8-22-2011

Connecting brain research with teaching practice among middle school teachers

Irene Sanders

CONNECTING BRAIN RESEARCH WITH TEACHING PRACTICE AMONG MIDDLE SCHOOL TEACHERS

By
Irene M. Sanders

A Dissertation

Submitted to the
Department of Educational Leadership
College of Education
In partial fulfillment of the requirement
For the degree of
Doctor of Education
at
Rowan University
April, 2011

Dissertation Chair: S. Jay Kuder, Ed.D.

Dedication

Jim, You inspired me with the path you took to get where you needed to be – and that inspired me.
Christy, You inspired me when you stood your ground and became an incredible role model for your precious daughter, Leah – and that inspired me.
Dan, You inspired me when you moved halfway around the world all by yourself and thrived for a semester – and that inspired me.
Pat, You inspired me every time you forged a new path or went to the beat of your own drummer – and that inspired me.
Matt, You inspired me when you became an entrepreneur and took sole charge of your life and your destiny –and that inspired me.
Mom, You inspired me with every weather forecast, every medical opinion, and every golden word of wisdom that you have ever shared with me – and that inspired me.
Thanks for the love and all that inspiration! You are, each of you, my heart and soul.
I love you all.

Acknowledgements

Dr. Kuder, Thank you for taking a chance on a total stranger to shepherd through this endeavor. You were a guide in unfamiliar territory and brought me through unscathed. You were positive and calm and always reassuring – all the things I needed you to be when I was the most unsure of myself and of this outcome. Thank you for giving me a solid footing to move forward when it seemed that I was moving backward. Thank you for getting me to my destination.

Dr. Sernak and Dr. Walpole, You are the two who know me the best and who always gave me the push I needed. I have always admired and respected your dedication, professionalism, and the extra mile that both of you go for your students. The two of you have made my dissertation committee complete and you will see the task through with me to the end. Thank you for your fairness and kindness, your challenging questions and observations, and your excellent grasp of grammar!

Abstract

Irene M. Sanders
CONNECTING BRAIN RESEARCH TO TEACHING PRACTICE
AMONG MIDDLE SCHOOL TEACHERS
2010-11
S. Jay Kuder, Ed.D.
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The discipline of mind, brain, and education science is the merger of psychology, neuroscience, and education. Its focus is to address complex problems in education and provide evidence-based solutions. One facet of this mixed methods action research study expanded middle school teachers' knowledge of brain function and brain-based strategies through a five-part workshop series and created a ten session professional learning community. Participants selected strategies such as relaxation, working memory tasks, or taught students about their brains to increase academic achievement, and tracked two groups' progress. Strategy implementation was judged to be too time consuming except for relaxation exercises. Alternate classes were suggested for strategy implementation instead of core classes. At its conclusion, teachers gained usable knowledge affecting their lesson planning and teaching, some students' working memory scores increased, and some students gained practical knowledge of their learning strengths and weaknesses. Although mixed, these results support the continued use of empirical brain research to inform teaching practices in a middle school setting.

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Chapter 1

Introduction and Overview

Public education in the United States has been under intense scrutiny and criticism for nearly fifty years. From the Coleman report in 1966 which indicted the influence of schools on student achievement; to the damning 1983 treatise known as *A Nation at Risk: The Imperative for Educational Reform* which sounded a death knell to public education; to the Goals 2000 initiative and subsequent legislation; to the various summits attended by government officials, legislators, business leaders, and educators; to the re-naming of the Elementary and Secondary Education Act as No Child Left Behind (NCLB) in 2000, public education and the perceived lack of student achievement has been repeatedly dissected and autopsied (Marzano, 2003). What has emerged from this scrutiny and as a direct result of government and business input is the standards based education reform movement that is legislated by NCLB. Extending beyond the establishment of measurable standards in the core curricula for elementary and secondary students, the mandate includes directives for curriculum development; raising the bar on student achievement; annual standardized assessments of student progress; and the alignment of curriculum, assessment, and professional development to the standards (AFT, 2003, reprinted 2009; Darling-Hammond, 2010; Marzano, Waters, & McNulty, 2005; McREL, 2005).

Operational Definitions

One of the tenets of standards based education is the alignment of teaching practices with research based strategies (McRel, 2005). This study addresses the potential advancement of student achievement through the implementation of research based teaching strategies such as those found in the emerging field of mind, brain, and education science. A field as specialized as mind, brain, and education (MBE) science includes an equally specialized vocabulary corpus.

The following definitions are included to clarify concepts pertinent to this action research project. Educational Neuroscience investigates "neural activity in the brain through the combination of cognitive neuroscience and behavioral methods" (Szucs & Goswami, 2007); it is the study of "mind, brain, and education" which brings together cognitive science, neuroscience, biology, and education (Battro, Fischer & Lena, 2008; Tokuhama-Espinosa, 2010, 2011). Mind, brain, and education science is the merger of education, psychology, and neuroscience to create "a strong research base for educational practice – a groundwork of usable knowledge about what makes for effective learning and teaching" (Fischer, 2009, p. 1). Neuromyths are popular ideas about the brain and its function that have not been validated by the scientific community (Atherton, 2005; Bruer, 1997; Goswami, 2004; Szucs & Goswami, 2007). Neuroplasticity refers to the malleability of the brain. It has been determined that learning and experience change the brain's structure and function throughout the lifespan (Doidge, 2007; Merzenich, Kaas, Wall, Sur, 1983). Useable knowledge is the outcome of connecting research and practice for educational leaders (Harvard Graduate School of Education). Finally, working memory is the ability to hold information in mind, manipulate it, and use it to problem solve; the place in the brain where thinking happens (Alloway, 2011; Gathercole & Alloway, 2008; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Klingberg, 2009; Sternberg, 2008).

Problem Statement

U.S. students continue to underachieve 10 years after the authorization of NCLB and more than 15 years after the inception of the standards based reform movement. The global view is the most concerning as U.S. 15 year-olds rank 21st in science and 25th in math out of 30 nations worldwide in the 2006 Program in International Student Assessment (PISA). Nationally, the most recent results of the 2009 National Assessment of Educational Progress (NAEP) test results for reading among middle schools indicates that the achievement gap is stable, despite some improvement in individual scores. The achievement gap is the lack of academic achievement experienced by subgroups of students within the entire population being analyzed, i.e., by class, by grade level, by school, by state, and nationally. It typically refers to disparate scores between White and minority students, as well as between poor and more economically advantaged students. The achievement of English Language Learners, students with disabilities, and males vs. females are factored into the gap as well. The gap signifies that students, K-12, are not achieving at the levels prescribed by state standards. At my local level, the 2008-09 and 2009-10 scores in language arts/literacy, for example, on the standardized New Jersey Assessment of Skills and Knowledge (NJASK) for Sandersville Middle School are a microcosm of those at the national level. Achievement gaps are noted for students with disabilities, males v. females, and ethnicities across 6^{th}, 7^{th}, and 8^{th} grade levels. On the various assessments used nationwide, some achievement gaps are 50 percent or more, while others are only 1 or 2 percent apart (Darling-Hammond, 2010; NAEP, 2010; NJASK, 2009; U.S. Department of Education, 2004).

One approach to advancing student achievement is through the implementation of research based teaching strategies, part of the state and federal mandate guiding public education. This directive from the Individuals with Disabilities Education Act (IDEA 2004) is legislated through NCLB and stipulates the inclusion of research based teaching strategies in 21^{st} century classrooms. Robert Marