as bar models that are used in mathematics were reviewed. In connection with thinking, I examined literature on cognitive strategies, mathematics discourse to build concepts, and critical thinking, such as Numbers Talks (Parrish, 2014). The literature revealed that VTS has been used in areas of study other than art but was lacking in mathematics. This study will add to the current knowledge about VTS and fill the gap as it relates to mathematics.

The review of the literature focuses on four topics. One topic is problems in mathematics education to capture some of the issues that students—especially urban students, who are the focus of this study—face to acquire success in math. The history of visual thinking with its eventual connections to visual thinking strategies and the thinking process is reviewed. A more expanded discussion of the visual part of thinking strategies emphasizes Number Talk as collective thinking, mathematics discourse, critical thinking, and integrating VTS. Lastly, this review includes a conclusion that addresses possibilities for future studies related to VTS.

Problems in Mathematics Education

Since *A Nation at Risk* was published in 1983, there have been concerns regarding America's education system and how our students compare to those of other countries in the world. When federal money for school districts was tied to assessment data with the 2001 No Child Left Behind Act, that concern brought mathematics and literacy education under even more scrutiny. Every Student Succeeds Act (ESSA, 2015) requires annual testing in reading and mathematics and that school districts report the test results, increasing pressure on school districts to improve mathematics proficiency. Yearly assessments in math and reading have revealed that the achievement gap between races and socioeconomic statuses in our country have narrowed very little in the past 30 years. The National Council of Teachers of Mathematics (cited in Grouws, 2000), affirmed that it is a time of accelerating change, and because of this, it is important that our students to be more mathematically proficient. "The globalization of markets, the spread of information technologies, and the premium being paid for workforce skills all emphasize the mounting need for proficiency in mathematics" (National Academies of Science, Engineering, and Medicine, 2005, p. xiii).

The 2008 National Mathematical Advisory Panel Report stated that students begin to drop out of math (they fail to pass or stop taking math) after eighth grade at a rate of over 50%. Of the 3.6 million ninth graders taking math in 1972, less than 300,000 went on to college, with 11,000 earning a Mathematics Baccalaureate Degree in 1980. Of those 2,700 went on to earn a Master's in math by 1986 and then only 400 of the original 3.6 million earned a Doctorate in Mathematics. The report called our national education system for teaching math "broken and needs to be fixed" if we want to keep any competitive edge in the world economy.

National Assessment of Educational Progress (NAEP) reported that test data show we are making some gains in lower grades, but only one third of eighth graders are at or above proficiency in math. The latest data show that less than one fourth—about 22% of high school seniors—are at or above proficient. Urban schools score even lower than that because these are national averages (Reardon, 2013).

Sirin's (2005) meta-analytic review of literature to assess the magnitude of socioeconomic status (SES) suggested that students from lower SES had lower academic achievement, with the strongest correlation in mathematics. The study reviewed journal articles published from 1990 to 2000, which I consider one limitation since it is just a ten-year span. The study reviewed data from 101,157 students from 6,671 schools, and 128 school districts from 74 independent samples. The studies chosen had to report in qualitative data, have a SES measure, involve students K-12, and be in the United States. Sirin (2005) attempted to replicate a study done 15 years earlier to see if the magnitude had changed. He found that SES includes neighborhood culture at the time of his study, but very little had changed.

Morgan, Farkas, Hillemeier, and Maczuga (2014) used data from the empirical study The Early Childhood Longitudinal Study Birth 2001 and Kindergarten 1998-99 Cohorts to examine children's mathematic difficulties with a sample size of over 900 students who scored in the bottom 25 percentile. Logistic regression used in this longitudinal study included children ages four and five and as well as a second study of the same students in grades three, five, and eight. The study examined many factors common in urban schools and present in my own school, among them socioeconomic status (SES), preschool attendance, and learning difficulties that may be related to persistent mathematics difficulties. They found a strong relationship between low SES and children's risk of persistent math difficulties. The study further concluded that Head Start and other preschool care significantly reduced persistent math difficulties for children ages four and five, but did not maintain that effect at the later grades of three, five, and eight. This conclusion justifies the need for support throughout elementary and high school for those struggling with math. The study also validated previous findings that vocabulary and reading difficulty can predict persistent math difficulties (Morgan et al., 2014).

Kirkland's (2016) study about mathematics anxiety found key themes of fear, avoidance, dislike, poor attitude about learning math, and test anxiety. Findings suggested a strong correlation between those who have math anxiety and their performance. Kirkland (2016) found that mathematics anxiety interferes with mathematics performance. He also found that teachers who are anxious, negative, or used mostly rote drill themselves tend to perpetuate this in their students as well. As a teacher, I have found this to be true about many things. We teach the way in which we were taught, thinking that it was "good enough and worked for me"—when in many instances, it was not and it did not.

Hughes (2016) did a quantitative survey study at Georgia State University to explore the relationships among mathematics anxiety, mathematical beliefs, and instructional practices of practicing elementary teachers. The study included 153 practicing elementary teachers who taught mathematics to students in Pre-K through fifth grades. The data analysis included descriptive statistics, correlational analysis, and multiple regression analysis. Results showed a significant correlation between mathematics anxiety, mathematics beliefs, and instructional practices. Regression analysis revealed mathematics beliefs as a significant predictor of instructional practices, but not mathematics anxiety. One limitation was that surveys and some of the other instruments used relied on self-reporting. However, other studies have shown that elementary teachers are honest and open using self-reporting instruments. In my personal experience, there is more anxiety when teachers who have trained for lower elementary grades find themselves teaching in intermediate grade levels instead. Due to a shortage of teachers at upper levels, my school had a displaced teacher with 30 years of experience in kindergarten, but no experience trying to teach complex math concepts when placed in the sixth grade classroom. She experienced a lot of math anxiety.

History of Visual Thinking

Rudolf Arnheim, a famous psychologist, began in 1920 to apply Gestalt psychology to art. The Gestalt theory states that there are common connections in nature in which the whole is comprised of an interrelationship of its parts and that perception is not a random collection of sensory data. In his writings, he compared the ideas of historical thinkers to define visual thinking. Arnheim believed that reasoning can happen only after information is received, usually through sight. If our brain only worked to take in just the sensory input of things around us, it would not help us learn (Arnheim, 1984). The mind performs both functions of gathering information and processing that into generalities. We take for granted all that happens in seconds, changing the raw data into concepts. Our thoughts influence what we see, and what we see influences our thoughts (Arnheim, 1984).

Some philosophers whom Arnheim (1984) studied think that messages from our senses are confused and jumbled together until we reason them out. Arnheim quoted Aristotle—"the soul never thinks without an image"—to support his claim that art contributes to the development of reasoning and imagination. The case he made for visual thinking is that perception and reasoning need each other but are different from each other. Cognition is all the mental operations working together, receiving, storing, and processing information: sensory, memory, thinking, and learning.

Today our educational system is based on the study of words and numbers, and fine art is extra-curricular. Arnheim (1984) argued that numbers and letters have evolved historically from a search for sets of shapes simple enough to be produced, perceived, and remembered. He asserted that vision is the primary sense or medium of thought and that visual perception is an active performance. "Visual exploration builds, and is subject to continual confirmation, reappraisal, change, correction, and deepening of understanding" Abigail Housen extended the work of Arnheim in her research at Harvard's Graduate School of Education.

History of Visual Thinking Strategies

The research for visual thinking strategies began with Abigail Housen's theory of aesthetic development, which has been refined over the past 30 years to develop an effective teaching strategy. Visual Thinking Strategies has been used in Kindergarten through twelfth grade in education programs across the United States at museums and in schools. It has been used to train police detectives in improving visual skills to make them better at crime scenes (Yenawine, 2013). It has been used in medical schools to help physicians-to-be accept ambiguity and uncertainty (Klugman, Peel, & Beckmann-Mendez, 2011). VTS improves observation and communication skills (Moorman, 2015), and increases group collaboration to think together and build on each other's ideas. It has been used in art galleries and museums to deepen art appreciation (Longhenry, 2005). Local galleries can train teachers or have programs that partner with schools to bring art and facilitators to the school. There are conventions at the local and national levels throughout the year in which interested teachers may participate to learn the strategies. VTS has been used in studies to train nurses in improving observation skills to make them think more holistically with patients (Moorman, Hensel, Decker, & Busby, 2017).

In the mid-1970s, Housen developed the Aesthetic Development Interview to collect data from art museum visitors as they looked at a work of art. She analyzed over 6,000 interviews and created the stages of aesthetic development (see Table 2). It is a continuum of ability or pattern of thinking. Each stage has certain understandings and skills that the viewer possesses before reaching the next level or stage. The first stage is Accountive viewers. They are storytellers using their senses, memories and personal associations to make concrete observations of a painting or other are medium and weave those observations into a story. The second stage is Constructive viewers. People on this stage build a framework using logic, their knowledge of the world, and their values but not their emotions to make meaning. Stage 3 is called Classifying Stage, viewers are more critical and want to classify the work according to place, school, style, and time to expand their art knowledge. Stage four viewers are Interpretive, and want a personal encounter and appreciate the

Table 2

Housen's Aesthetic Development Stages

Aesthetic development	Viewers understandings/skills	Continuum order
Accountive Stage	Viewers are concrete storytellers. Making personal associations	First stage
Constructive Stage	Viewers build a framework to judge art	Second stage
Classifying Stage	Viewers analyze works of art for meaning and message	Third stage
Interpretive Stage	Viewers let underlying meanings of the work and what it symbolizes emerge	Fourth stage
Re-creative Stage	Viewers willingly suspend belief and begins imaginative contemplation	Final stage

aesthetics, line, shape, color, and symbolism of the work of art and think it is up to reinterpretation every time they see it. The fifth and final stage is Re-creative viewers with a long history of looking at and reflecting on art. They are willing to look at the piece daily like an old friend for personal contemplation.

In 1991, Philip Yenawine was working in the New York City Museum of Modern Art when the Board of Trustees wanted to know if their educational opportunities were effective. Surveys showed that audiences were responsive, enthusiastic, engaged, and positive, but Yenawine wanted to know if he made a difference. He thought that teaching without learning, wastes time and misses the point. I concur on this point, especially as it pertains to mathematics. With the urgency of raising test scores, we do not have the luxury of wasting time in classrooms.

Yenawine contacted Housen, and they began to work together. Housen (2005) said that at the beginning stage, where most visitors to the educational parts of the museum belonged, knowledge is irrelevant. The museum experts did not think like their visitors, so their teaching was disharmonious. They could engage but not enable or empower their visitors. This is true in classrooms in every subject, not just art. Yenawine (2013) believed that teachers confront the issue that what they think they are teaching is not being learned. Most teachers want to change that. I totally agree, and have felt this frustration many times. Yenawine and Housen began working to find effective teaching strategies.

Visual Thinking Strategies Process

Proponents of VTS believe that finding meaning in art is a way of problem solving. To start, all you need are eyes, memories, openness, time, and encouragement to explore. Art images show people, places, things, expressions, interactions, and everything since the beginning of time in most cultures. All the possible interpretations for any one piece of art give rise to broader understandings. The VTS curriculum begins with art and is then applied to other subjects. You follow basic, logical, tested rules, even if they seem restricting at first, to make it a discovery process. The steps are thought provoking and get students to focus, reflect, and think critically. Using the VTS process, teachers and schools can provide students with the same skills in the Common Core such as, “thinking skills that become habitual and transfer from lesson to lesson, oral and written language literacy, visual literacy, and collaborative interactions among peers.”

The basic steps for conducting a VTS discussion are as follows:

1. Present a carefully selected image, based on Housen/VTS research criteria. Ideal images contain:

- Subjects of interest for the specific audience
- Familiar imagery for a given audience
- Accessible meanings for a given audience
- Ambiguity: complex enough to puzzle

2. Allow a few moments for silent looking before beginning the discussion.
3. Pose three specific research-tested questions to motivate and maintain the inquiry:
    - What is going on/happening in this picture?
    - What do you see that makes you say that?
    - What more can we find?
4. Facilitate the discussion:
    - Listen carefully to catch all that students say
    - Point to observations as each student comments
    - Paraphrase each comment, taking a moment to reflect on it while formulating the response to make sure all content and meanings are grasped and helpfully rephrased without judgment
    - Link related comments to build on one another's ideas
    - Remain nonjudgmental by treating everyone and each comment the same way
    - Conclude by thanking students for their participation

Applying VTS to other subjects after practice with art can be done with a little spin on the three basic questions.

For text:

- What is going on in this poem/story/text/graphic?
- What did you read or what part of the image makes you say that?
- What more can we find?

For math:

- What is going on in this graph, or with this problem?
- What did you see/read that makes you think that?
- What more can we find?

For science or social studies images:

- After the standard three VTS questions
- What do you know about __________ (shadows, fossils)?
- What can we learn from this __________ (letter, chart, map, and diagram)?
- What more are you curious to know?

The question, What is going on in this picture?, is open-ended because there is no one single right answer and suggests a story, not just a list. It engages the constantly used neuropathway in the brain that connects the sensory perceptions part to the language center part. It gets students to probe for meaning. The first stage of aesthetic development is the storyteller (Housen, 1983).

What do you see that makes you say that? It is a nonthreatening way to get students to reason. They provide evidence anchored in the image. If you ask, “Why do you say that?” it suggests that there may be wrong answers and asks for judgments, not details. Even if a student only repeats what has already been said, it counts as an observation, and the agreeing with someone else helps those students who are usually shy have something to say. For English language learners, it anchors words with images, which increases vocabulary (Echevarria et al., 2013).

What more can we find? This deepens the process of observation and reflection. It encourages thoroughness and helps students look closely and deliberately. Many times, it draws attention to details missed the first time. When there is more difficulty finding anything new, it is time to conclude the lesson and thank the participants.

Repeating these three questions consistently encourages students to begin to use the same questions in their own exploration of unfamiliar things. VTS promotes cooperation, respect, and tolerance for the ideas and views of others if discourse protocols are followed. The teacher facilitates the discussion by staying neutral and just rephrasing every observation with conditional words such as might and may. This shows they understood what each child contributed, which honors the skill of active listening. It allows the whole group to hear every comment because it is said again and often louder. Paraphrasing student answers into more concise vocabulary with correct grammar is not judgmental, if you begin with, "What I hear you saying is…" Linking comments that are similar draws conclusions and those that are different offers more perspectives, so elaborates meaning. Debate and discussion are ways to test ideas and show that most problems have more than one solution. The layered thinking helps the class work through a problem together while expressing several possible solutions.

Two to ten lessons on art gets the process to stick and then may be applied to other subjects. The curriculum Yenawine (2013) suggests is across all grade levels and all classes. According to Yenawine and other VTS advocates, teachers need a daylong workshop at the beginning of each year for three years and a series of debriefings spaced between the ten lessons. Mentors come twice a year to the classroom for co-teaching and one-on-one reflections. Professional development would vary according to the resources available to different teachers and school districts.

Several studies cited on the VTS website highlighted the inclusion of VTS in many public school systems in partnership with local art museums. In Florida in 2005, the Miami-Dade County Public School System partnered with the Wolfsonian-FIU (Florida International University) museum, library, and research center in a three-year project called Artful Citizenship. The purpose was to understand the relationship between visual literacy and other academic skills. They reported significant findings about the efficacy of the VTS curriculum. Students who received VTS for three years had significantly higher growth rates in visual literacy than comparison group students. There was a strong relationship between growth in visual literacy and growth in both reading and mathematics. VTS promoted good citizenship skills, cooperation, respect, and tolerance for the views of others, and VTS was especially effective with students with limited English proficiency (Curva et al., 2005).

In Boston, there was a partnership between the Boston Public Schools and the Isabella Stewart Gardner Museum from 2003 to 2006 in a study called Thinking through Art. Adams, Foutz, Luke, and Stein (2006) investigated the dependent variable of critical thinking skills they coded as seven different types: observation, interpretation, evaluation, association, comparison, flexible thinking, and problem finding. Students in third through fifth grades from five Boston schools participated. There were two treatment schools and three controls in this posttest-only control group design. The schools had similar demographics ranging from 70% to 98% Hispanic and African-American, and 77% to 90%

free or reduced lunch. Because of the three-year study, the museum shifted its pedagogy of teaching art to VTS instead of their previous Socratic method of questioning with students. They found that students in the program generated significantly more instances of critical thinking skills, had more to say, and were more likely to provide evidence for their thinking (Adams et al., 2006). For fifteen years, Boston Public Schools collaborated with Boston's Museum of Fine Arts because of similar results from several studies. Cities that have art museums like Boston make integration of art into academics easier and may be able to replicate a growth in critical thinking skills in doing so.

DeSantis and Housen (2001) worked with the San Antonio Independent School District, Artspace, and the San Antonio Museum of Art to study the effects of using VTS multiple years. From 2000 to 2002 a random sampling selection from grade three through five were placed in experimental and control groups with 25 students each to measure the impacts of VTS after two years. According to pre- and post-VTS aesthetic development interviews, the experimental group significantly outperformed students who did not have VTS lessons in both aesthetic and critical thinking growth. The students who received the VTS curriculum transferred critical thinking skills, such as supported observations and speculations, to their individual art-viewing experiences independent of the group or a teacher. The students also transferred critical thinking skills fostered by VTS discussions about art to individual viewing experiences of non-art objects. These students were similar to the students in the school where my study was done in that they were low income and had not passed a math and reading readiness test. However, they were largely Hispanic.

One negative comment mentioned in the studies is that when implementing Visual Thinking Strategies, one must begin with art images and not just jump into other subjects first. It also mentions that the three questions must be asked verbatim until practiced because research has shown these specific questions to be the most thought provoking. It has been found that other substitutes do not get the same results. Teachers may think that this is too scripted and prefer following the discourse on its own journey, but research has shown that VTS is more successful if the exact questions are posed in the exact same manner.

Another drawback mentioned in Yenawine's book, *Visual Thinking Strategies: Using Art to Deepen Learning across School Disciplines* (2013) is that VTS is more difficult to adhere to since the core subjects such as mathematics or science often require an exact or specific answer. He suggested that specific material not be used in the VTS type of lesson. Visual images must be crafted intentionally to start the inquiry process in those areas. Math images can launch a discussion facilitated to arrive at correct answers, but after exploring all the observations and evidence without judgment first.

Adult learners have affirmed the efficacy of using the VTS curriculum. Teachers report that most students who participate in the VTS curriculum learn to read more quickly, have greater comprehension skills, and are more capable of expressing whole concepts and completing whole thoughts in a sentence (Landorf, 2006). This study cited other positive things about VTS, such as it is a student-centered method to examine and find meaning in visual art, to teach thinking, communication skills, and visual literacy. VTS uses facilitated discussion to practice respectful, democratic, collaborative problem solving among students that transfers to other classroom interactions. The thoughtful participation nurtures verbal language skills and follows that with interactive writing assignments with a transfer from oral to written ability.

A study from the Public Library of Science explored visuospatial memory, which I find synonymous with visual-spatial intelligence (Gardner, 1983). Li and Geary (2013) asserted that visuospatial memory predicts mathematics achievement through early adolescence. As the focus of mathematics develops from mostly number and arithmetic to algebra and geometry across grade levels, it increases the use of visual aids. More and more diagrams map out mathematical relationships. The study that showed developmental gains in visuospatial memory from first to fifth grade did predict mathematics achievement at the end of fifth grade. The study controlled the variables of prior achievement, intelligence, and parental influences. The 145 participants found the better their working memory assessment, the higher their scores on mathematics achievement tests in sixth and ninth grades. Li and Geary (2013) claimed their findings were consistent with other studies that cognitive abilities have a correlation with visual memory.

Wai, Lubinski, and Benbow wrote, “Spatial Ability for STEM Domains: Aligning over 50 Years of Cumulative Psychological Knowledge Solidifies Its Importance” (2009). This empirical study analyzed both a longitudinal and follow-up study. The researchers asserted that there were certain character traits that help people become scientists and engineers. The year that Sputnik was launched, our nation felt threatened to do better in math and science or be outdone by other world powers. Additionally, The National Science Foundation (NSF) commissioned an advisory panel to develop a report to find the attributes needed in scientific careers. Other landmark publications at the time through the American Psychological Association (APA) stressed the importance of making educational interventions and opportunities to meet individual differences. All recognized spatial ability as key for learning STEM material. Spatial ability was defined as an ability to generate, retain, and transform well-structured visual images. I include this study because it involves visual ability.

Wai, Lubinski, and Benbow (2009) examined the Study of Mathematically Precocious Youth, which was a longitudinal study over 40 years with five cohorts designed to find the best methods for identifying and nurturing talent for STEM. The researchers tracked 563 talent search participants from the Scholastic Assessment Test (SAT) that were 13 years old and scored in the top 0.5%. Over twenty years at five-year intervals, data were collected on their life, education, and career criteria. Wai et al. (2009) found a significant variance that those who said math and science was their favorite course in high school went on to get degrees in STEM areas and ended up in STEM careers 20 years later. The SMPY study also revealed that there was negative z-score value on both math and spatial ability for those who scored high in verbal ability and majored in humanities. Strengths and weaknesses found at age 13 by SAT correlated with spatial ability and STEM coursework and careers. VTS may be one method to nurture spatial ability to increase the number of students going into STEM areas.

Other studies that Wai and his associates (2009) analyzed were Project TALENT (1960-1974), an 11-year follow-up study, and data from the Graduate Record Examination July 1, 2002-June 30, 2005. They found that 90% of all those with advanced degrees in STEM areas were in the top 4% on spatial ability in high school. The conclusion was that spatial ability is a characteristic of young people who go on to achieve degrees and eventually a job in STEM fields. They also concluded that more research is needed on how to "effectively structure educational opportunities to serve students talented in spatial ability" to identify and develop scientific and technical talent in the information age (Wai et al., 2009). VTS may be one such educational opportunity in which to develop visuospatial ability in students.

The nursing field appears to benefit from the use of VTS. Moorman and colleagues performed several studies. In 2017, they conducted a qualitative descriptive study with 55 baccalaureate-nursing students at entry level after a one-hour VTS session with a trained facilitator. Data included written responses to a survey. The study found that student nurses thought they gained observational, cognitive, interpersonal, and intrapersonal skills from following the VTS protocol. These are skills, I think, that are important for success in school at any level. The researchers thought these skills were also essential for career readiness (Moorman et al., 2017).

It is important for many professionals, but especially for those in nursing to be able to understand, interpret, and evaluate visual data. Moorman and Hensel not only were researchers, but also were instructors of nursing. They did two more studies on VTS. They conducted a study of their doctoral students using qualitative methods that examined written responses to how 14 doctorate-nursing students thought they might use VTS in their practice after engaging in classroom VTS sessions. Three themes came from the analysis: facilitating interpersonal relationships with patients, changing thinking in practice, and as a teaching tool to promote listening intently and considering other possibilities (Hensel & Moorman, 2017).

Visual literacy skills help people understand culture and its diversity. Art has also been used with nursing students to promote deep learning and improve communication, facilitate reflection, and develop empathy (Klugman et al., 2011). The primary intrapersonal skill that student nurses perceived was openness, with 14 students understanding that there can be more than one right answer or interpretation (Moorman et al., 2017). I think this would be helpful in math lessons as well.

The Making Math Real curriculum is a relevant example of how multi-sensory approaches can improve the teaching-learning process (Berg & Knop, 2008). The researchers deduced that the more senses a teacher uses in the lesson, the more students would be reached. Using the visual sense for numbers and other symbols in mathematics may help students make sense of what they are seeing so they are able to remember it long term. Maria Montessori (1909) used multi-sensory learning in her method. She believed that everything we know we learned by using our senses. Each sense can interpret stimulus, but act together in an interconnected way. Auditory aids such as music and song have been used to teach mathematic ideas such as multiplication tables and fractions. Likewise, visual aids may be used to teach mathematic ideas.

Katai, Juhasz, and Adorjani (2008) conducted an empirical study using a didactical method. Two ninth grade classes divided into an experimental and control group took a pretest and then for two weeks learned an algorithm. The control groups were taught from a syllabus with classical methods that did not involve multiple senses. The experimental groups were taught the material through many senses. The posttest showed they improved the most, especially in the skills to analyze and design algorithms. A VTS lesson that combines art and mathematics involves multiple senses; the visual sense is the springboard.

The classical methods of teaching mathematics have not been successful with enough of our students. Maybe it is time to teach mathematics with a more multi-sensory approach. The studies with elementary, high school, and college students that explore VTS show significant gains with critical thinking skills. Let us examine the visual part of VTS.

Visual Part of Visual Thinking Strategies

There are two parts to VTS: visual stimulus and thinking strategies. There are many visual resources available to teachers of mathematics, which increase in number as technology expands. Teachers utilize many cognitive strategies to build mathematical conceptual understandings and to get students to think. In efforts to find resources to accomplish better math instruction, many educators have tried to abandon worksheets for computer programs and the drill and practice for modeling and problem-solving. This in turn calls for more thinking or at least a higher depth of knowledge than just simple recall. Let us look deeper into the visual part first.

People process differently through visual stimuli. One theory that supports this is that people have more than one type of intelligence, according to Howard Gardner (1983, 1999, 2011). Using this theory, one could reason that students who are able to activate verbal/linguistic and visual/spatial intelligences along with their mathematical/logical intelligence will be able to make sense of math in multiple ways. These intelligences categorize a person's unique capabilities and the ways they prefer to learn and teach. I believe Gardner's Multiple Intelligences are means to integrate educational theories, teaching strategies, and other pedagogic tools to better address the needs of students. Gardner asserts that just because a student has a stronger intelligence of one type does not mean the others should be ignored. I contend that if a student has a stronger verbal intelligence than math, then using strategies to foster those together makes sense. The New City charter school in St. Louis is one of several in the country that organizes their curriculum and delivery based on the Multiple Intelligence Theory (Gardner, 2011).

Gardner's Multiple Intelligences (2011) are:

- Verbal-linguistic intelligence (well-developed verbal skills and sensitivity to the sounds, meanings and rhythms of words)
- Logical-mathematical intelligence (ability to think conceptually and abstractly, and capacity to discern logical and numerical patterns)
- Spatial-visual intelligence (capacity to think in images and pictures, to visualize accurately and abstractly)
- Bodily-kinesthetic intelligence (ability to control one's body movements and to handle objects skillfully)
- Musical intelligences (ability to produce and appreciate rhythm, pitch, and timber)
- Interpersonal intelligence (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 intelligence (ability to recognize and categorize plants, animals, and other objects in nature)
- Existential intelligence (sensitivity and capacity to tackle deep questions about human existence such as, What is the meaning of life? Why do we die? How did we get here?)

Douglas, Burton, and Reese-Durham (2008) carried out a quantitative study to test the effects of the Multiple Intelligence (MI) teaching strategy on the academic achievement of eighth grade math students and found it made a significant difference. The students in one class were taught using the Direct Instruction teaching strategy incorporating lectures, notes, textbook drill, and practice. The end of the semester test scores averaged 71%. The students in another class at the same school with the same teacher incorporated MI strategies such as logic problems, creating rhymes of the math concepts, building models, inventing a board game, and performing presentations about the math concepts. The same test given on the same day showed these students averaged 79%. The hypothesis confirmed a positive correlation between using Multiple Intelligence strategies and academic achievement.

Second, facilitating a strategy to make up possible stories behind the picture in art can also be applied to mathematical pictures or graphics and eventually other types of problems to make the abstraction of numbers more concrete. Visual learners think in pictures, and VTS will engage that modality, not just the auditory modality, as some current math instruction supports (Kolb, 1984). One vehicle to make students more visually aware is the practice of looking at visually stimulating works of art. There are effective ways to teach different core subjects, and integrating art can motivate and engage some students who may not like those core subjects, such as math (Yenawine, 2013). Visual representations have been used to successfully model math in other types of popular math programs (Schaffhouser, 2013; Tang, 2003). Visual thinking strategies can be an extension of any type of program already in place if facilitated with classroom discourse to get students talking about the mathematics they see and using evidence to back up their assertions (Parrish, 2014).

Two examples of resources popular with educators, parents, and students are Kahn Academy and Singapore Math (Cavendish, 2014). They both have a visual component that brings more attention to that area. The popularity of Kahn Academy is partly due to its use of technology to make math more visible and accessible (Schaffhouser, 2013). Letting the user see what is being said in color with both correct terminology and student-friendly descriptions to help them make the connections between the abstract and the concrete. Singapore Math also contains a visual component called bar diagrams. Drawing a model or bar diagram to illustrate problems again connects the abstract into a more concrete representation.

A multiple-baseline design study was done to investigate the effects of bar model drawing for cognitive strategy instruction (Morin, Watson, Hester, & Raver, 2017). The research question was: To what extent will explicitly teaching bar models increase the ability of urban students to accurately solve word problems? Six random third graders were chosen from a small urban public school district serving 1,300 students in grades kindergarten through 12 at risk of failing mathematics. The students were selected randomly from those who had scored below the 16th percentile on state and district assessments. They were given the bar modeling instruction as an intervention strategy and then post-tested with 15 word problems. The intervention was systematic explicit instruction to teach the process and to enhance number sense. The result was that the resolute and absolute change increased from 0% to 100%. This revealed a functional relationship between the intervention and accurately using the cognitive strategy of bar models. This study's theoretical framework cites bar models as a visual-schematic strategy as well as a cognitive one because the thinking requires a representational aspect. Limitations of the study were that there were only six participants and they were all African-American, but raising scores from zero to one hundred percent caught my interest.

In a recent study, Shin (2013) explored model drawing as a strategy for fraction word problem solving for fourth-grade students with learning disabilities. She asserted that fraction work is harder because it involves conceptualizing number pairs in multiplicative relations to each other. The researcher also asserted that bar diagrams provide a global view of the entire problem. She studied three fourth-grade students who scored below basic on their state assessments. The students were categorized as learning disabled and had at least two mathematics goals on their IEP. The participants were given a pretest, given manipulation criterion intervention, and post-tested. The interventionist started with “think aloud” demonstrations of bar modeling of fractions and the steps of applying it to word problems. After ten lessons, all three were able to accurately apply the drawing of bar models and show mastery on assessments. In addition, they were still able to maintain this level two to four weeks after the intervention. The limits to the study were that the examiner was the researcher, so there may have been bias, and there were only three participants. Bar models—also called bar diagrams—is one visual way to represent mathematics problems. I would use bar diagrams as one way to convey mathematics visually, in combination with VTS. The success found in this study inspired me to conduct a math study with visual components.

The book company that publishes the math curriculum used by other school districts has what they call the “visual bridge,” which is a short video component for each day’s lesson. This company and other mathematics publishers use visual lessons in the technology pieces available to students, teachers, and parents to reinforce and enrich all math strands. See Table 3 for a summary of some commonly used visual components that are used to teach mathematics.

Thinking Part of Visual Thinking Strategies

The National Mathematical Advisory Panel (2008), as suggested in the theoretical framework of Chapter 1, recommended the implementation of curriculum that contains a growth mindset toward mathematical knowledge by encouraging the active participation of all. The Common Core State Standards assert that students will need to think critically, problem solve, reason, listen, speak, and write at higher levels than ever before to be college and career ready (Porter et al., 2011). Math talk or Number Talks support the thinking components of VTS.

Math talk or Number Talks are designed to elicit specific math strategies that focus on number relationships and number theory (Parrish, 2014). It was my belief that a lesson following visual thinking strategies could be designed with math concepts in mind, and VTS could be one more tool that an innovative teacher may use to improve math instruction.

Number Talks is collective thinking. As one of the steps in VTS includes discussion, there is a similar type of instruction called Number Talks (Parrish, 2014). Many mathematics teachers have begun to incorporate Number Talks as part of their mathematics block. My theory is that the premise of Number Talks, sometimes called Math Talks, to build community understandings is the same premise behind Visual Thinking Strategies. In Number Talks students are presented a problem in either a whole group or small group setting and are expected to solve it mentally. They share their thinking and defend their answers, their possible solutions, and the strategies they choose. The teacher asks for more than one example, as there are usually multiple ways to think about a problem and its solution. During the discussion, the teacher dispels misconceptions in a facilitative manner without judging and encourages students to self-correct along the process (Parrish, 2014).

Table 3

Methods to Represent Math Visually

Method	Representation	Results
Kahn Academy	Uses color to write out numbers and other math symbols as the concept is being explained.	2008: 1 instructor, 1 student and daily math lessons 2014: 37 instructors, 10 million students per month, and 3,400 short instructional videos on all subjects
Singapore Math	Bar modeling	1982: published 3-step method of math instruction, concrete (hands-on), pictorial (bar model), abstract (math symbols) Singapore ranked first in international assessments 1995, 1999, 2003, 2009, and spread their method all over the world
Mind Map	Graphic technique that starts with a central image and branches out in all directions to make connections as other words, ideas, and images, are associated	1960: Novak at Cornell researched concept maps Late 1974: Tony Buzan drilled it down to one word or idea to make a spider diagram Used worldwide when brainstorming and structuring knowledge
Pearson's Visual Bridge	Short video animations to illustrate the daily concept to bridge the hands-on to the abstract	Designed in 2000 to resemble Singapore Math's three-step method, but with its own digital spin. 2013: used in every country there is Pearson, esp. Australia and the U.S.
Visual Thinking Strategy	Pictures, graphs, geometric figures, story problems, etc.	1973: Housen develops aesthetic stages for art appreciation 1991: Yenawine & Housen create VTS for gallery education 2014: used by galleries and school districts

Teachers who routinely utilize Number Talks have a designated area in the room that allows the community proximity to the displayed problem and each other for discussion. It is important to build a cohesive community that is a safe, risk-free environment. Everyone needs to feel comfortable offering solutions and questioning their ideas as well as the ideas of others. There should be a feeling of mutual respect and a common quest because the students have the shared authority to determine if each of the solutions given is correct or not. Number Talk lasts only between five and fifteen minutes. It is often the mini-lesson that launches the daily routine. It begins with a problem being displayed and students being given quiet “think” time to not only have an answer but to be able to share “how” they solved it. There is usually some sort of hand signal, like a thumb up, that shows when a student has their answer, and then other signals when they have thought of another way to solve it. As answers are shared, they are recorded by the teacher on the board until all possibilities are exhausted, both the correct and incorrect answers. The teacher must maintain a poker face at this stage and allow the class as a group to clarify their own thinking. This is when students turn and talk to partners to discuss the ideas presented. Going back through the answers gives students an opportunity to consider and test the new ideas and dispel the common misconceptions if there were any.

It is the teacher’s job to facilitate the discussion and the students’ job to build a repertoire of problem-solving strategies. The teachers prepare for the Number Talk with a problem they create with a purpose that is developmentally appropriate for the age group with which they work. The teacher uses correct math terminology and refers to common math practices, such as make sense of problems and persevere in solving them. According to Chapin, O’Connor, and Anderson, (2003), a guided talk allows opportunities to discuss the meaning of words and symbols. This can help students develop understanding and provide practice in using terminology effectively.

Acquiring academic vocabulary is one reason math talks have become popular in classrooms in kindergarten through sixth grade. Having students talking with the correct terminology prepares them for being able to read and write the correct math words. In fact, a VTS lesson contains many of the same components as a Number Talks lesson, as summarized in Table 4.

Academic vocabulary is emphasized in a VTS lesson when the teacher/facilitator summarizes each participant's input. Instead of computation being the focus, as in a Number Talk, the focus is on graphics and pictures during a VTS lesson. The class coming together in a designated area, think time, facilitating group discussion, lasting only 5-15 minutes, and tying ideas to academic vocabulary are key to both Number Talks and VTS. Math concepts and number relationships are the driving force in Number Talks and could also be used while employing the Visual Thinking Strategies protocol if the images are as deliberate as the problems are in Number Talks and are crafted with a purpose.

Mathematics discourse. It is through mathematic discussion that students learn to reason aloud and explain their thinking. In mathematics discourse, the teaching and learning roles in the community are fluid and depend not only on the teacher moves and teacher expertise, but on student academic contributions and relationships (Parrish, 2014). Many students may be new to a learner-centered classroom and must be made aware of the norms.

Students trained in discourse norms often have hand signals and respect each speaker by attentively listening. The older the students and the more they have been in teacher-centered classrooms, the more they need the training. Peer pressure and low self-esteem of many young mathematicians are challenging to overcome, but the safer the community, the

Table 4

Comparing Lesson Components of VTS and Number Talks

Component	Number Talks	VTS
Teacher Preparation	Craft a problem with a specific purpose	Find image appropriate to age and ability of group
Class comes together in a designated area	Yes	Yes
Display	Problem	Image
Quiet think time (1-2 min.)	Yes	Yes
Student Actions	Solve then explain process	Point out what is going on and what they see that made them say that (evidence)
Teacher remains nonjudgmental	Yes	Yes
Teacher asks group for input	Do you agree?	What more can we find?
Students participate risk free	Yes	yes
Group gestures and sentence stems to agree and disagree	Yes	Yes
Teacher facilitation	Dispels misconceptions. Makes terminology precise	Paraphrase each response and bump up vocabulary
Length of lesson 5-15 minutes	Yes	Yes

more risks will be taken. Mathematical misconceptions should be addressed, but they must be handled with care, so that participants will not become discouraged and reluctant to contribute ideas next time.

Lack, Swars, and Meyers (2014) conducted a descriptive, holistic, multiple-case study focused on the participation in mathematics discourse of two low and two high achieving sixth-grade students. The study was done to see which students participated and which did not and why. They observed and videotaped nine lessons in a standards-based classroom. They wanted to examine whether there was equitable opportunity to learn during mathematics classroom discourse between both low and high achieving students. They found that different roles emerged: the evaluator, answer-supplier, claim-maker, listener, solution-reporter, and questioner during the small group and whole group interactions.

There was more equity when the teacher intentionally stepped in and out of the discussion to facilitate engagement and understanding. Rewording a student's response to clarify, or just to make sure it was heard by all, is an important protocol also followed in a VTS lesson. The study found that all students preferred just finding solutions and not having to explain the process. I find that to be the case with many students. Students want to say, "I just know, I don't know how I got it."

Lack, Swars, and Meyers (2014) also found that high achievers profit more than low achievers from mathematics discourse because they found validation. Low achievers had a hard time in small group discussions probably because they needed the teacher to include them and set a slower pace. When given a choice, the two high achievers chose to work exclusively with each other. The researchers also found improvements in the discourse after the students reflected on their participation and interactions by watching the videotapes of the lessons (Lack et al., 2014). Some of the limitations I found with this study were that all the participants were female from a suburb in Texas that was 83% White with few low SES students.

Critical thinking. Camelot Intermediate School in South Dakota implemented VTS and the fourth and fifth grade teachers wrote an article about their findings, "The Synergy that Occurs between Creativity and Critical Thinking Allows Powerful Learning to Occur" (Moeller, Cutler, Fiedler, & Weir, 2013). They thought creativity was addressed by VTS because it involves exploring patterns, shapes, textures, and colors, elaboration, and thinking outside the box. Critical thinking involves examining clues, considering alternatives, using inductive and deductive reasoning, making connections, and exploring possibilities, which is a part of VTS too. Critical thinking also includes analyzing interactions of parts in a whole, analyzing from different perspectives, and drawing conclusions. All of this comes together in a correctly conducted VTS lesson so the students make meaning together as a group by observing, deciphering patterns, clarifying, supporting opinions, and generating several ideas about the same image without judgment. Critical thinking is used throughout the Visual Thinking Strategy.

In many classrooms, the teaching of mathematics focuses on algorithm and fact skill attainment, not critical thinking skills. Teachers could foster critical thinking skills intentionally with VTS. The VTS session addresses critical thinking, partly defined as reasoning, making judgments, and drawing conclusions. Research shows that children between the ages of three and five form thoughts and insights and are developing logical thinking and reasoning (Whittaker, 2014). This means that VTS could begin in grades as early as kindergarten. School districts that have adopted it as part of the curriculum start there.

Analyzing arguments, making inferences, reasoning, and making decisions to problem solve occur in all content areas, but especially in mathematics. This justifies teaching critical thinking skills. Gathering, understanding, analyzing, and interpreting information are significant skills for student success in school and to their future in the workplace and life skills. Whittaker (2014) asserts that very young children are capable of developing reasoning and problem-solving skills, and early reasoning development supports later learning. Teachers can foster critical thinking in children by giving experiences daily to construct explanations of cause and effect. Questions such as the following construct explanations of cause and effect: What is going in this picture? What do you see that makes you say that?

In the article, “Good Thinking! Fostering Children’s Reasoning and Problem Solving” (Whittaker, 2014), six suggestions were given to teachers to support problem solving and reasoning. The first was to facilitate play that involves all the senses: sight, sound, smell, touch, and taste. Then encourage children to talk about those experiences during play and afterward in reflection. The second was to help children understand the difference between guessing and knowing by helping gather evidence to support or reject initial hypotheses. Third, foster categorization skills with materials that allow students to explore, compare, and sort by different attributes, such as, size, shape, and color. Then reinforce vocabulary when describing the attributes’ similarities and differences. Fourth, teach students to think first and then respond to allow for incubation of ideas and respect. Communicating there is more than one right way to solve a problem respects all ideas shared in the brainstorm. Fifth, demonstrate good habits by using the language of problem solving to make observations, make predictions, and share thinking. Teachers’ think-aloud activities demonstrate the process. Finally, scaffold lessons for understanding; allowing children to explore their environment, manipulate objects, and interact with other students helps them construct knowledge and develop negotiation skills. It also helps them gain the ability to ignore distractions, maintain focus, and regulate their emotions and behavior.

VTS may not address all six of these suggestions, but it addresses many. Through a VTS session, the sense of sight is engaged, and there is wait time to foster multiple ideas.

Children are asked to gather evidence to support their hypothesis of what is going on in the picture. Children are encouraged to participate in the discussion and respect all other possibilities. The facilitation process constructs meaning and fosters academic vocabulary. Both critical thinking and VTS capitalize on children's natural curiosity, which is fostered by adult input to help students make sense of this world.

Integrating VTS. There are different debates about cognition and about how humans learn. One group of learning theorists wrote about the need to explore teaching math in different ways than it has been taught in the past in an article titled, "The Enactive Roots of STEM: Rethinking Educational Design in Mathematics." Hutto, Kirchhoff, and Abrahamson (2015) asserted that visualizing mathematics means it may be a multimodal interaction. In other words, it involves visual, auditory, and kinesthetic all at the same time. This is the very reason I explored VTS: because it is multimodal. The study was with 22 students in grades four, five and six, who were given a tutorial task-based clinical interview. Instead of telling students what to do, a teacher fixed an environment, task, and student engagement to steer formative knowledge. All participants could explain the outcomes of the task without ever being told. As in sports, the researchers believed that STEM lessons could put learners into scenarios that resembled the performance environment to refine responsiveness. Like athletic ability is innate, some specific natural numbers are innate and explain why human minds can do mathematics in the first place. Some cognitivist researchers believe that learning always involves manipulations of mental representations of content. Radically enactive approaches to cognition challenge that idea. During the VTS lesson, it is important to guide the group thinking as the individuals contribute their own thoughts. The perceptions of one member of the group at a time can lead to the cumulative perception of all members of the group. If the picture that is examined in the VTS lesson had a math or science focus, then the learning and understanding could increase STEM thinking.

There are many partnerships between schools and even entire school districts and local art museums and galleries to implement VTS. One such partnership between Boston Public Schools and the Boston Museum of Fine Arts has existed for the past 15 years. It continues because of the correlation found between VTS and elementary students' increase in critical thinking and descriptive writing (Longhenry, 2005). Their program, called Thinking through Art, provides slides, a teacher guide, and a culminating field trip to the museum. A case study of the program and five of its teachers found a positive impact on teachers changing their practice to be more student-led, group dynamics improving by respecting more diverse opinions, and increasing student participation and articulation that exhibited critical thinking.

Franco and Unrath (2014) explored if VTS helped boys in kindergarten and first grade in a literacy program that used images in a visual arts classroom as engagement pieces for struggling writers to reach Common Core State Standards (CCSS). The boys grew from "casual, random, idiosyncratic viewers to thorough, probing, reflecting interpreters" (Franco & Unrath, 2014). Including VTS curriculum increased writing abilities and risk taking in these young students. The researchers felt strongly that many of the goals of CCSS are reached through VTS and gave several examples such as standards emphasize integrated literacy, high-order thinking, and cross-disciplinary understandings, which are met with the unique content of art and developed by this art education program. The researchers thought that "constructive evaluation of others' use of evidence and differing viewpoints" (p. 31) came from the boys' different individual experiences. The boys argued less as they accepted multiple possibilities based on the real experiences of others that were different from their own (Franco & Unrath, 2014). I agree that several standards goals could be reached through VTS using higher-order thinking skills and helping the participants learn from one another's reflections.

Across other disciplines, the questioning sequence of VTS aligns with the CCSS, which focus on critical thinking and problem solving, and the Next Generation Science Standards (NGSS), with their emphasis on inquiry-based learning. Capello and Lafferty (2015) explored the use of VTS in science classes. They believed that VTS requires students to inquire (What is going on?) and draw conclusions based on evidence (What do you see that makes you say that?). These are same processes readers engage when negotiating text. Careful review of photographs and illustrations observed and discussed through the VTS process gave students opportunities to use academic vocabulary. In the pre-assessment, nine of the 23 students in the class could identify minerals, whereas in the post-assessment, all students could identify them. Images became tools that helped students gain and use content knowledge as well as academic vocabulary. Support through multiple modalities allowed alternate pathways for students to access the earth science concepts and express understanding (Cappello & Lafferty, 2015).

In some of the studies cited on the VTS website, teachers shared their perceptions of the benefits and drawbacks of integrating VTS within their curriculum. I found that some teachers believe that VTS supports students as they find evidence in text, use academic vocabulary, and engage in accountable talk, all within an instructional setting where students feel comfortable taking risks. One drawback teachers reported was the "occasional tension between lesson objectives and fruitful classroom discourse" (Cappello & Walker, 2016).

Sometimes there must be precise conclusions or just one right answer, and those objectives were not good VTS material. This would be a pitfall to avoid when planning a VTS lesson focused on a mathematical concept.

Because spatial ability and mathematic ability share the same cognitive process, two researchers, Cheng and Mix (2014), decided to test it. They randomly assigned 58 six- to eight-year-olds to either the spatial training group or a no-training group. The groups were given three pretests, two spatial and one math. A week later, the experimental group completed a 40-minute spatial training while the control group worked on a crossword. Both groups given the posttest showed the trained group improved significantly and the control group did not. The strongest link between spatial training and improved mathematics scores was on missing-term problems, such as 2 + __ = 7. One limitation was that the study was done mostly with middle-class White students from Michigan. I would like to see if the same positive results are replicable with a diverse population in an urban setting like mine.

Conclusion: Possibilities for Future Study

Some teachers may be more comfortable with tangible products of each student's connections rather than the verbal connections made with oral discussions used with VTS. Many teachers want individual accountability. Further research may show how to combine these two ideas of visually representing math or that mind mapping would yield more connections per student individually. One of the benefits of a VTS discussion is that it is a group collaboration and a community building exercise. If properly implemented, students learn to agree and disagree with polite scholarly discourse, and how to find evidence to support claims. Language learners should read, write, speak, and listen daily; VTS lends itself to the speaking and listening whereas other math problem-solving strategies focus only on reading and writing to model the solutions.

VTS is a method grounded in artwork that I wanted to expand in this study to include math content. The images would need to be gathered or created that would promote math content that can be represented visually. Showing the teacher-crafted math images following the VTS method would be the next step, then practicing the VTS lessons with artwork for five to ten lessons, and finally branching out to math images, such as graphs, tables, number lines and other visual models.

Currently many programs attempt to incorporate a visual piece to increase mathematic skills (see Table 3). Many mathematics teachers who have used these programs know firsthand how teaching with more than one modality increases learning and reaches more students.

Being able to draw a picture is one effective strategy for problem solving, so I believed that learning how to analyze a picture previously drawn, such as a graph, through VTS would also be an effective problem-solving strategy. The use of bar diagrams in Singapore Math has been adopted and adapted by many math instruction experts to help students see the numbers in visual representation. Color, animation, and mind mapping have been used in several attempts to visually represent math.

There is a gap in the literature about using VTS with mathematics. This study will add to the current knowledge on VTS, which currently focuses more on language and would expand it to include the discipline of mathematics more fully. VTS has been used with students from age five to adult with a positive impact on increased observation skills and critical thinking. These two skills are required in all core subjects. The core subjects that make up STEM besides mathematics would also benefit from VTS, especially science. The step after setting up the experiment in scientific inquiry is making observations and then finally using critical thinking skills in the step of inferring to draw conclusions. VTS has shown through many studies to increase observation skills. Science teachers may see this study of using VTS in math as analogous to include art instruction prior to teaching observation skills. Any program that increases thinking is worth doing, right?

Transformational leadership focuses on developing the organization or school's capacity to innovate. Rather than focusing specifically on direct control and supervision of curriculum and instruction. A transformational leader seeks to build capacity in others to select purposes and to support the development of changes to practices of teaching and learning (Hallinger, 2003). VTS is a change of teaching practice and an innovative leader could empower innovative teachers to get training and then apply the protocol to their area of expertise.

Transformational leaders create school climates in which teachers engage in continuous learning. Then they encourage teachers to share their learning with others. Transformational leaders help staff to identify personal goals and then link those to the broader organizational goals (Hallinger, 2003). The principal creates a climate of committed and self-motivated teachers that work towards the improvement of the school without specific direction from above. It was a transformational leader that gave me the autonomy to embark on this VTS journey to increase critical thinking in mathematics.

CHAPTER 3

METHODOLOGY

I have heard adults say things like, "I was never good at math." People would not so readily admit difficulty in reading but proclaim deficits in math and laugh it off. Teachers have asked me for guidance with certain math concepts they did not know well enough to teach. When I took a job in a SIG school that achieved less than 5% proficiency in math on the state achievement test, I began an earnest search for better ways to teach mathematics. I think Visual Thinking Strategies may be one way to do that.

This study was implemented to address the problem of low math scores in urban schools that have students with low socioeconomic status that may be impacted by the way math concepts are generally taught. The State Assessment Program for this Midwestern district reflected math scores in 2013 where only 53.9% of the students were proficient or advanced in mathematics. The achievement gap reported by the state shows passing rates of white students at 59.2% and black students at 30.2% (Sarah, 2014). The low scores continue to be a problem for math teachers and school leaders.

Mathematic concepts taught with ineffective strategies compounds the problem. Academic performance is influenced by environmental and cultural factors. Moreover, public schools often disserve and underserve African American males (Noguera, 2003). Students are active participants in their own education, and the structures and culture of a school influences how they see themselves. Teachers who can capture a student's imagination and keep them engaged help them learn to take risks in a psychologically safe environment. Teachers who do not show confidence in themselves or their students create distrust, apathy, and resentment and perpetuate the lack of efficacy and equity.

The purpose of this heuristic descriptive study was to explore of the use of Visual Thinking Strategies as it applies to mathematics instruction for teachers in a small, urban elementary school, grades 1-6, in a large Midwestern city. Heuristic inquiry fit this study because it falls under phenomenology, which involves the researcher living the experience of the phenomenon with the participants. Heuristic inquiry also fit this study because the researcher was the primary instrument of this type of qualitative research, and I, as the primary instrument shared VTS lessons during the implementation of the study. VTS was the intervention that I wished to share with other teachers in my building. I undertook this experience and then analyzed the interpretations of each co-participant to build an understanding. I focused on the described experiences of each teacher-participant through observed VTS sessions, field notes, surveys, in-depth interviews, focus groups, and my journal reflections. Heuristic inquiry differs from other forms of phenomenology in three ways: the researcher has a personal connection instead of detachment; it leads to personal meaning rather than description of a structure of an experience, and it challenges objectivity (Patton, 2015).

At this stage in the visual thinking strategy research, which is used in studying art (Housen, 1983), three main questions are posed:

- What is going on in this picture/graphic?
- What do you see that makes you say that?
- What more can you find?

At first, the questions are asked by a teacher/facilitator who points out the items in the picture or graphic mentioned as they summarize what each participant shares while bumping up the vocabulary and constructing meaning as a group by exploring all the possibilities. I explored how teachers can apply these strategies to academics such as mathematics.

The unit of analysis was teachers' experiences with the implementation of the visual thinking strategies in the classroom gathered from data and analyzed during the illumination step of the heuristic process. The implementation of VTS began with elementary teachers who have an interest in VTS training and who teach mathematics daily. I began with a survey to assess their current knowledge of VTS. Then I went to classrooms twice a week to model lessons in VTS using art and eventually applied VTS to math images. Then, through reflective conversation following the lessons, in-depth interviews, and a focus group discussion, the co-participants communicated their experiences.

The significance of the study will be to include VTS in the professional development of math teachers as a way to improve math scores and possibly narrow the achievement/opportunity gap with a new tool that incorporates verbal and visual intelligences with the mathematical. Educational leaders who are attempting to improve math achievement and keep STEM movement goals will have an interest in the outcome of this study. There have been studies conducted with VTS, but none have been applied to mathematics. This study will add to the current knowledge on VTS.

The following central question and sub-questions guided this study:

Central Question: How can Visual Thinking Strategies improve mathematics instruction?

a. How do teachers apply the three main questions of VTS with teacher "moves"?
b. What do teachers do to reinforce restatements of evidence regarding explicit teaching of mathematical concepts?

c. What are teachers' perceptions of the facilitation of group discourse related to the reinforcement of academic vocabulary?

This chapter contains the following subjects: the rationale for qualitative research, the design of the study, data analysis procedures, limitations, and ethical considerations. Throughout this chapter, I show that each aspect of the study design was carefully selected to produce the most fruitful data for in-depth analysis and thick, rich descriptions.

Rationale for Qualitative Research

Qualitative research is strategic and theory driven and conditions are the concern not the generalization of findings to other settings. My study was qualitative because it used real world evidence with empirical data that was time and context bound. Qualitative research involves intense and prolonged contact with participants in a naturalistic setting to investigate a phenomenon (Patton, 2015). As a mentor teacher, I have prolonged contact in the school and the classroom settings. The assignment of qualitative researchers is to provide a framework that allows co-researchers the freedom to express their perspectives of the world as they experience it (Patton, 2015). I am a colleague and peer of my co-participants and encouraged their honesty.

Qualitative researchers seek to learn about a subject matter in a natural environment, as opposed to a lab or controlled setting; this allows the researcher to experience the phenomenon first-hand and describe the experiences of the participants as closely as possible. Denzin and Lincoln (1995) stated:

> Qualitative research is multimethod in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them. (p. 3)

It was appropriate to utilize qualitative research in this study because I was studying groups or populations to obtain a complex understanding of a phenomenon and to understand the contexts and setting in which participants live that phenomenon (Creswell, 2013). This type of research allows for in-depth study and a rich description of the findings. It does not seek to measure variables or prove hypotheses, but to describe the experiences, perceptions, and beliefs of people. I wanted to describe the experiences of the teachers and myself as we explored VTS.

There are several differences between qualitative and quantitative research. Qualitative research is an inductive method using research questions to gather data, form conclusions, and then present findings in a narrative form. Qualitative research methods produce ample detailed data about a small number of participants (Patton, 2015). It explores reality only as it exists for a particular study and in a particular context; therefore, study reproduction is almost impossible, as the study could not be replicated exactly as it was before.

"In contrast, quantitative research," as Grbich (2013) stated, "is generally viewed as deductive, where the conclusions drawn follow logically from certain premises—usually rule based—which are themselves often viewed as proven, valid, or 'true'" (p. 26). The open-ended, unsystematic responses given by participants in qualitative research allow the researcher and audience to better understand the experiences of the participants (Patton, 2015). Qualitative data do not make judgments about whether what has occurred is good or bad; it simply recounts the circumstances and describes what has occurred (Patton).

Qualitative research also utilizes a theoretical tradition or orientation, from which the researcher shapes research questions, study design, and methodological procedures. These traditions help clarify the diversity within qualitative research, as it cannot be lumped into one singular research method; they also help to identify the goals of the study, as each tradition reveals the perspective and the lens through which the research is conducted. Heuristic inquiry is a form of phenomenological inquiry that emphasizes the personal experience and insights of the researcher (Sela-Smith, 2002).

Heuristic Inquiry

Heuristic was chosen as the inquiry method for this research because it is process-oriented, concentrates on events and aspects of the experience and not results, allows the researcher to live the phenomenon and be passionate about the subject matter, and provides structure to explore meaning of a lived experience. After a lengthy career in education, I have tacit knowledge about math and instruction, which is a part of the heuristic method. This method design chose me more than I chose it because of the word intensity (Patton, 2015). I was intensely excited to study how VTS might be used to improve math instruction, which may be one contributing factor to low math achievement by low SES urban students.

After studying Moustakas (1990), Sela-Smith (2002) concluded that there are six key components to heuristic inquiry:

- The researcher has experienced what is being researched.
- The researcher has some intense or passionate concern that causes the investigator to reach inward for tacit awareness and knowledge.
- The researcher surrenders to the question (living, waking, and dreaming the question)
- Self-dialogue, not just a one-way report of thoughts or feelings, but dialoguing with the feeling.
- The search is a self-search.
- There is evidence that transformation has taken place by way of a “story” that contains the transformation and may transform who “reads” it. (p. 29)

This trial-and-error process, this discovery of what works, is heuristic. Heuristic inquiry is open-ended with only the initial question as the guide (Moustakas, 1990). I have had a long personal journey as I learned, taught, and tested math in classrooms in rural, suburban, and urban schools around a Midwestern metropolis. My experience in the field of Visual Thinking Strategies has created a passion for applying the method in mathematical instruction, leading me to select heuristic inquiry as the theoretical tradition for my study.

The systematic process for data collection and analysis for heuristic inquiry is:

- Immersion: the researcher becomes totally involved in the experience.
- Incubation: the researcher deliberately withdraws into quiet contemplation to construct meaning.
- Illumination: themes and patterns emerge that bring new discoveries and clarity.
- Explication: the researcher organizes the data to refine meaning.
- Creative Synthesis: the researcher communicates a rich description of the experience in a personal and creative way. (Moustakas, 1990)

The process of heuristic inquiry began five years ago for me. My initial engagement was when I was first introduced to Visual Thinking Strategies through a professional development workshop at a local art gallery. One classroom teacher allowed me and the museum facilitator to come in once a week for ten weeks to provide lessons focused on art images with the discourse piece, and then as a springboard for writing. I experimented with a only few math graphs at that time, and I got hooked.

I felt intensely from that moment on that the process could be useful in mathematics instruction. I was immersed the following year as VTS expanded from one class in my school to three and I observed its use in those classrooms. I have been in the immersion and incubation phases while doing a literature review, enrolling in more professional development opportunities, and having three classrooms involved with the local art museum and VTS for two school years. When I began the data process in my new classrooms, I lived with the study before, during, and after work.

My journey began with VTS in the classroom of one third grade teacher and a museum facilitator. The first teacher was a veteran African-American female teacher of 30 years. The VTS program broadened the following year to include a first grade, a fourth grade, and a sixth grade with diverse male and female teachers that had between 1 and16 years of experience, and a different museum facilitator, but the academic focus that accompanied the art was writing. I was the VTS facilitator who co-taught with five new teachers in grades 1, 3, 4, and 5 who had between 2 and 30 years of experience. We analyzed the teacher moves that worked best and those that did not aid in math conceptual understanding. When they felt confident in the visual thinking strategy, I observed them teaching VTS sessions.

The incubation has been throughout the past five years as I researched VTS and the reasons I believed it would work applied to mathematics. The incubation continued throughout the study and was cyclic as I collected and analyzed data from each observation. My tacit knowledge of mathematics and effective instruction was reflected in field notes and a journal as I coded the data to find connections and patterns and themes. I described my personal experiences and those of my fellow participants as I reflected with them, both individually and in a final focus group. The tools I used as a heuristic researcher were self-dialogue, tacit knowing, intuition, indwelling, and focusing. My sampling was purposeful as I selected different grade levels, but focused on the co-participants who shared the experience with VTS. The reflective time was to construct meaning and develop ways and images to incorporate VTS in math.

I first experienced illumination when I observed obstacles in classroom cultures regarding discourse and a growth mindset. I felt a light bulb go on when I began to wonder if the questions asked in VTS could be applied to a visual image based on mathematics content. In my study, I continued to experience illumination through the data collection process of observations, field notes, questionnaires, in-depth interviews, focus groups, and my journal reflections.

In the explication phase, I organized and transcribed the data according to themes and searched for pattern regularities or irregularities. I included data that confirmed my beliefs as well as those that did not. I sought validity after transcribing the questionnaire, interviews, and observations in a focus group discussion by having the co-participants read over their parts and giving them the opportunity to add anything that I missed. I remained open to new possibilities of meanings and confirmations of meanings throughout the reflective discussions. This phase was the unfolding of the process through focus, self-dialogue, and reflections (Patton, 2002, p. 486).

My creative synthesis step was writing my dissertation conclusions in an acrostic poem. I attempted to create as thick and rich a description as possible from a holistic perspective. I hope the intensity of feelings and intuitiveness is conveyed with my words, because as a mathematics teacher, I am better with numbers than words. Creativity is limited by my vocabulary and inability to express myself with words and phrases. This part of the process was most difficult for me; however, the study was fun and creative as an alternative method to teach mathematics.

Design of the Study

The setting was a small urban elementary school with grades 1-6 in a large Midwestern city given the pseudonym, Smart School. It is a school where I started this VTS journey, and in which I currently teach. There were a lot of advantages to direct, personal contact with participants and observations of the setting. One advantage was getting a more holistic perspective to capture the context within which people interact with the phenomenon of VTS (Creswell, 2013). Another advantage was that firsthand experiences allowed me as an inquirer to be open, discovery oriented, and inductive. I found teachers willing to have lessons in the classroom that focused on art first, and then mathematics topics, and who encouraged proper classroom discourse protocol.

Possible participants had to be willing to complete surveys regarding VTS, reflect on our practice twice a week, and collaborate to explore math concepts and images. I chose colleagues that I knew to be “warm demanders” (Delpit, 2012) from collegial discussion and observation to ensure high expectations. The purposeful sampling was based on these criteria, as defined by Creswell (2013), as “all cases that meet some criterion” (p. 127). Participants were ensured responses were confidential and that their participation was voluntary. Co-researchers were informed that participation included classroom observations, surveys, interviews, and a focus group discussion, all of which were voluntary.

I advised my fellow researchers to be careful with the VTS protocol to adhere to the three guiding questions, but also allow roles of the speaker and listener within the participating group to be fluid and interchangeable. Many cultural communities believe in pooling resources to solve problems. I see VTS as just that, where everyone contributes to the collective task.

Data Sources

Qualitative research typically incorporates three different data sources: in-depth, open-ended interviews, direct observations, and written documents (Patton, 2015). By using three separate methods for data collection, crystallization of the data occurs. Patton (2015) stated, "A rich variety of methodological combinations can be employed to illuminate an inquiry question" (p. 248). By using multiple methods, the researcher is answering research questions to his or her fullest extent and corroborating the findings through what he or she sees in observations, hears in interviews, and reads in documents.

Surveys. Surveys were used to gathers participants' perceptions of VTS before the implementation of the study and after the final data set of focus group interviews were conducted to discuss findings and confirm emerging themes. Open-ended questions were used in the construction of the survey. These types of questions provided participants with the opportunities to share their experiences, thoughts, and feelings without the restricted response choices available in Likert-type items. These were not questions that could be answered with a "Yes" or "No" response; these questions were exploratory and allowed participants to be more open about their experiences with VTS. Their answers served as a dataset to help crystallize the findings (see Appendix A for survey).

Documents. The term data, according to Bogdan and Biklen (2007), refers to the rough materials researchers collect from the world they are studying; data are the particulars that form the basis of analysis. Data also include what others have created, such as diaries, photographs, official documents, and newspaper articles. Documents allow for objective analysis and can validate the themes identified through the other methods. For this study, I used documents used in image selection for VTS with art lessons and my field observation notes and reflective journal.

I used electronic folders of art images from our local art museum that are appropriate for various grade levels (see Appendix B). The VTS images depict a wide variety of subject matter with regard to age, gender, time, place, social class, and positional diversity within and across ethnic groups. I considered preparing for culturally responsive teaching (Gay, 2010), but the symbolic curriculum was only the instrument. It was up to the teacher or facilitator to convey values and actions about diversity for the classroom culture and climate to promote responsive learning communities.

Interviews. Qualitative interviews are used when researchers want to gain insight from participants concerning particular phenomenon or experiences (deMarrais & Lapan, 2004). Words are concrete, vivid, and more meaningful than numbers (Miles, Huberman, & Saldana, 2014). I focused on words as the basic medium and used the words involved in interviews that have been refined from raw notes or recordings into a text that is clear to the reader or analyst (Miles et al., 2013).

I recorded, transcribed, and analyzed all the interviews according to the heuristic analysis process in order to be objective, specific, and to quote rather than summarize (Bogdan & Biklen, 2007, p. 7). Interviews were a semi-structured model, with an interview guide (see Appendix C) to help direct the interview. The interview guide consisted of open-ended questions to ask but also allowed for follow-up questions as needed (Patton, 2015). According to Patton (2015), with an interview guide, the interviewer is free have a normal conversation, word questions spontaneously, and establish a focus on a predetermined subject. I interviewed participant teachers for their perceptions because perceptions were my unit of analysis. I interviewed participants before and after the study until I had enough data to draw some conclusions (see Appendix C for interview guide).

A focus group interview was organized to generate a discussion regarding the findings as well as confirm themes (see Appendix D). Focus group interviews are similar to individual interviews; the difference is that participants can hear the responses of others and decide to elaborate on what they hear. Group interviews require a more skilled interviewer than individual interviews (Fontana & Frey, 2008), balancing the tasks of moderator and manager of the focus group. With this in mind, I served as both moderator and manager of the group, careful to set up the audio recording ahead of time and keep the conversation intentional, but flexible.

Observations. The use of direct observations in qualitative research is important to provide crystallization among findings from interviews and documents, as well as to increase credibility of the study's findings. They also provide a holistic view. In this study, direct observation helped fully answer the stated research questions. I had teachers observe me implement VTS lessons that applied the strategies to mathematical images and content. When observing the art lessons to learn the strategies, I was a participant-observer because this role was grounded in the establishment of considerable rapport between the researcher and the host community and required the long-term immersion of the researcher in the everyday life of that community (Angrosino, 2005). I am a teacher in the building, so it was natural to the students for me to visit and teach in their room.

Fieldwork is more effective when grounded in building and keeping relationships (Brayboy & Deyhle, 2000). I felt unobtrusive during the observations since I am in those classrooms on a regular basis. The students know when I am in their room that I am observing them and expecting participation. I used an observation guide to capture the aspects of VTS (see Appendix E for Observation Guide).

Data Analysis Procedures

My tacit knowledge of math and effective instruction was noted in a reflective journal in which I planned to code the data in order to find connections and patterns or themes. I described my personal experiences and asked my co-participants to do the same in conversations that followed the lesson. The tools I used as a heuristic researcher were self-dialogue, tacit knowing, intuition, indwelling, and focusing. My sampling was purposeful since I selected different grade levels and teachers whom I knew had established some discourse protocols in their classroom culture. The incubation phase was reflective time to construct meaning and develop ways to incorporate VTS in math.

In the explication phase—the unfolding of the process through focus, self-dialogue, and reflections (Patton, 2015)—I organized and transcribed the data according to themes and searched for pattern regularities or irregularities. I included data that confirmed my beliefs as well as those that did not. This is the point that was cyclic, as I sought validity from my co-participants after transcribing each interview or observation. I had to refer to the research questions in order to construct meaning of the phenomenon. I remained open to the possibilities as they emerged.

The creative synthesis was writing about the findings. I wanted to create as thick and rich a description as possible from a holistic perspective. I hoped to also eventually create a guide about how to use VTS in classrooms to improve mathematic instruction and possibly utilize the visual and verbal intelligences and learning modalities in a more meaningful way when teaching math.

Qualitative data collection produces a large amount of data from field notes, journals, transcripts, and observations to analyze and synthesize so that the themes emerge and research questions are answered. The heuristic process outlined by Moustakas (1990) was my research process.

Codes divided into categories of descriptive and interpretive during analysis make sense of the data. Miles, Huberman and Saldana (2014) stated, "Descriptive codes…entail little interpretation. Rather, you are attributing a class of phenomena to a segment of text" (p. 57). Interpretive codes provide deeper insight into the phenomenon and data collected; they also allow for grouping to determine the third class of codes, pattern codes. Pattern codes are inferential and illuminate the study results in even greater depth; they indicate an inferred theme or pattern in the latter part of a study, when patterns become more apparent.

Pattern coding, or developing themes, is a process of grouping segments of data and interpretive codes into a smaller number of sets (Miles et al., 2014). This process involves grouping interpretive codes according to meanings and relevance to the studied phenomenon; they contribute to the significance of the study and, through pattern codes, answer research questions. Themes develop using the enumerative process, outline by Grbich (2013), who stated:

> This involves the listing or classifying items by percentages, frequencies, ranked order, or whatever is useful to the research question. These approaches involve you in the production of 'objective' accounts of verbal, written, or visual texts, the development of codes or categories, and the definition and measurement of units of analysis. (p. 18)

Using this process to examine the frequency of the interpretive and descriptive codes allowed me to understand the larger themes. The process of coding and identifying themes is one of the essential elements of analysis. Though time-consuming, it is a critical piece to answer the research questions accurately.

Analysis of survey items. The analysis of qualitative items followed the qualitative data analysis steps described in the previous sub-section. Codes divided the survey into categories of descriptive and interpretive text during analysis. Descriptive analysis of the phenomenon associated items with interpretive codes, providing a more inductive process leading to the grouping of the data into pattern codes or themes. From this process, a smaller set of themes emerged (Miles et al., 2013). I made codebooks of the theme categories to analyze the interviews and observations to determine if common themes were identifiable in the data. All survey responses that were associated with various themes came together as part of the data sorting process, leading to findings from the survey. Often the results of the qualitative analysis help to explore themes from the other data, as it did in this study.

A discussion follows concerning the limitations, including validity and reliability of this study and the strategies employed to address the limitations; ethical considerations for working with human subjects are reviewed.

Limitations Including Validity, Reliability, and Ethical Considerations

Limitations

Limitations are the weaknesses of the study; the reader must keep them in mind as they judge the study. This study is limited by the use of participants from an urban public school in the Midwestern United States. The purposeful sample limited the study in its possible transferability, as the strategies may yield different outcomes in a variety of settings. The findings are tentative and knowledge elusive (Creswell, 2013). This heuristic study was guided my personal experience; and as the research instrument (Patton, 2015), I constantly examined my biases as a mathematics coach and instructor. I maintained a journal throughout the study to record my reactions to participants and capture my thoughts regarding the experiences of participants. I wrote daily in order to minimize the problem of forgetting details. I wrote down my observations while they were fresh in my mind, but since I did not tape the lessons or reflective conversations, the observations were solely from my memory, or from what I understood my co-researcher had conveyed.

Another limitation is that the data collection took place in a school where I teach. I guarded against the possibility of reactivity or influencing the participants. In an attempt to avoid influencing the participants, I refrained from asking leading questions during the data collection phase. I used a critical friend in peer debriefing to maintain validity. As facilitator, I tend to be a nurturing mentor to prepare the other teachers to conduct lessons on their own; and this, in turn, tends to make the mentees feel loyalty and obligation. I fostered an equitable peer mentality and purposely built collegiality to avoid reactivity. I treated the other teachers as co-researchers in our VTS journey. I sought their help and input by involving them as reflective teachers to make each math lesson effective.

To assist with capturing the data, I kept a reflective journal to include a daily schedule and logistics of the study, a diary section for reflection and insights, and finally a methodological log to record the data for each method chosen. I know that distancing oneself does not guarantee objectivity. I strived for empathic neutrality toward the co-participants while still being passionate about the phenomenon.

Validity and Reliability

In a qualitative study, strategies of addressing validity and reliability overlap. Validity is the correctness, credibility, trustworthiness, and authenticity (Denzin & Lincoln, 1994; Maxwell, 2005; Patton, 2002). Credibility, according to Patton (2002), depends upon rigor in methods, researcher credibility, and an appreciation of and belief in the value of qualitative research. Creswell (2013) suggested that "reliability and generalizability play a minor role in qualitative inquiry (while validity) is used to determine whether the findings are accurate" (p. 195). Reliability refers to trustworthiness, whether the findings would be similar in repeated studies. Reliability is about the participants in the study being truthful and recognizing their potential biases when analyzing the results of the data (Creswell, 2013).

It was up to me as the researcher to identify strategies to control the bias so that it did not interfere with the validity of the study (Maxwell, 2005; Patton, 2015) such as bracketing as Moustakas (1990) suggested. I bracketed or suspended my own belief in VTS to study the reality of each lesson with the new phenomenon. I attempted to suspend my preconceptions, to hold up the phenomenon of VTS for serious inspection, especially as applied to mathematics instruction.

In this study some potential threats to the validity and reliability were: (a) the accuracy of data captured; (b) the interpretation of events as seen through my lens as a researcher (bias); (c) influencing the participants during data collection (reactivity) and (d) my limited writing expertise. I have a stronger mathematical intelligence than linguistic. I recognize that writing is a process of discovery. I tried to find my voice to allow me to record my observations accurately, while also uncovering the voice of the participants in their experiences. As Richardson (2000) warned, observations filtered through human eyes and human perceptions has its limits and feelings. I know there is always more to know, and I can only get a partial understanding.

Recordings, field notes, and transcriptions from interviews and observations accurately described the experiences. The recording technology, specifically an iPad, allowed me to record without some of the limitations that come with the bulk and intimidation of a tape recorder. However, a limitation did exist in the behavior of the participants when an iPad is present and recording; people often behave differently when being recorded. This can result in reactivity, with teachers altering behavior simply by reacting to the technology. By recording, the researcher may not see a true experience. However, to limit this threat to validity, the iPad was discreetly used to record only the audio part of the interview (although participants knew the iPad was present). In addition, to support my data, I used field notes to corroborate the experiences in interviews and observations.

To address the validity and reliability concerns, I used multiple data sources. I used reflective journaling along with the interviews, observations, open-ended surveys, and the focus group discussion with my participants. I had each participant review my interview questions, as well as transcripts and data analysis of their interview to ensure my interpretation of the data was logical and accurate. This also was to allow them to add anything they thought may have been missing from their experiences. I used member checking and peer debriefing to maintain validity. Member checking involved letting the participants read over their reflective conversations, observations, and the focus group discussion transcriptions (Grbich, 2013) to check for clarity and a true picture of the data.

Ethical Issues

According to the compliance procedures of UMKC's Review Board (IRB), cases of research involving human subjects should show respect for all persons involved and demands that subjects enter into the research voluntarily and with adequate information as to the nature of the study. As the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research (1979) stated in The Belmont Report, there are three basic ethical considerations, which one must observe when conducting research with human participants. The Department of Health, Education and Welfare (1979) stated:

> The expression "basic ethical principles" refers to those general judgments that serve as a basic justification for the many particular ethical prescriptions and evaluations of human actions. Three basic principles, among those generally accepted in our cultural tradition, are particularly relevant to the ethics of research involving human subjects: the principles of respect of persons, beneficence and justice. (p. 5)

My understanding of this was assessed in the CITI Exam to ensure that I treated my co-participants with respect and fairness, and to look out for their welfare. Sales and Folkman (2000) warned researchers to give their human subjects all the information possible and to stress that their participation is voluntary in order to be truly respectful. Thus, I was forthright with the participants about the purpose, procedures, goals, risks, and anticipated benefits of this study. I let them know up front as truthfully as possible what my intentions were for conducting this qualitative study, which ultimately was to be a better mathematics teacher and broaden students' mathematic conceptual understanding. Each participant signed a consent form acknowledging that their participation was voluntary and free of coercion and undue influence; withdrawal was possible at any time.

Angrosino (2005) explained that the researcher is in a privileged position and must take steps when disseminating results to "avoid hurting or embarrassing people who have been trusting partners in the research endeavor" (p. 736). I maintained confidentiality and used preselected fictitious names when analyzing and presenting the data. Following the procedures and taking the Collaborative Institutional Training (CITI) exam ensured I conducted my research safely, responsibly, and ethically. My goal was to protect my co-participants, my staff, my research, the university, and myself as they enabled and encouraged academic exploration, collaboration, and innovation. I did not deceive the participants about the purpose, procedures, goals, risks and anticipated benefits of this study. I kept all transcripts on an external drive that I kept under lock and key while at my home office. Data security was also of the utmost importance. All recordings, such as interviews conducted with the use of the iPad, were only accessible by the researcher using a security code. Immediately after recordings, written transcription took place. At that time, all recordings were erased; while in the possession of the researcher for analysis purposes, all data were kept in a locked filing cabinet in the researcher's home office. In keeping with IRB guidelines, data pertaining to the study will be kept for seven years in the office of the principal investigator in a locked cabinet.

No personal or identifying information of participants was on my laptop because I kept all records saved on an external hard drive. A master list of pseudonyms of participants with identifiable information were kept on a password-protected computer.

In conclusion, my study design employed in-depth interviews, documents, surveys, observations, and a focus group discussion as major data sources. In this study, I used multiple data sources to crystallize the perceptions as my unit of analysis.

CHAPTER 4

INTERPRETATION OF DATA

This chapter presents the data from co-researchers of the VTS study as it applies to mathematics. In it, I will convey our perceptions, as they became clear in the illumination step of the heuristic process.

The problem of persistently low mathematic scores of many free and reduced lunch students in urban schools was addressed in this study. Nearly one-third of fourth grade children from low socio-economic households do not reach basic achievement levels in mathematics as defined by the National Assessment of Educational Progress (Lee et al., 2007). This statistic remained significantly unchanged from 2005 to 2011 (National Center for Education Statistics, 2011). Math teachers' and school leaders' attempted reforms have not yielded significant positive results (U.S. Department of Education, 2011). Ultimately the problems for the students who continue to have limited proficiency in math include the chance to attend college or other post-secondary opportunities, chances of procuring a job in any STEM field (Fielder, 2012), and facing a lifelong challenge with budgets, income tax, managing time, and other math-related life skills.

Compounding the problem may be ineffective math instruction. Too many worksheets or plugging students into computers is not the answer. Mindless practice does not teach problem solving. I agree with Lisa Delpit (2012), that teachers can be ineffective by what they misconstrue as nurturing, but is in reality, lowering expectations. In her article, "Multiplication Is for White People: Raising the Expectations for Other People's Children," she contends that teachers should be warm but demanding. I have seen effective teachers modeling what Delpit describes. These "warm demanders" recognize the obstacles in their students' lives but still expect a lot from them. Because their teacher believes in them, the students believe in themselves. I chose co-researchers (see Table 5) whom exhibited growth mindsets and warm demanding from collegial interaction and observation to participate.

Table 5

Demographics of Co-researchers

Pseudonym	Gender	Race	Grade	Experience	Degree Held
Bear	Male	W	5	1	Masters
Tropical	Female	W	4	30	Bachelors
Sunny	Female	W	1	3	Bachelors
Lazer	Male	W	4	5	Bachelors
Tres	Female	B	3	21	Masters

Instruction, in general, is a concern in urban education. Geneva Gay (2010) asserts that teachers should also be culturally responsive inside a classroom. Since I am not African American but 75% of my students are, I must make a conscious effort to address issues such as racism and powerlessness, and encourage the study of a variety of ethnic individuals and groups. Using art as the medium to teach the VTS protocol allows a culturally responsive teacher to find images that represent a wide variety of age, gender, place, social class, and diversity. The discourse in VTS could help create a classroom climate that is conducive to learning for ethnically diverse students if the teacher is a partner in learning with respect, honor, and a growth mindset. VTS could teach mathematic concepts and values simultaneously.

The purpose of the study was to explore the use of Visual Thinking Strategies as it applies to mathematics instruction for teachers in a small, urban elementary school containing grades 1-6 in a large Midwestern metropolis. The purpose of this chapter is present an overview of the study and its findings. The organization of the chapter is a review of the methodology, a summary of the study itself, and highlights of the data.

The research design was heuristic because in heuristic inquiry the researcher is the primary instrument of qualitative research. I, as the primary instrument, shared VTS lessons to initiate the phenomenon. Heuristic inquiry falls under the phenomenology umbrella because it involves researchers living the experience of a phenomenon (Patton, 2015). VTS is the phenomenon that I wished to share with other teachers in my building. We experienced VTS lessons together and then analyzed the interpretations of each co-participant to build a shared understanding. I focused on the descriptions of what each co-participant experienced through informal reflective interviews following each of VTS lessons.

Heuristic inquiry is different from phenomenology in three ways: the researcher has a personal connection instead of detachment; the method leads to personal meaning rather than describing a structure of the experience; and since the researcher is the primary instrument in the research, the approach challenges objectivity (Patton, 2015). I found myself purposely refraining from suggesting the end of a sentence during conversations. I forced myself to hold back judgment and instant rationalization. I took advice from my critical friend to "fix my face" or, in other words, to control facial expressions and body language during informal conversations. I can be an animated conversationalist, so the complete lack of expression was also disconcerting. It was a balancing act to achieve objectivity.

I employed phenomenology to understand the experience of each participant as novice VTS teachers (Creswell, 2012). Heuristics afforded the opportunity to share my own experiences and be a part of the reflective processes in this study (Moustakas, 1990; Patton, 2002). Heuristic inquiry emphasizes the personal experience and insights of the researcher. (Patton, 2002). I wanted to understand more about how to apply VTS in the mathematics curriculum. The heuristic method has six phases: initial engagement, immersion, incubation, illumination, explication, and creative synthesis. My initial engagement for VTS began five years ago when the local art museum brought it into the school where I was a math coach. Back then, it was used in connection with writing, but my passion was math, so I wanted to expand my knowledge and find personal meaning. The question I discovered was, How can VTS be used with mathematics. This chapter shares findings for sub-questions a, b, and c.

The central question was: How can Visual Thinking Strategies be used to improve mathematics instruction?

The sub questions were:

a. How do teachers apply the three main questions of VTS with teacher “moves”?
b. What do teachers do to reinforce restatements of evidence regarding explicit teaching of mathematical concepts?
c. What are teachers’ perceptions of the facilitation of group discourse related to the reinforcement of academic vocabulary?

It is important to note that teacher "moves" in this study are defined as the instructional strategies and decisions teachers make that either aid or inhibit mathematical conceptual understanding.

The topics in the theoretical framework included: Multiple Modalities, Visual Intelligence, Thinking, and Art Integration. Multiple Modalities are important because they show how teaching with more than one modality allows teachers to reach more students, thus increasing learning and cognitive ability. Visual Intelligence is part of Howard Gardner's (1983, 2011) Multiple Intelligence Theory and acknowledges that children bring many different types of intelligence into the classroom. VTS can utilize not only visual/spatial intelligence, but also linguistic intelligence to help students discuss math and increase mathematics intelligence. Finally, I included art integration as a way of increasing critical thinking skills. The VTS process began at this point—looking at art—which informed my study. The strategy used with art encourages students to analyze pictures, think, and make up many possible stories. I believed that training students to look at pictures closely could apply to analyzing mathematic images as well.

The research methods were surveys, observations, informal reflections, in-depth interviews, and a focus group discussion. The data collection procedures were collecting documents, conferencing, journaling, audiotaping interviews and the focus group, and transcribing and annotating those tapes.

The unit of analysis was the experiences of teachers with VTS, as I explored their implementation of the visual thinking strategies in the classroom gathered from an open-ended survey, observations, informal conversations, and in-depth interviews analyzed during the illumination step of the heuristic process. During the reflection time after a VTS lesson, I worked with teachers to analyze how the three fundamental VTS questions elicited mathematical understandings from the students as a group. As the facilitator of the process, I hoped to illuminate how VTS factors into the instructional decision-making process throughout the lesson. One of the characteristics of a Visual Thinking Strategy discussion is that it involves group collaboration and is a community building exercise. Students learn to agree and disagree with polite and scholarly discourse (Yenawine, 2013). The collaboration efforts included preparing images for lessons with the math concepts in mind and then reflection to determine if the concept emerged, and if so, to what extent. Another focus of the reflection time with the teachers was to see how incorporating math vocabulary during lesson facilitation helped students acquire academic math vocabulary.

Initial Engagement

I started the initial engagement of my study by conducting a survey of the co-researchers. The beginning paragraph reminded them of the purpose of the study, stated that their participation was voluntary, and asked for some demographic information. I wanted to survey their knowledge and interest in VTS specifically and math in general. My open-ended questions were:

1. What does Visual Thinking Strategies mean to you?
2. What do you see as the biggest problem in teaching mathematics?
3. In what ways have you used visual aids in teaching mathematics?
4. How much discourse is there in a typical math lesson and in what ways have you encouraged or discouraged it?
5. How do you typically teach mathematics?

6. Briefly describe your math block. What components do you include? How much time do you devote to each component?
7. Briefly describe a few ways that you increase student engagement during mathematics instruction?

The responses showed that only one teacher had heard of VTS beforehand, but she did not really understand the process. Most guessed that VTS had something to do with accessing information in a visual way, such as a nonlinguistic representation. In the survey repeated at the end of the study, all participants were able to define VTS and understood its protocols.

Participants listed several problems teaching mathematics, such as students lacking number sense, problem-solving strategies, and the ability to bring abstract concepts to practical application or cope with a frustrating pace. In the end, the one who had listed a lack of time to plan engaging lessons added using correct math terms and getting students to explain their thinking. I believe this became more apparent from the study. The honesty and concern revealed in their answers reaffirmed that I had chosen good co-researchers.

Participants listed several ways they use visual aids to teach math, such as posters, anchor charts, videos, and number lines. They kept these lists and added more ways in the post-survey, such as graphs, artwork, and manipulatives. Since three of the five included artwork in the post-survey, I think it reveals that VTS had become a tool in their math instruction tool belt. Since all five included graphs, I believe they had ownership in the collaboration efforts to create math images with which to apply VTS.

Questions 4, 5, and 6 were the most indicative of a changed mindset. In the first survey, there were examples of accountable talk in the responses to the discourse question. In the first survey, teacher responses about the quantity of discourse ranged from 10%, 15 minutes, only in practice stations, and only in talk moves during whole group instruction. The later survey quantity responses changed to “Not enough” and “I need to reflect on this,” and that they encouraged more kid talk and less teacher talk to bounce ideas off one another. Not a single answer was a repeat of the first survey as it had been for the other questions. I think this is because they learned how to facilitate a VTS lesson. They all came to believe, as I do, that building a collective understanding from student ideas makes learning math concepts or vocabulary authentic and relevant.

Question five responses included teaching vocabulary with models, context clues, interactive notebooks, and anchor charts changed to drawing pictures, bumping up discussions, and modeling academic vocabulary when opportunities presented themselves. All of the idea revisions seem to be indicative of our reflections on teacher moves during VTS lessons.

Participants also revised or planned to revise their math blocks to allot Number Talk time or problem discussions to have students explain solution processes, provide evidence for ideas, and explore more than one way to find answers. Again, all the new components belong to the VTS protocol and seem adopted by the co-researchers. The study either changed their perceptions or brought those ideas to the forefront in their repertoire.

Comparing the ways the teachers described their plans to increase student engagement, it was evident they had great ideas about practice stations, hands-on opportunities, technology, and relevance. Three of the five added VTS to their arsenal and the other two added “Number Talk time,” which may or may not be VTS. I want to believe that it is. During reflective conversations, it became clear that all the co-researchers perceive VTS to be a way to increase student engagement.

After the survey, we devised a schedule to conduct observations of introducing the VTS protocol, discourse expectations, and a method to display the art and math images. I began going into the participating classrooms for 15-20 minutes facilitating VTS lessons. My literature review revealed that Housen (2005) and Yenawine (2013) suggest 8 to 10 lessons following the VTS protocol with just art images before branching out to other core subjects. For a list and an example of all the images used, see Appendix B. The images came to me in a file from VTS contact person at the Nelson-Atkins Museum of Art. The images are ones they use in first grade, but I thought the content was appropriate for the entire grade levels studied, which include first, third, fourth, fifth, and sixth. With consistent images, I thought I might interpret data comparing grade levels or age ability descriptively since this is a qualitative study. It was not an attempt to control variables as in a quantitative study. It was not possible to schedule the VTS lessons as a part of the class math block, so it was scheduled as a stand-alone lesson. We decided to look at two images a day for four days before incorporating a mathematics image. On the fifth and sixth days, the plan was to have students look at an art image first, sort of as a warm-up, and then a math image. The seventh and eighth days, the VTS lesson was to be solely a math image. The co-researchers thought we could collaborate and create some math images together by then. The art images came to us as a set, but we would be responsible to determine the math images.

The first lessons were to introduce myself to students who did not know me and to introduce the Visual Thinking Strategies protocol. In first, third, and sixth grades, the classroom routine to “come to the rug” was conducive to getting a good look at the art and to having a community. Two classroom routines of sitting in alternative seating also brought students closer to the images and closer to one another. One classroom had students remain at their desks, which were all facing front in pairs, so some students were farther from the image. Each classroom displayed the image on a 4’ x6’ whiteboard through the teachers’ computers and a projector. I sent each participating teacher the picture file and we decided to present the pictures in the order they appeared in the file (see Appendix B) in order to stay on track with the study.

> Observational researchers traditionally have attempted to see events through the eyes of the people being studied. They notice seemingly mundane details and take nothing in the field setting for granted. They contextualize data derived from observation in the widest possible frame without overgeneralizing from a limited sample. (Angrosino, 2005, p. 732)

I chose participant observation because it is grounded in the establishment of rapport between the researcher and the host community and it requires the long-term immersion of the researcher in the everyday life of that community (Angrosino, 2005). I conducted my study in the school where I work daily. I followed the observer-as-participant protocol because participation in the group is secondary to the role of information gatherer. Fieldwork grounded in building and keeping relationships (Brayboy & Deyhle, 2000) was my intent and goal. I attempted to re-confront the phenomenon of VTS with a blank sheet for each observation, each interview, and each reflective conversation. I tried to listen carefully and remain open-minded and passive after bracketing myself (Grbich, 2013).

Immersion

Typically, when I would enter a classroom, students would already be in their lesson seating position, or would get there quickly since we were on a schedule. I visited classrooms other than my own during my plan time and lunchtime since I was also a teacher in the building. The classroom teacher would bring up the image on the whiteboard, and I would say, "Look carefully at this picture/photograph/painting (whatever the image) for a couple of minutes. Just look without talking. Get in your mind a story that explains what is going on in this image. Also, be ready to tell why you think that. You should have a couple of different ideas in mind. Do not raise your hand until our think time is over." Then I would also spend the time looking at the image.

After two minutes, I would ask, "What is going on in this picture?" I would select someone who had a raised hand. They would share their idea and I would repeat what I heard and ask, "What do you see that makes you say that?" Sometimes if it was a small detail, they would walk up and point it out. I would restate what they suggested while bumping up the vocabulary. I would then restate the evidence they pointed out. Then I would ask, "What more can we find?" During the first lessons we discussed how to make hand signals to show the speaker that those listening had that same idea. We used the signal of thumb and pinkie finger out and other three fingers curled to the palm; then moving that hand parallel to the floor with the thumb pointing to yourself and the pinkie to the speaker several times. I would keep taking suggestions, pointing out evidence, and restating while bumping up vocabulary until the possibilities were exhausted. I would thank the class for their participation and great ideas and leave. The teacher would be taking observation notes all the while, because we planned to meet later to reflect on the lesson. Sometimes their notes were simply anecdotal; I asked that they complete the formal Observation Protocol sheet at least twice before our in-depth interview (see Appendix E).

The first reflective conversations focused on comments made by students during the lesson; the teachers noted how happy they were with the creativity, vocabulary, and the number of ideas produced. They found that students who were reluctant to raise their hand would at least signal their agreement and feel engaged with some type of input. Some teachers also thought that students who liked to argue purposely found alternative suggestions as to what was going on in the picture, but agreed that was a good way to teach students how to disagree politely. Teachers decided to reteach accountable talk stems, such as, "I agree with_____________ because…" and "I disagree with _____________ because…" in order to get more students talking.

Immersion in facilitating lessons in six classrooms was reflected in conversations, journals, interviews, and living the phenomenon of VTS for three months. I was in a different classroom every day sharing art or math images with students, talking to different teachers every afternoon, and writing in my journal every night. Even in sleep, my brain was thinking about different ways to increase creative and critical thinking with students and how to capture that for my study.

Collecting data through observation was a clarifying process. The three questions of VTS developed through years of research by Abigail Housen (1983) have little leeway in their delivery for the best results. As shown in the literature review, the strategies have been applied to other content areas (Adams et al., 2006; DeSantis & Housen, 2001; Klugman et al., 2011; Moorman et al., 2016). Now I was studying their application in mathematics instruction. I believe that students learn in unique ways, each a combination of preferred modalities and naturally inherent intelligence. If a teacher can combine the visual modality and intelligence with the verbal intelligence through creating a story, finding details, and discussing the evidence, and then combine those with logical/mathematic intelligence, maybe deficiencies will be overcome by more students.

By the third image, student engagement increased. One teacher, Lazer (pseudonym), remarked, “Even the quiet and those that do not feel they are mathematically inclined are engaged.” Another teacher, Bear, said, “Kids are getting more comfortable. We are just learning to find our voice, build community understanding, and how to have civil discourse by disagreeing with reason and agreeing with evidence.” It was at this time in the study that teachers noticed how students already answered, “What do you see that makes you say that?” with their initial suggestion by stating their idea and finishing with, “because I see __________” as their evidence.

The tipping of the balance in favor of more engagement happened after a black and white photograph. The photo contained children and dogs, so perhaps the subject was more familiar to the students than previous pictures. The title of the piece is *Outskirts of Paris* (see Appendix B), so that was surprising. I never told the students the titles of any of the images, but the teachers had the file and brought it up in our reflective conversation. There is no Eiffel Tower and the piece does not depict the Paris in my head. The photograph has three small, dark-headed children and four dogs in the foreground on a dirt road lined by shanties. There appear to be apartment buildings in the background. One story idea suggested by a student was, “These boys are getting the dogs to feed them after the storm passed.” When asked what he saw that made him think that, “They have on rain boots and there are mud puddles.” In the same class, the storm expanded to a flood because they saw trash and the houses looked torn up. The nationality of the kids in the photo was suggested to be Mexican or Indian because their hair was black and straight.

My rephrasing of the aforementioned statements was, “One suggestion for a story about this photograph is that there has been a storm and the children got to come outside when it passed if they wore boots because the road was still full of mud puddles. What more can we find?” Then I rephrased a second suggestion: “Maybe the storm was really bad or lasted a long time and caused a flood because this row of houses seemed to get damaged and debris was left scattered around the community. What more can we find?” After details about straight hair, a boy playing with one of the dogs, and big buildings back in the fog, a third story suggestion emerged. I rephrased it as, “Maybe this is a picture of a really poor area in a cold place because the boy is wearing a sweater and his sister is wearing a coat.”

The teacher facilitates the discussion by staying neutral and just rephrasing every observation with conditional words such as might and may. This teacher “move” shows they understood what each child contributed, which honors the skill of active listening. It allows the whole group to hear every comment because it is repeated and usually louder than at first. Paraphrasing student answers into more concise vocabulary with correct grammar is not judgmental, if you begin with, “What I hear you saying is…”

Paraphrasing is another teacher “move” to elicit intended math concepts and academic vocabulary. Linking similar comments helps students draw conclusions. Encouraging more comments that are different offers more perspectives and thus elaborates meaning. Debate and discussion are ways to test ideas and show that most problems have more than one solution. The layered thinking helps the class work through a problem together while expressing several possible solutions.

The VTS lesson discussions in every grade level progressed from lots of silence and simply agreeing with previous statements to lively debates, attention to detail, creative imaginations, and multiple perspectives. The first two art images may have lacked cultural relevance and we may decide not to include them next year, but this may have been because VTS was such a novel idea. The reflective conversations with teachers also progressed from "I think the kids like you coming in" to "the details my kids saw was surprising" and "I love seeing how their minds work."

The following VTS lesson images sparked lively discourse, creative imaginations, and multiple perspectives. The first grade teacher reflected that her younger students related better to bright colors and images that included people. All the teachers thought engagement was up, stories were diverse, and they were surprised daily by comments. The reflective conversations led to collaborative efforts to create the math images to transition into the VTS lessons.

There was consensus that students were ready to apply Visual Thinking Strategies to math images. When it was time to apply VTS to math images, the co-researchers were all in the data unit in their math block. This meant they were studying how to read and create different graphs to display data. With their input, I created a bar graph (see Appendix F). It was at this time that one of the co-researchers finally understood where the study was going. He had been unable to connect why we were looking at art in the first place. I had not shared my research on VTS and now wondered if perhaps I should have. I made a bar graph of leaf colors. The plan was to share an art image first as a warm-up, and then a math image. Only the math observation data is described in this chapter in order to answer the research questions. I included the data from all the VTS lessons when making the codebooks to find what the participants felt most strongly about in the study and to locate the salient themes or recurring ideas and language (Ryan & Bernard, 2003).

Math Images Begin

I told students when we started our journey that I was going to teach them how to use a new strategy with math. When we began to study the math images, I reminded them of this because several weeks had passed. The VTS images from the art museum had been displayed on a whiteboard with a projector, but the VTS math images were 30" x 40" posters created by hand to prop up against that same whiteboard. On the transition day, we started with the art image *Circus* (see Appendix B) as a warm-up. When I thought the suggestions for that image had been exhausted, I pulled out the next image. The first math application VTS lesson was a bar graph titled, *Leaves Collected* (see Appendix F). Four different colors are listed at the bottom, and the bars themselves are made of that color of paper. The red bar goes up to 24 to represent that 24 red leaves were collected. The orange bar goes up to 18; yellow goes up to 10 and green to nine. The y-axis numbered evenly has no nine, so the green bar is between the 8 and 10.

After a minute of think time, the hands went up in response to my first VTS question, "What is going on in this image?" Every class had over half the students wanting to share a detail and knew the evidence that supported their assertion. Those who did not find a new detail agreed with previous suggestions either verbally or with a hand signal. There was over 90% engagement in every grade level with the bar graph image. Examples of some of the stories that emerged follow.

A first grader asserted, "Kids in class went outside to collect leaves because it says leaves in the title." Since this child gave her evidence, or what she saw with the initial response, I pointed to the title and said, "__________ believes maybe a class went outside to collect leaves and thinks that because he sees the word leaves here in the title of the graph. What more can we find?"

A fourth grader suggested, "The class had a contest to see who could pick up the most leaves. Red won because it is the tallest bar." I rephrased it, saying greatest number of leaves instead of tallest bar as I pointed to the red bar.

A sixth grader said, "The boys raked off their basketball court. Remember that day when all the leaves fell off at once? That red tree was right there, but the wind must've brought some more from other trees." When asked what they saw that made them say that, they were able to point out the parts of the graph that supported their answers. For example, the first grader pointed to the graph title. The fourth grader pointed to the red bar and said 24 was the greatest number. The sixth grader also pointed to the bars of different colors, but that red was the most because it was the tallest.

During reflective conversations following the first VTS math lesson, the first grade teacher was happy and smiling and talking my ear off. I had to have her write it down since I had not planned to audiotape. This is part of what she wrote:

> I love that I don't have to give answers, that by talking about it and letting there be more than one right answer and giving evidence and always finding more in, 'What more can we find?' they talked it out.

The fourth grade teacher answered my question, "How do you think the lesson went?" with,

> My creative girls love making up stories when you ask, 'What's going on in this picture?' I never would have thought about the contest thing. In her mind, she pictured kids running around picking up leaves, but there was a red team running around picking up the red leaves, orange picking up orange, etc. and the red team won. And she was able to justify her answer.

This same teacher also commented on the academic vocabulary piece of our study when she mentioned the number of leaves being "greatest and least" instead of biggest or tallest, and even instead of "by 2's."

The fifth grade teacher's reflection also showed a positive perception. He said,

> I was wondering when we would start math images. I did not see how it would tie together until today. This bar graph was a little easy, but I guess a great start, with tons of hands up, and confident smiles. I liked you bumping up the vocabulary to y-axis and x-axis. One student suggesting the time of year for the graph being fall because of the color of leaves was great, but when another suggested in Missouri because California would have palm trees, I was floored. I was so happy that every student had some input, even my reluctant introverts did not just use hand signals, BUT raised hands.

The transition to math images may have been hindered by the fact that the images were not as large as those in the art file, and teachers made note of this in our reflective conversations. The reason was that I did not want to use just any old graph on-line that could be projected at the same size. Instead, I wanted an original one that we strategically created with our kids in mind and one that would challenge them while at the same time offering a story narrative. Constructing original graphs for the study was how I intended to analyze whether the intended math concepts were conveyed and to what extent the VTS protocol helped achieve that.

We found that every class was able to read the graph and come up with the intended main idea. What we discovered was that each class connected the graph to their personal realities. The bar graph was about leaves collected and the tallest bar was red. The idea that the leaves were collected made kids think about making graphs in school, and their stories included contests, assignments, raking the playground, and real-world scenarios. The fact that there were more red than green leaves made kids think about seasons, even in first grade. The discussion even led to types of leaves in different biomes in fifth grade. The connections the students were able to make got the teachers excited. I had bracketed by keeping a poker face when I asked, “How do you think the lesson went?” and tried to remain neutral as we dove deeper into the possibilities.

Teacher perceptions were that the math images eventually could be any on-line graph or one found in a book, but they agreed that I should continue to create original graphs with an intended purpose. My research question was answered, at least partly. VTS can be used to improve math instruction with graphs to make numbers real and to make a display of data more connected to their real world.

Line Graph VTS Lesson

The co-researchers and I decided to use a line graph next because it looks like a bar graph except with a dot above the x and to the side y where the top of the bar would be. In other words, everyone but the first grade teacher thought that since the line graph also has an x- and y-axis that it should be next. The first grade lesson confirmed the teacher’s doubts when I displayed the line graph titled, *Monday’s Temperature* (see Appendix F). Their responses to “What’s going on in this picture?” were literal. “A line is going up and down.” “It is a connect-the-dot line.” They were able to read Monday and time and point out those words, but the math concept was not present without some input from me. I had to deviate from the true VTS protocol of the three questions verbatim. Eventually, as a class they got more meaning because they tied the pattern of the line to the heat rising and the line going up and that later in the day it got cooler because the line went down.

The older students were more successful. A third grader suggested, “The students had to take temperatures for science class every hour on Monday to see if it goes up or down." What they saw was the titles. Other details following this initial suggestion were, "They were learning how to use a thermometer" and "They saw the y-axis title." As a class, they understood the meaning of temperature going up as the day gets hotter, represented by the line going up, and if the temperature was the same between hours, the line was straight. I made the concept more concise during my rephrase step of the VTS protocol: as a line graph tracks change over time, it shows how much a given thing, such as temperature, increases, decreases, or stays the same by showing the pattern with a line. The teacher later reflected, "It seemed like little light bulbs went off all over the classroom."

The older the students, the more sophisticated the details offered. Fourth graders made the same observations as the third, but suggested a class was collecting "data." Fifth graders expanded the observations by suggesting that students took the temperature outside every hour even if the time was not on the x-axis, because the times listed only even hours. Sixth graders finally noticed that the y-axis was broken and went from zero to sixty. They suggested the season was spring and noticed a point missing on the grid, which suggested to them that the students forgot or were in their support class or taking a test that hour. These teachers were pleased and proud of their class. Fourth and fifth graders saw connections they could transfer to their math class since they were also currently studying their data and statistics unit.

Circle Graph VTS Lesson

I suggested we proceed with a pictograph since it is similar to a bar graph. The consensus was to come back to that later and share a circle graph instead. Since I wanted the image to span several grade levels, I put two circle graphs on one poster that depicted the same type of data. One circle was *Mrs. Brown's Favorite Class Pets,* and the other was *Ms.*

Hines's Favorite Class Pets (see Appendix F). I debated using current teacher names to address relevance and decided to use former teacher names, which some of the fifth graders did recognize.

A first grade suggestion after think time was, "Class wants a pet and the biggest part means that was what they get." What that student saw was the title and particularly pointed out the word, "favorite." When asked what more they could find, students replied, "The little part means they are not going to get a rat. I don't blame them. I don't want a rat either. Oooh." "Miss, _________, can we get a rabbit?" Their teacher's reflection was that many hands were up, and she was not sure if that meant students had more confidence or they were afraid that they would not have anything to add if they were not first to share.

Fourth grade suggestions were: "Two classes are voting on a pet for their classroom." "Both circles show the same animals, so there is only one list to choose from. They don't get no snake or lizard." "The colors help show what was chosen because it had the biggest part of pie." The students loved to come up and point out the items on the poster that helped them determine their assertion. Their teacher's reflection was that the two circles must have made them think about Venn Diagrams, because they did compare the circles a lot. You could tell from the details like the color of each animal being the same on the different circles. We dug deeper in our conversation and even though someone reading this paper would think the comment about no snake or lizard was intended to be funny, it was part of our reality, since a teacher in this building has both of those as classroom pets.

We diverged from a typical VTS lesson after the details were exhausted, because the teacher wanted to make the connections learned that day in mathematics class. When the class was asked, "How many students voted for a rabbit in Ms. Hines's room?" The answer given was one half. We explored further. “How many students is that?” The “ah-ha moment” was revealed in the answer, “We can’t tell that.” As math teachers, we were high fiving each other. The teacher rephrased that statement as, “A circle graph can only show data about parts or fractions or percentages of a whole entity, like a class. You are right when you said one half, and maybe you have seen a circle graph labeled ½ or 50%, but you cannot tell the exact number of students of that part until you know how many total students are in the class.” We continued to extrapolate. “What if there are 24 students in Ms. Hines’s class?” The class answered his question with half is 12 and were able to tell him that half of a half is a fourth and were able to tell him six.

During our reflection afterward, we celebrated being the best math teachers ever! This is what I thought could happen with VTS and experiencing it alongside one of my co-researchers was exhilarating. I knew that he shared my interest in VTS, but now it was at a much deeper level. I decided to add this piece of digging deeper after the VTS protocol with the rest of the upper grade levels with the circle graph. State testing had begun, and this was exactly like a potential test question, so I decided to add, “The VTS lesson of getting the details and story out has been great, so we are going to use it as a Launchpad and dig deeper mathematically.” Then I repeated the aforementioned questions, and each class built a community understanding that a circle graph is a representation of a whole divided into categories or parts. Students could apply the picture and portions of the circle to fractions of the preselected number 24 since it is divisible by two, three, four, six, and eight.

Pictograph VTS Lesson

My study ended with a pictograph *Books Read* (see Appendix F). Excerpts depicted in Table 6 illustrate a linear connection of the parts of a VTS lesson as applied to mathematics. The school year ended, so the lessons stopped. It was time to reflect. I met with each teacher during the following workdays for in-depth interviews. I audiotaped each and transcribed later. We all agreed to meet in two weeks for a focus group.

Table 6

Excerpts from the VTS Math Lesson with a Pictograph

What is going on this image? What more can we find?	What do you see that makes you say that?	Teacher Reflection
The boy who had to draw a picture graph said there were too many books to draw, so he let one book mean five books.	He pointed out the key at the bottom which had a picture of a book = 5	You can tell we are doing the data unit in math. So funny that they said, “had to” make a graph. This story line is following their real life.
There was a contest to read the most books and kids with the same number of books was in a tie.	She pointed out that Luke and Jennifer both had three books drawn.	Every detail after this was the name and the number of books they read.
Tasia likes to read books, so she won the contest.	She pointed to each book, 5, 10, 15, 20, that is the most.	I later asked them how they would represent six books.
Luke read 15 books.	3 x 5 = 15. There’s 3 books	This took some thinking, but they did try to divide the book picture.
Mia read 10 books.	2 books = 10 really	I am proud that they know how to use a key now.

My interview guide was:

1. How do you feel about VTS in general, so far?
2. How can the art integration be improved for your group of learners?
3. How have the restatements during facilitation moved the lesson through the three VTS questions?

4. What do you see as the advantages and disadvantages of the evidence step when students are asked, “What do you see that makes you say that?”
5. What has been your experience so far with the discourse lending itself to improving academic vocabulary in mathematics?
6. What are your ideas on how to apply the VTS protocol to mathematic images?

All but one teacher had positive comments about VTS in general. They thought it was something different and that it was fun watching the kids use different parts of their brain. One wants to start the school year with VTS next year instead of waiting until the end of the year, because it “draws in students that are not mathematically inclined.”

One teacher was still confused as to the purpose of art, but thought the images were culturally relevant and increased engagement, except for the first two. One teacher thought the titles of the artwork should be revealed after the lesson and related it to the fact that all the graphs had a title. The suggestions for improvement for younger learners was that brighter was better and having people in the picture was more relatable, whereas the teachers of older learners wanted to add more abstract or modern art.

Participating teachers believe that restating or rephrasing student input during facilitation not only let each voice get recognition and be heard by all, but also kept the lesson moving automatically and flowing naturally. One teacher thought that the restatements helped students avoid lists and think more critically.

The step of evidence was, “a justification piece that forces them to find reasons and is metacognition.” Another thought it “pushed their thinking. They are not used to backing an argument.” The teachers in test-taking grade levels mentioned that explaining a response is something they must be able to do on tests and requires higher order thinking. Students need to be able to verbalize their thinking and answer not just what, but how.

All of the teachers thought they implement Accountable Talk, but that in VTS with the facilitator rephrasing there is an opportunity to teach academic vocabulary. One teacher thought that it built a deeper understanding. One teacher added to their interactive notebooks after VTS lessons or had them refer back to vocabulary mentioned during the lesson and thought it was more important for upper grade levels. Again, in reference to high-stakes testing, “students will have to be able to read and understand the mathematics vocabulary on tests and need to practice daily.” The ideas for future VTS math lessons included fraction and ratio images, arrays, number lines, volume, area, and spatial reasoning. Most said they could probably think of more given more time. This input leads to future studies.

Incubation

In keeping with the heuristic process, I needed time to digest my experience and that of my co-researchers. I went on a ten-day trip in middle of June to Hawaii. This Bucket List trip planned a year ago was perfect for some detached involvement with my study. I would not be able to stop my mind from making connections, but I needed to get myself reorganized for the final leg of my journey. I hiked the beautiful trails in Maui and thought about VTS. I snorkeled in clear beautiful bays to catch a glimpse of tropical fish and thought of funny things the kids said. I surfed for the first time and thought about how I was going to write down my experiences. Actually, I had gotten into such a habit of journaling that I captured my trip experiences in a journal, too.

My trip companion was my youngest daughter, who is also a teacher. We talked a lot about teaching in general. I never discussed my research specifically, but she knew I was in the middle of my dissertation work. She is a language arts teacher, and my passion is math, so we have different types of brains. Together we would make an epic teacher. We also both know how to compartmentalize and keep school at school so that we can live in the moment. We lived some unforgettable moments in paradise. It was a trip of a lifetime, and I get to relive it every time I read my journal.

We were out of school for several weeks and got some much needed recharging. I invited the co-researchers to lunch. I believe they felt enough like colleagues to overcome feeling like a guest or a mentee. We had been immersed in the study for months. Throughout that time, the usual business of ending a school year with testing, grade cards, programs, and fieldtrips kept us busy. One of the five teachers had not been able to be as involved due to logistics of schedules, testing, and so forth. She did not attend the focus group.

Illumination

Illumination is the step of the heuristic process in which one tries to reach a breakthrough by clustering notes into themes. It is the time to get fragmented knowledge to come together and look for patterns. I read over my notes to find recurring ideas and language and create codebooks. It became clear to me that I had spent too much time and effort writing about the lessons solely with art images since what I needed to analyze more deeply were those lessons with math images. I had to start over many times with coding and enumerating as I found myself trying to tie my notes to my initial research question. In the middle of the study I was afraid I might miss some significant detail, so I wrote down everything I thought was important. During this step, when I reread my journal, I found I had too much information about too many pictures. I deduced the possible themes to be metacognition, engagement, discourse with vocabulary, and visual math. It was time to see if my co-researchers had reached similar illumination during their incubation time.

My Focus Group Protocol (see Appendix D) asked which themes they disagreed with and why, which they agreed with and why, and if they had any themes to add. The final question was how they thought their experience with Visual Thinking Strategies had changed their teaching practices.

After eating and catching up with how summer vacation was going for each of us, we sat around a table and I turned on the iPad recorder. I later transcribed the conversation; from the transcription came the following illuminations. Metacognition was determined to be too narrow a category, but was a big part of all the thinking that goes on in a VTS lesson. We decided to rename that theme Cognitive Operations. Engagement was agreed upon as a part of that theme. Lazer stated it best: “We need to discuss how to look at problems differently. Looking at any situation differently can help approaching different math problems and real-life situations from many perspectives. How Einstein thought differently and changed the world.”

Discourse with explicit vocabulary teaching seemed like a good marriage. Bear suggested that more kid talk and less teacher talk leads to a discovery method for learning vocabulary. Tropical agreed, saying that she focuses on the math brain when teaching math, and the language brain when teaching reading, but now sees how it would be more beneficial for more students to focus on both sides all the time because they coexist.

Teacher Moves resulted from that insight. It was a theme that emerged from lesson facilitation descriptions. The facilitator thinks first about the image and uses criteria to decide whether it will lend itself to discourse that can be speculative. In other words, the image is not too narrow and allows for multiple responses to the question, What is going on in this picture? Teacher moves kept the discourse flowing naturally and helped build a community understanding of the concepts. Tropical said that she perceived student confidence to increase when they found out there were no wrong answers and that every answer was a possibility and should be considered. She also mentioned that she liked to see her ELL kids more engaged, to which the others nodded in agreement.

We debated visual math as the name of a theme because it did not seem to encompass all our thoughts, but they could not find a substitute. In the end, the themes fit into my theoretical framework nicely, and I chose Visual Learning as the name of that theme which came from the interpretive coding of math images. The co-participants agreed that Visual Thinking Strategy was a good protocol because viewing, thinking, and talking kept the learners engaged.

The final illumination discussed as a group was how VTS might change the way the co-participants will teach math in the future. Sunny believed,

> I think I will not necessarily just use it with math. Even in reading, I will not fly through picture books with my first graders. I will have them look at the pictures for a minute before predicting the possible stories. I always took one answer and felt it was straightforward. Now, I want to hear their ideas. I enjoyed their responses when reacting to different pictures through VTS discussions.

Lazer thought it would be interesting to use VTS in a way to help students learn to visualize more.

> Even straight up computation problems like 3 x 5, as opposed to what is the answer, rather what is the story behind this. Like, baking cookies with three rows of five spoons of dough will make fifteen cookies. Teachers who are natural storytellers help students think this way. Now VTS can help those of us who are not natural storytellers help students become the storyteller instead.

He said even with his Read Aloud books that do not have pictures he will ask them, "What is going on in your mind right now? What do you picture or visualize?"

Tropical wanted to transfer the students' learning that there can be many possible stories about a picture to math. Likewise, she wanted students to understand that there are so many ways to figure out a problem. "There is not just one way to get to the answer, but figure out more than one way and be able to share your process and your thinking. I often learn from my kids."

Bear planned to teach VTS before his graphing unit in math because it was such a success in our study. The change he would make is the time of year. He would make it earlier in the year in order to reinforce visual thinking strategies before state testing.

Explication

In the explication step of the heuristic process, unique experiences depend on internal frames of reference. When I fully examined the layers of meaning in the data, it crystallized into a comprehensive depiction of themes. It was time to focus and articulate the answer to my research questions. The co-researchers had all given me an in-depth interview during the workdays right after school was out. I was aware of social constraints, so I purposely bracketed myself for a more complete understanding of each conversation. We all have trusting collegial rapport, which led me to believe they would be honest with their opinions and observations, as they had in the past on many subjects. They may see me as the expert resource for mathematics content, materials, and resources and desire to experiment on my behalf rather than from any of their own initiative. I tried to keep this in mind as I conducted and analyzed the interview and focus group transcripts.

Guided by the research questions and theoretical framework of the study, I present the final themes gleaned from the process. The themes emerged from the reflective journal, conversational and in-depth interviews, observations, surveys, and a focus group discussion. The four themes I used to categorize my findings and where they emerged in the data are depicted below in Table 7.

Table 7

Explication of Themes

Theme	Survey	Observations	Journal	Interviews	Focus Group
Cognitive Operations					
Engagement	X	X	X	X	
Metacognition		X		X	X
Teacher Moves					
Selection			X	X	X
Facilitation	X		X	X	X
Discourse with Vocabulary					
Paraphrasing		X	X	X	X
Academic			X	X	X
Visual Learning					
Math Images	X	X		X	X
Evidence		X		X	

Cognitive Operations, Teacher Moves, Discourse with Vocabulary, and Visual Learning are the themes that encompassed the ideas found through crystallization of the data. The interpretive codes of metacognition, engagement, selection, facilitation, paraphrasing, academic vocabulary, math images, and evidence came from descriptive coding.

The data from the survey focused on engaging the students, how to facilitate a VTS lesson, and how different images are used in the teaching of mathematics. Observation data included all interpretive categories except selection of images and academic vocabulary. My journal reflections focused on how student engagement progressed, which math images we were planning to incorporate, and how my paraphrasing could bump up the student input into more academic language. The conversational and in-depth interviews included the most data, so it makes sense that all of the themes crystallized there. (See Table 7)

Cognitive Operations Theme

Cognitive Operations was a theme that emerged from analyzing the data. The interpretive code of cognition came from descriptive codes of engagement, thinking, and metacognition. Engagement is activating and keeping the interest of learners. I interpreted this theme from observations made by Tropical in statements like, “Having people or a person in the picture helped my students put themselves into the story.” Thinking is the mental work of processing ideas creatively and critically. Sunny illustrated this best when she stated, “I think VTS helps because you are pushing students past their normal thinking and getting them to use their imagination and find proof too.” Metacognition is thinking about thinking. During a lesson reflection Lazer said, “The justification piece forces them to come up with the reasons behind their reasons. That metacognition piece is huge!”

Enumerative data by itself is only a superficial overview, and thematic interpretation by itself does not entail frequency information to structure the data (Grbich, 2013). Thinking synonyms were enumerated, but because the act of thinking changed from facilitator to viewer and back, again there had to be an interpretive category because the role of thinking never really stops. VTS is challenging and thought provoking for students and teachers. A good facilitator will elicit three or four possible scenarios and validate everyone's thinking.

To prepare for the first graph lesson my thinking began with things relevant to my students. I thought about graphs I had seen in books, bulletin boards, and math assignments. I thought about the time we counted eye color and found that every single person in the room, including myself, had brown eyes and decided that would not be very interesting. I thought about the time that we graphed student birthdays and had twelve categories to depict each month. Again, not a good graph for our purposes. I needed to be able to have between four and six different categories. After brainstorming with co-researchers we agreed on leaf color. There was a lot of thinking that went into making the graph itself easy enough for first graders, but complex enough to engage sixth graders. Our schoolyard has many sugar maples, so red being the greatest amount would make it more relevant and authentic. Enumerating this process was difficult because besides thinking, the strategic decisions behind image selection is what I consider a teacher move in lesson preparation.

The thinking in the lesson itself begins with the first directive of looking at the picture or graph to figure out what is going on. The first minute or two is using only brains and not voices to develop ideas about the story behind the image. Then with every idea shared, the teacher must think about how to rephrase it in order to illicit the intended mathematic concepts and vocabulary. Then the student must think about what detail in the picture or graph is the reason or evidence for their assertion. The teacher then must be able to articulate that reasoning in a manner that validates the viewer's thinking, but at the same time allows for speculation for different scenarios. Each viewer is also thinking about what is being said, what he or she are looking at, and whether that idea is similar or different than their own. Thinking bounces around with each idea until the possibilities are exhausted, which generally takes about ten minutes. Finally, the facilitator thinks of a way to embody all of the suggestions into a closing statement. The thinking continues later during lesson reflection and when analyzing transcripts.

Teaching Moves Theme

Teaching Moves was a theme that emerged from lesson facilitation descriptions. The facilitator thinks first about the image and uses criteria to decide whether it will lend itself to discourse that can be speculative. In other words, the image is not too narrow and allows for multiple responses to the question, what is going on in this picture? In the documents, I enumerated 23 mentions for the word think. In the interpretive phase, thinking had to be fleshed out into who was doing the thinking—the viewers or facilitator. The thinking process occurs before the VTS lesson when the teacher selects or creates an image to be viewed, during the lesson to engage the viewers and facilitate the discourse, and in summarizing, each viewer's input, and after the lesson to draw the conclusions and help everyone understand the thinking that occurred.

During an interview, Bear pointed out that the teacher move of asking the students what they see in an image that made them give an idea brought about higher levels of thinking. He said, "One advantage to VTS is its higher order thinking, especially in math we as teachers don't ask for evidence- the why- even in Number Talks, so it's hard for us to reach that next level of thinking." One teacher move that could be used in every lesson to take it to higher levels is to ask students, why?

Flexibility draws in viewers who are reluctant to participate because they can simply agree or disagree with other stories given and repeat the detail evidence or add details that support their opinion. The descriptive codes enumerated for facilitation were learning styles, evidence, selection, and speculation. I assert that with good image selection delivered through the VTS process, the visual modality will increase mathematical understanding. An example of a statement that I interpreted as being made because of learning styles being considered is when Tropical said, " My quiet, reluctant-to-take-risks kids are raising their hand and doing the agree signal because they know that all answers are accepted." I made note of when the co-researchers did not like a particular art image as a selection interpretation. Sunny remarked, "My students seemed to have more to say with the colorful pictures. I think the black and white photos were good, but my kids did not respond to them as well." Another comment she made, "I have used pictures to predict a story. I always thought of them as straight forward, but now I want to hear their ideas instead of looking for the one right answer," I interpreted as speculation.

Discourse with Vocabulary Theme

While discussing the VTS process, patterns emerged regarding the Discourse theme. The interpretive code of talking with vocabulary in mind came from data rephrasing student responses to what they saw in the picture, what they speculated was going on and why, and how they provided evidence. When I enumerated, discourse types of words occurred 21 times throughout the study and vocabulary 33. Tropical had this to add about paraphrasing, "As an upper grade teacher it is important to teach vocabulary in a lot of ways, so I use a word wall, interactive notebooks, and anchor charts. When you rephrased their ideas with correct vocabulary that helped in our reflections." Lazer had this to say, "I am going to repeat what I hear you saying, see if I understand you correctly so far. Then I restate their ideas with the correct vocabulary and grammar and ask them, 'Is that what you meant?' and they usually nod and we go on." I counted that as academic vocabulary, but it could have also been interpreted as paraphrasing. The observation comments were filled with notes about academic vocabulary, so to illustrate one let us go back to the leaf graph lesson. The upper grade teachers all commented about me rephrasing with the correct terms of y and x-axis. Graphs were their current unit of study and the term axis was being introduced, so they all felt strongly that it was important and helped students make connections.

Visual Learning Theme

The documents included words associated with visual intelligence or the act of viewing, and the outcome of visual literacy, so the Visual Learning theme emerged, which is tied to Multiple Intelligence from the study framework. Codes are triggers for deeper reflection on the data's meaning, to enable the researcher to get the material out that can go together and condense into analyzable chunks (Miles et al., 2014). It was important to use appropriate images to build the skills of VTS first using art, and then to find or create mathematic images to utilize those skills. The two key ingredients are the image itself and those viewing it. The descriptive codes in the documents and their enumeration referring to this theme were words about visual literacy, which is the ability to look at images and analyze what is seen. A lesson demands something to look at and a group to view and discuss it. In math lessons, the "something to look at" included different types of graphs. Comments made by co-researchers, such as the one by Bear in a lesson reflection, "I thought the bar graph was going to be too easy when I first saw it. Then the details they came up with about being done in the fall because of the color of the leaves and in Missouri because that doesn't happen with California palm tree." I interpreted as visual learning with a math image.

Synonyms for viewing and seeing were enumerated if they reflected the use of eyes to absorb visual stimuli. I assert that with good image selection delivered through the VTS process, the visual modality will increase mathematical understanding. It should be the anticipated outcome for every lesson, to construct insightful meaning. I finally decided to include the evidence piece here because viewers had to see the details and discern how that supported the first thing they saw and shared. There is sometimes only one right answer when asking questions in math, but the story behind the image can be creative and used as a springboard and can have many possibilities.

Creative Synthesis

The final step of the heuristic method is creative synthesis. It requires one to create something that captures the experience of the phenomenon. Once you are thoroughly familiar with the data and the themes, you are to use narrative to describe your story. I decided to attempt an acrostic poem to share my passion and journey of discovery.

VTS training was offered during professional development, so I went.

I fell in love with the protocol and how it made kids think.

Since I was a mathematics coach I wanted to try it with math images.

Understanding how one could create different stories from one picture hooked me.

Art files were shared by the Nelson Art Gallery staff.

Lots of higher-level thinking was what ignited my passion.

This led to my study to earn my doctorate.

Heuristic inquiry method became my qualitative tradition.

I researched VTS and reviewed literature for months and months.

Not much was found using the protocol in mathematics.

Knowledge of math concepts and how to learn them helped along the journey.

I got my study proposal written and approved.

Now I had to find some co-researchers to study the VTS phenomenon.

Guidelines called for confidentiality, so my warm demanders chose pseudonyms.

Schedules and lessons began.

Thinking about thinking and all that entails was fun, but demanding.

Reached more students by combining verbal, visual, and math strengths.

Academic vocabulary and building a community of active listeners was purposeful.

Teacher moves were practiced and analyzed during facilitation.

Engagement increased and so did story ideas.

Graphs were being studied, so that is the math images we incorporated.

Immersion to illumination came from journals, observations, and interviews.

Explication of the themes from data for crystallization was important.

Strategies to foster creative and critical thinking is possible in every core subject.

Chapter 4 showed the steps of heuristic inquiry as I experienced them in my study of applying VTS to mathematics. I shared the experiences of my co-researchers and their students as we used visual thinking first with art images (see Appendix B), and then with graphs we created. (See Appendix F)

Chapter 5 discusses the conclusions of these findings and the implications of the study as it informs the practice of mathematics instruction. It includes how VTS could be implemented, the transformational leadership that would be needed, and gives ideas for future research. Finally, I end the chapter and this dissertation with my personal reflections of what I learned about myself on this journey.

CHAPTER 5

DISCUSSION

The purpose of the study was to explore the use of Visual Thinking Strategies as it applies to mathematics instruction for teachers in a small, urban elementary school containing grades 1-6 in a large Midwestern metropolis. This study was implemented to address the problem of low math scores in urban schools that have students with low socioeconomic status compounded by the way math concepts are generally taught. One-third of fourth-grade children from low socio-economic households do not reach basic achievement levels in mathematics as defined by the National Assessment of Educational Progress (Reardon, 2013). This statistic remained significantly unchanged from 2005 to 2011, according to the National Center for Education Statistics (U.S. Department of Education, 2011).

The following central question and sub-questions guided this study: Central Question: How can Visual Thinking Strategies improve mathematics instruction?

a. How do teachers apply the three main questions of VTS with teacher "moves"?
b. What do teachers do to reinforce restatements of evidence regarding explicit teaching of mathematical concepts?
c. What are teachers' perceptions of the facilitation of group discourse related to the reinforcement of academic vocabulary?

Five teachers became co-researchers from different grade levels, backgrounds, ages, and years of teaching experience, who were similar in growth mindsets and established discourse procedures in their classroom. The purposeful sample limits the study in its possible transferability as the strategies may yield different outcomes in a variety of settings. The findings are tentative and knowledge elusive (Creswell, 2013).

The unit of analysis was the experiences of teachers with VTS, as we explored their implementation of the visual thinking strategies in the classroom gathered from open-ended surveys, observations, informal reflective conversations, in-depth interviews, and reflective journals analyzed during the illumination step of the heuristic process in a focus group discussion. This study was qualitative and followed the heuristic tradition of research.

This heuristic study was guided by my personal experience; and as the research instrument (Patton, 2015), I had to constantly examine my biases as a mathematics coach and instructor. I maintained a journal throughout the study to record my reactions to participants and capture my thoughts regarding the experiences of participants. I wrote daily in order to minimize the problem of forgetting details. I wrote down my observations while they were fresh in my mind.

Another limitation is that the data collection took place in a school where I teach. I guarded against the possibility of reactivity or influencing the participants. In an attempt to avoid influencing the participants, I refrained from asking leading questions during the data collection phase. I used a critical friend in peer debriefing to maintain validity. As facilitator, I tend to be a nurturing mentor to prepare the other teachers to conduct lessons on their own; and this, in turn, tends to make the mentees feel loyalty and obligation. I fostered an equitable peer mentality and purposely built collegiality to avoid reactivity. I treated the other teachers as co-researchers in our VTS journey. I sought their help and input by involving them as reflective teachers to make each math lesson effective.

To assist with capturing the data, I kept a reflective journal to include a daily schedule and logistics of the study, a diary section for reflection and insights, and finally a methodological log to record the data for each method chosen. I know that distancing oneself does not guarantee objectivity. I strived for empathic neutrality toward the co-researchers while still being passionate about the phenomenon.

In a qualitative study, strategies of addressing validity and reliability overlap. Validity is the correctness, credibility, trustworthiness, and authenticity (Denzin & Lincoln, 1994; Maxwell, 2005; Patton, 2002). Credibility, according to Patton (2002), depends upon rigor in methods, researcher credibility, and an appreciation of and belief in the value of qualitative research. Reliability refers to trustworthiness, whether the findings would be similar in repeated studies. Reliability is about the participants in the study being truthful and recognizing their potential biases when analyzing the results of the data (Creswell, 2013).

It was up to me as the researcher to identify strategies to control the bias so that it did not interfere with the validity of the study (Maxwell, 2005; Patton, 2015), such as bracketing as Moustakas (1990) suggested. I bracketed or suspended my own belief in VTS to study the reality of everyday life with it being a new phenomenon. I attempted to suspend my preconceptions, to hold up the phenomenon of VTS for serious inspection, especially as applied to mathematics instruction.

In this study some potential threats to the validity and reliability were: (a) the accuracy of data captured; (b) the interpretation of events as seen through my lens as a researcher (bias); (c) influencing the participants during data collection (reactivity) and (d) my limited writing expertise. I have a stronger mathematical intelligence than linguistic. I recognize that writing is a process of discovery. I tried to find my voice to allow me to record my observations accurately, while also uncovering the voice of the co-researchers in their experiences.

The ethics outlined by my university IRB and CITI Exam and the Belmont Report (1979) were daily considerations. I respected my co-researchers' opinions and input and kept them confidential by using their preselected pseudonyms. I was grateful for their participation, but they knew they could withdraw at any time without any adverse effect.

Implications of Findings

The facilitation of the VTS protocol gets easier with practice and flows when the questions are posed, think time is allowed, and input is restated as potential possibilities. Teachers learn how to restate by paraphrasing from kid talk to more academic language when they have a predetermined concept or vocabulary in mind first, but allow the student community to discover it. Teaching vocabulary in context and in conversation was possible with VTS if the facilitation let it happen naturally, but intentionally at the same time. I wanted to find out if VTS is a worthwhile endeavor by exploring the experiences of teaching and learning mathematics with VTS, as a new tool that incorporates verbal and visual intelligences with mathematical intelligence (Gardner, 1983). I believe that it is. The co-researchers felt that they would continue to utilize VTS in their classrooms after the study and start their next year in the classroom with VTS much earlier.

Talking and discussing math by using pictures combined the verbal, visual, and math intelligences. The topics in the theoretical framework included: Multiple Modalities, Visual Intelligence, Thinking, and Art Integration. Multiple Modalities (Katai et al., 2008) are important because they show how teaching with more than one modality allows teachers to reach more students, thus increasing learning and cognitive ability. Visual Intelligence is part of Howard Gardner's (1983, 2011) Multiple Intelligence Theory and acknowledges that children bring many different types of intelligence into the classroom (Douglas et al., 2008). VTS can utilize not only visual/spatial intelligence, but also linguistic intelligence to talk about math and increase mathematics intelligence.

Explication found that VTS can be used to improve math instruction with collaboration to create images such as graphs, which answers my central research question. Visual thinking strategies using pictures and photographs to think creatively and critically was later applied to math graphs. Those same strategies helped students make sense of bar, line, circle, and picture graphs. They were able to build deeper understanding as a community from diverse individual input when teachers got students engaged and confident. Restating evidence in a teacher "move" was a way to bump up vocabulary from student language and made math concepts explicit.

In every lesson with the math images, the facilitator restated the details given by students to build a collective understanding of the data being displayed. It was through the simple act of pointing out the details from each idea given by viewers that connected the evidence or support for their thoughts. Teaching the fellow viewers to use hand signals kept the facilitator aware of those that agreed with the idea and its evidence and those that did not. Probing those that did not as to why and getting those that did to elaborate.

It was through the paraphrasing and use of academic math terms that the concept was understood. Articulating the student suggestion into more scholarly language was not judgmental because it was all speculation and asking for validation and clarity. The connection that different types of graphs serve different purposes was huge for upper grades.

The connections the students were able to make regarding how to display different types of data and that their collected information would fit better into a specific type of graph was an ah-ha moment for two of the co-researchers.

Concerning applying the three main questions of VTS, the VTS questions were adhered to during this study with the art images, but once a discussion of graphs started, it was sometimes difficult to keep them verbatim. The sub-question regarding teacher moves included the mentions of learning styles, the evidence step, the selection of images, and speculative language to increase perspectives and find multiple possibilities when I enumerated the documents of transcripts from interviews, observations, and the focus group discussion.

The final sub-question about teacher perceptions to facilitate group discourse to increase academic vocabulary was answered only in part. All the co-participants started with accountable talk protocols in their classroom. They now include purposeful math discussions because they perceive that talking increases connections and that a community can build understanding of math concepts together. The perception that discourse increases academic vocabulary is debatable. Most of the teachers thought that kids only use the correct term when forced to. They did not believe that just using VTS will convince students that more concise language is needed to fully discuss a subject in a way that all understand. They struggled with facilitating a VTS lesson and preferred that I do that part. This leads me to ideas for a future study. How long does it take a teacher to feel comfortable as a facilitator so that they can guide a discussion using VTS protocols to connect with all viewers the math concepts and vocabulary they intended for the lesson?

The Achievement Gap Initiative (AGI) at Harvard (2017) found that improving classroom instruction is one key to closing the gap. As summarized in Chapter 1, The National Mathematical Advisory Panel of the U.S. House of Representatives Committee on Education and Labor (2008) made several recommendations in its report. They found that most class instruction is from textbooks, workbooks, and worksheets, which involved a lot of drill and practice. Instead, teachers of mathematics should have classrooms that model problem-solving behavior whenever possible and help all students feel more comfortable with math by exploring and experimenting along with students (National Mathematics Advisory Panel, 2008). I believe that is exactly what a VTS lesson should be. Explore all the possibilities together.

Educational leaders who are attempting to improve math achievement and keep STEM movement goals will have an interest in this study. There have been studies conducted with VTS, but none have been applied to mathematics. During the VTS lesson, it is important to guide the group thinking as the individuals contribute their own thoughts. The perceptions of one member of the group at a time can lead to the cumulative perception of all members of the group. If the picture that is examined in the VTS lesson had a math or science focus, then the learning and understanding could increase STEM thinking. VTS has been used with students from ages five to adult with a positive impact on increased observation skills and critical thinking, which are used in all core subjects. This study will add to the current knowledge on VTS.

Implementation of VTS

Many large cities have an art gallery to explore beautiful and interesting pieces. There is a Visual Thinking Strategies website and many books to use as a resource to start your own program. It is important to start with art images first before branching out to other core subjects (Yenawine, 2013). Founded in 1995 Visual Thinking Strategies is a research-based education nonprofit organization. It provides a teaching methodology, an image curriculum, and a professional development program. Individuals, schools, or entire school districts can join by going to vtshome.org or contacting a local art museum. Their program is a three-year professional development model K-8 curriculum. It starts with training at the beginning of each school year, involves some co-teaching, consulting, and usually culminates in field trips. It can be for the entire staff, or grade level specific, or for some content-area groups.

As stated earlier in Chapter 2, Proponents of VTS believe that finding meaning in art is a way of problem solving. To start, all you need are eyes, memories, openness, time, and encouragement to explore. Art images show people, places, things, expressions, interactions, and everything since the beginning of time in most cultures. All the possible interpretations for any one piece of art result in broader understandings. You follow basic, logical, tested rules, even if they seem restricting at first, to make it a discovery process. The steps are thought provoking and get students to focus, reflect, and think critically. Using the VTS process, teachers and schools can provide students with the same skills in the Common Core such as, "thinking skills that become habitual and transfer from lesson to lesson, oral and written language literacy, visual literacy, and collaborative interactions among peers."

The basic steps for conducting a VTS discussion are as follows:

1. Present a carefully selected image, based on Housen/VTS research criteria. Ideal images contain:
   - Subjects of interest for the specific audience

- Familiar imagery for a given audience
- Accessible meanings for a given audience
- Ambiguity: complex enough to puzzle

2. Allow a few moments for silent looking before beginning the discussion.
3. Pose three specific research-tested questions to motivate and maintain the inquiry:
    - What is going on/happening in this picture?
    - What do you see that makes you say that?
    - What more can we find?
4. Facilitate the discussion:
    - Listen carefully to catch all that students say
    - Point to observations as each student comments
    - Paraphrase each comment, taking a moment to reflect on it while formulating the response to make sure all content and meanings are grasped and helpfully rephrased without judgment
    - Link related comments to build on one another's ideas
    - Remain nonjudgmental by treating everyone and each comment the same way
    - Conclude by thanking students for their participation

Applying VTS to other subjects after practice with art can be done as we did with math in this study. If you live in New York City, San Francisco, Portland, or Seattle then you have a VTS office near you. They do offer trainings in several other cities in the United States and even internationally. In fact, the website boasts of “reaching 1 million students in 33 states and 18 countries through over 5,000 educators in over 300 schools, and 100 museums.” I am sure you can find help by reaching out to the art community.

There are several school districts from which to model implementation procedures. Miami, Boston, and San Antonio all have models to research and emulate. You have permission to emulate my study as well. If you are adventurous and believe in inquiry methods teaching then get yourself VTS training and experiment with the images I attached from an art museum. (See Appendix B) You even have permission to try the graphs I created if you want to try VTS in math. (See Appendix F)

I suggest that you have an established VTS time either once or twice a week. I suggest showing only 1-2 pictures depending on time. I would allow 10-15 minutes per lesson in order to keep engagement high. Follow the procedure outlined earlier every time. After 5-6 art images, you may want to try images from other core subject areas that you design with outcomes specific to your needs.

Leadership Support Needed

The mission statement on their website states, “We believe that thoughtful, facilitated discussion of art activates transformational learning accessible to all.” That is the key word, transformational. Transformational leadership focuses on developing the organization or school’s capacity to innovate. Rather than focusing specifically on direct control and supervision of curriculum and instruction. A transformational leader seeks to build capacity in others to select purposes and to support the development of changes to practices of teaching and learning (Hallinger, 2003). That is why I consider the principal where I conducted my study a transformational leader. She supports shared commitment to school change and is willing to give time, energy, and other available resources to initiatives that seek to improve instructional effectiveness.

Transformational leaders create school climates in which teachers engage in continuous learning. Then they encourage teachers to share their learning with others. Transformational leaders help staff to identify personal goals and then link those to the broader organizational goals (Hallinger, 2003). The principal creates a climate of committed and self-motivated teachers that work towards the improvement of the school without specific direction from above.

A transformational leader understands that some teachers are more qualified and more passionate about curricular areas than they themselves may be and allow them autonomy on instructional matters in those areas. For example, a principal that knows a teacher trained in mathematics at levels beyond him or herself allows that teacher to try innovative math techniques entrusting them to raise conceptual understanding in their students. Principals that organize and provide a wide range of activities aimed at intellectual stimulation and development for staff can transform and energize their school. Every teacher has some area of expertise and after being introduced to VTS would be inspired to try it in that area. I would encourage a transformational leader to support them in applying the VTS protocol to their area of interest or expertise. VTS only takes 5-10 minutes of instruction time once or twice a week and is the springboard for looking at everything with a different lens.

A transformational leader that is interested in improving mathematics instruction could empower a teacher by providing VTS training. Then support that teacher to share those methods with other staff members. I believe that investing in on-going professional development, such as, the three-year model of VTS ensures lasting change. Benefits of improved critical thinking would have a ripple effect.

Future Research

A VTS lesson that combines art and mathematics involves multiple senses; the visual sense is the springboard. The classical methods of teaching mathematics have not been successful with enough of our students. Maybe it is time to make teaching mathematics a multi-sensory approach. The studies with elementary, high school, and college students that explore VTS show significant gains in critical thinking skills (Adams, Foutz, Luke, & Stein, 2006). These studies have been in other core areas and now I have begun to see its use in mathematics. I advocate for a multi-sensory approach to all core subjects, but especially mathematics.

We explored VTS applied to mathematics through graphs because that was the math we were studying when this study was done. In our Focus Group discussion, there were other areas of mathematics mentioned that would be interesting in which to apply VTS. Their suggestions included multiplication arrays, fractions, algebraic expressions, story problems, and patterns. The future applications are limited only by our imagination. Just think of the other ways in which we could pose the question, "What is going on in this ___________?" My co-researchers plan to use the VTS protocol in communication arts and science next.

As I mentioned earlier I would be interested to find out how long it takes a regular classroom teacher to feel comfortable enough with the VTS protocol to branch out to other curricular areas other than art. Any area in which one feels successful and passionate would make a good study applying VTS. The website shows its use in the area of science and communication arts.

I have completed a qualitative study of VTS, but many studies I read did quantitative. However, I did not find quantitative studies using VTS to improve mathematics achievement, so perhaps I should try that next. The question could be aligned to a achievement test in mathematics and even be a mixed methods study.

Final Reflections

As I come to the end of this long arduous journey, I have a tremendous feeling of gratitude and satisfaction. I am grateful for all the teachers that are committed to making a difference in the lives of the students in their classroom. I am grateful that some entrusted their small community of learners to the VTS endeavor and me. I am grateful for the creative, imaginative students that were eager to learn and surprised us each day with ideas and connections they had. I hope each has improved in critical and creative thinking.

I enjoyed the heuristic method because learning is such a personal journey for me. I wanted to learn more about my favorite topic of math and specifically math instruction and I did. I believe the heuristic method made that possible. Learning and thinking is a phenomenon that has been studied, and shall remain so forever. There is always more. Just like the third question in VTS asks, what more can we find?

I learned that I am a good listener, but sometimes I cannot keep up with notetaking. I felt that taping the lesson reflections would have been intrusive. I wanted the conversation to flow naturally, but sometimes when they said something I wanted to remember verbatim I had to stop and have them write down exactly what they just said. I think if I carried my phone around with me all the time, I would have been tempted to tape our conversations. I did a good job of bracketing myself partly because I am a scientist and have no preconceived notion of what will happen. I live in the moment. I believe that the journey is more important than the destination.

I learned that I have persistence. I knew I had endurance because I have run two marathons. Persistence is different. I started with a goal of earning a doctorate on my Bucket List; yes the same one that had traveling to Hawaii. I felt like giving up more than once. I am old and will not have time to reap the financial benefits for this degree. Instead, I was paying for the pain and exhaustion of reading and writing more than I have ever read or written in my life. All of my previous degrees were easy work for me, but this one was NOT. I would not have made it without the help of colleagues, teachers, professors, and family. I am very proud of this accomplishment. Metaphorically, it is like giving birth. I have carried this extra weight around a lot longer than nine months, but it developed inside me and I feel like I have painfully produced an offspring of myself.

I am a mathematics/science teacher. I am not a communication arts teacher. The task of writing is more difficult for me than solving equations. I love puzzles and patterns and can figure out abstract problems; but when I sit in front of my computer to write I struggle and am easily frustrated. I believe in Multiple Intelligence and my gift for visual spatial reasoning is great, but my verbal linguistic is tiny. This dissertation is my magnum opus.

The teacher in me hopes that it will be read and that it inspires others to try VTS or at least make their math instruction multi-sensory. The learner in me hopes that I will remember to allow think time in every endeavor and believe there are no wrong answers. I will forever ask, What more can we find?

APPENDIX A

VTS OPEN-ENDED SURVEY

Name_________________________________
(use pseudonym)

The purpose of this heuristic descriptive study is to explore of the use of Visual Thinking Strategies (VTS) as it applies to mathematics instruction.
Thank you for participating in this study. Remember that your participation is voluntary and that you may withdraw at any time with absolutely no consequence.
Demographics: (optional)
Gender _________
Highest degree earned __________________________________
Grade level you teach/have taught ____________ How many years? __________
Grade levels of mathematics you could teach confidently: __________________________
Briefly respond to the following questions:

1. What does Visual Thinking Strategies (VTS) mean to you?

2. What do you see as the great challenge in teaching mathematics?

3. In what ways have you used visual aids in mathematics?

4. How much discourse is there in a typical math lesson and in what ways have you encouraged or discouraged it?

5. How do you typically teach mathematics vocabulary?

6. Briefly describe your math block. What components do you include? How much time do you devote to each component?

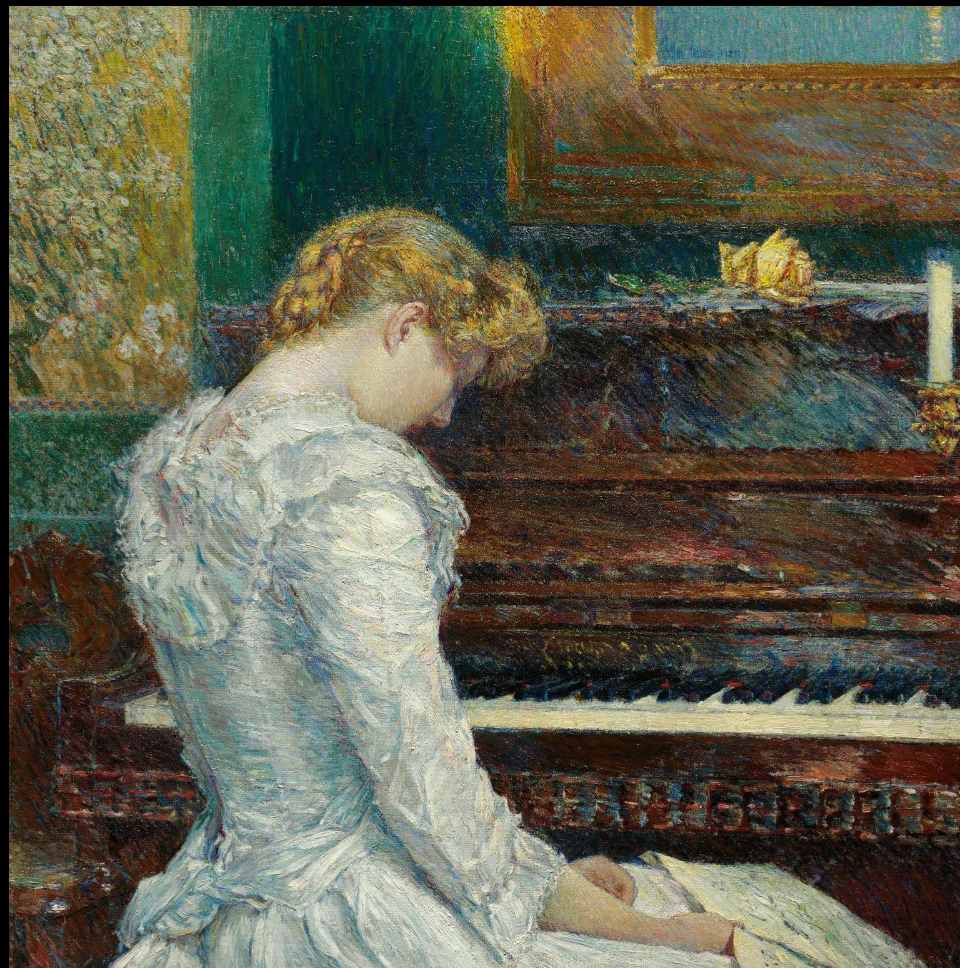
7. Briefly describe a few ways that you increase student engagement during mathematics instruction?

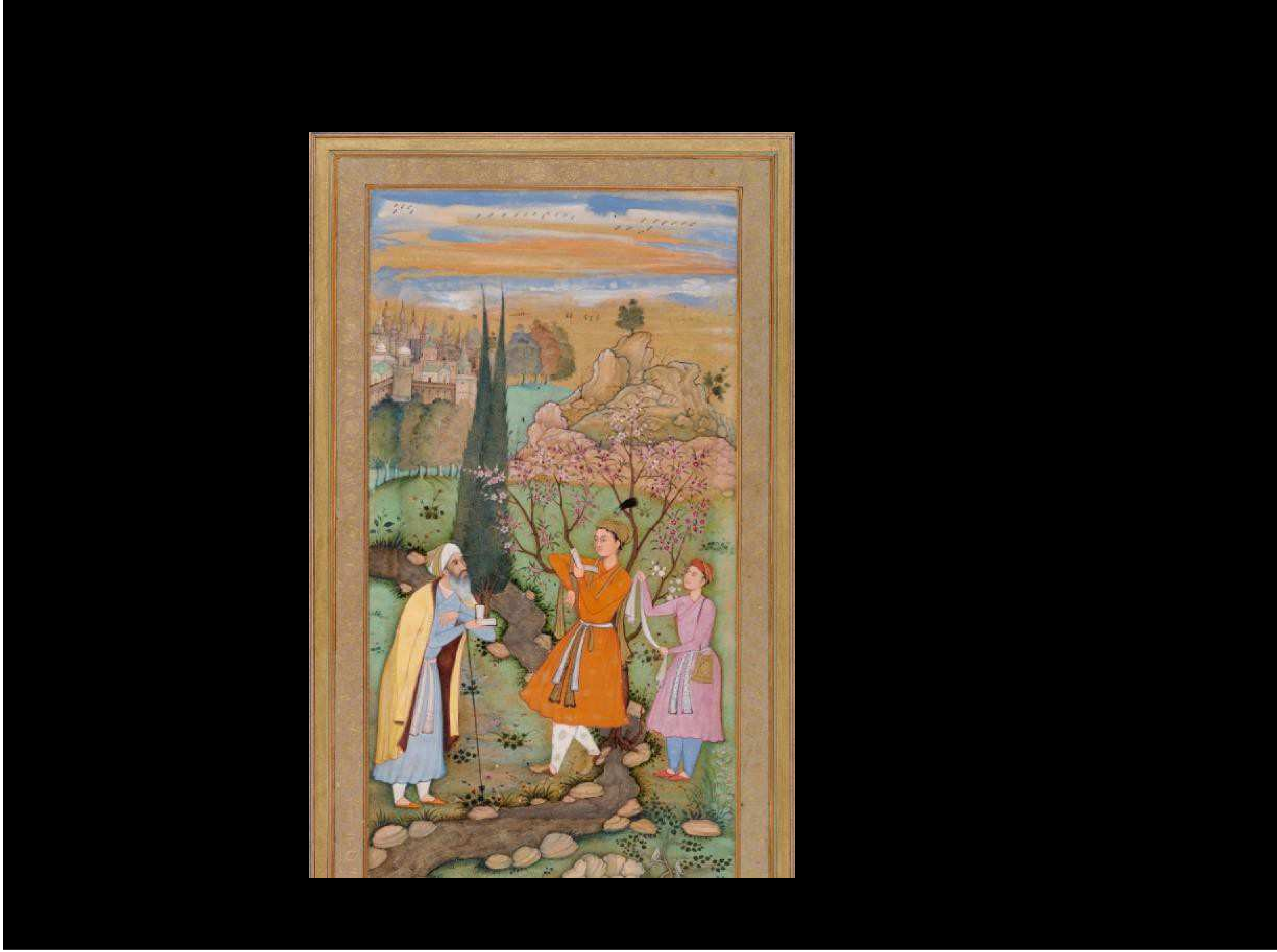
APPENDIX B

VTS IMAGES

Thinking through Art

First Grade





Attributions:

1. Henry Ossawa Tanner, *The Young Sabot Maker*, 1895. Oil on canvas.
2. Childe Hassam, *The Sonata*, 1893. Oil on canvas.
3. Henri Cartier-Bresson, *Outskirts of Paris*, 1968-1969. Gelatin silver print.
4. Charles Wilbert White, *Good Night Irene*, 1952. Oil on canvas.
5. Francesco di Stefano Pesellino, King David Before the Ark of the Covenant, ca. 1450. Tempera on panel.
6. Francis William Edmonds, *The Thirsty Drover*, 1865. Oil on canvas.
7. Salim Quli, *Leaf from the Murraqqa Gulshan: The Poet and the Prince*, 1595-1597. Watercolor and gold paint on paper.
8. Herbert Gehr, *Harlem Family (in Living Room)*, 1943. Gelatin silver print.
9. Harry Louis Freund, *Circus*, ca. 1935. Oil on Masonite-type board.
10. Jonathan Green, *The Reception*, 1989. Lithograph.
11. Pieter Brueghel the Younger, *Summer Harvest*, ca. 1615-1625. Oil on wood panel.
12. Lawrence H. Lebduska, *Wild Horses and Owl*, 1938. Oil on canvas.

APPENDIX C

VTS INTERVIEW GUIDE

Name ___________________________________
(pseudonym)

Current position ___________________________

The purpose of this heuristic descriptive study is to explore of the use of Visual Thinking Strategies (VTS) as it applies to mathematics instruction.

Thank you for participating in this study. Remember that your participation is voluntary and that you may withdraw at any time with absolutely no consequence. Thank you for completing the open-ended survey and now this interview. I will also be taking some notes as we talk. If at any time during the interview you wish to discontinue the use of the recorder or the interview itself, please feel free to let me know. Everything will be kept confidential in that your responses will be credited to a fictitious name. When I ask questions, I will only use the pseudonym that you have selected for yourself. (My probing prompts will be things like: can you give me an example, can you elaborate, is there anything else you would like to add?)

1. How do you feel about VTS in general, so far?

2. How can the art integration be improved for your group of learners?

3. How have the restatements during facilitation moved the lesson through the three VTS questions?

4. What do you see as the advantages and disadvantages of the evidence step when students are asked "What do you see that makes you say that?"

5. What has been your experience so far with the discourse lending itself to improving academic vocabulary in mathematics?

6. What are your ideas on how to apply the VTS protocol to mathematic images?

APPENDIX D

FOCUS GROUP PROTOCOL

Opening Introduction & Description of Project: As a part of my research study, I wanted to bring the themes identified through your observations and interviews back to discuss as a group. This discussion will assist me in ensuring accuracy of the data along with considering your additional interpretations to the data presented. I would like your permission to tape record this group discussion, so I may accurately document the information you convey. I will also be taking some notes as we talk. All of your responses will be kept confidential and will only be used for the purpose of this research. Additionally, your identity will not be revealed in my findings. Let's get started!

1. Based upon the themes that I presented to you, are there any themes that do you not agree with? Why?

2. Based upon the themes that I presented to you, which themes do you most strongly agree with? Why?

3. Based upon the themes that I presented to you, do you feel that there are any other potential themes of mathematics discourse, concept or vocabulary development that support the use of VTS not identified? Why?

4. How have your experiences with Visual Thinking Strategies changed your teaching practices in mathematics?

APPENDIX E

OBSERVATION GUIDE

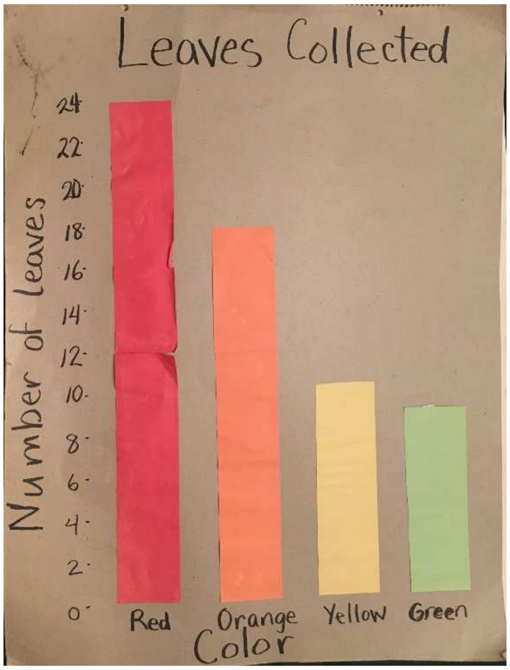
Observation Protocol

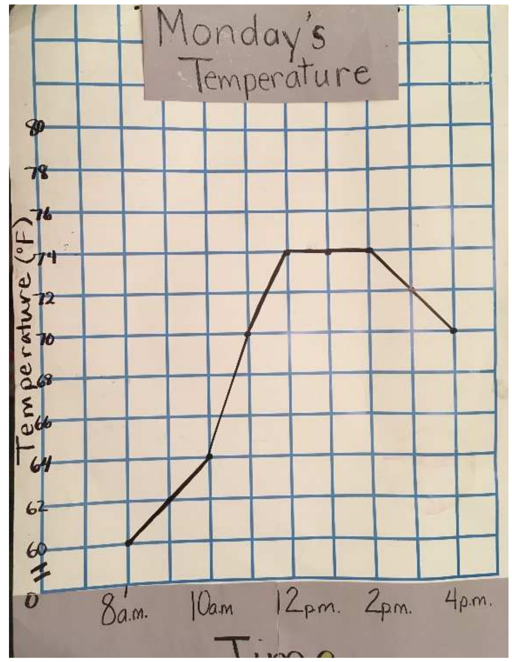
<table>
<tr><td colspan="2">Date: ___________________
Time: ___________________
Length of Activity___ Minutes
Site:
Participant Pseudonym: ____________________</td></tr>
<tr><td>Descriptive Notes</td><td>Reflective Notes</td></tr>
<tr><td>Activities</td><td>(Reflective comments: questions to self, observations of nonverbal behavior, my interpretations)</td></tr>
<tr><td>Classroom Environment: Climate</td><td>(Reflective comments: questions to self, observations of nonverbal behavior, my interpretations)</td></tr>
<tr><td>Teacher Instructional Behaviors: Delivery of instruction</td><td>(Reflective comments: questions to self, observations of nonverbal behavior, my interpretations)</td></tr>
<tr><td>Interactions of teachers with students</td><td>(Reflective comments: questions to self, observations of nonverbal behavior, my interpretations)</td></tr>
<tr><td>Interactions of students with other students</td><td>(Reflective comments: questions to self, observations of nonverbal behavior, my interpretations)</td></tr>
<tr><td>Teacher comments: Expressed in quotes</td><td>(Reflective comments: questions to self, observations of nonverbal behavior, my interpretations)</td></tr>
<tr><td>Student comments: Expressed in quotes</td><td>(Reflective comments: questions to self,</td></tr>
</table>

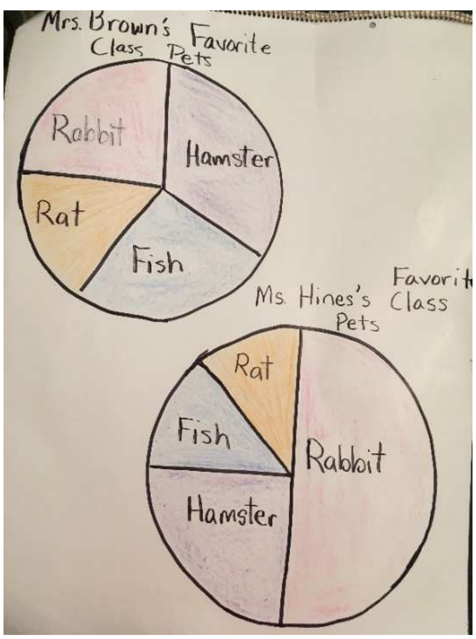
	observations of nonverbal behavior, my interpretations)
Nonverbal communications	(Reflective comments: questions to self, observations of nonverbal behavior, my interpretations)
Other relevant observations	(Reflective comments: questions to self, observations of nonverbal behavior, my interpretations)
Unplanned events	(Reflective comments: questions to self, observations of nonverbal behavior, my interpretations)

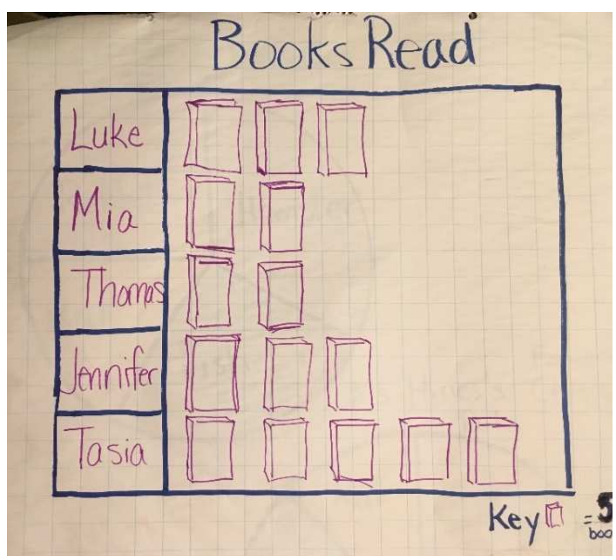
APPENDIX F

MATH IMAGES CREATED TO APPLY VTS









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VITA

Teri Yvonne Campos was born July 10, 1958, in Buffalo, Missouri. She was educated in Kansas City Missouri Public Schools and graduated from Fort Osage High School twelfth in her class of 317. She received a Regents Scholarship to the University of Central Missouri of Warrensburg, Missouri. She transferred to the University of Missouri-Kansas City, where she graduated in 1980 with a Bachelor of Arts in Elementary Education.

After teaching for six years at Blue Hills Elementary in Independence, Missouri, Ms. Campos began her master's program. She was awarded the M.A. degree in Curriculum and Instruction in August 1991 from the University of Missouri-Kansas City. She also achieved certification in Gifted Education and organized district science fairs. In 1992, she worked with a consortium of four local districts' profoundly gifted children housed in Center School District and was nominated for the Phoebe Apperson Hearst Award.

After she earned her Educational Specialist in Educational Administration in 2002, she worked as an assistant principal at Boone Elementary in Center Schools, then as an instructional coach in Kansas City's East K-8. After two years, she went to work in North Kansas City, where she ran district math competitions. She was awarded Excellence in Teaching in 2010 for Meadowbrook Elementary in North Kansas City, Missouri. She returned to Kansas City as an instructional coach and retired after 34 years in education.

She currently works as the Assistant Director of Curriculum for Operation Breakthrough, which opened a new STEM lab to serve underserved populations. She began work toward her doctorate in education in 2012. Upon completion of her degree requirements, she plans to continue her STEM endeavors and possibly teach at the college level.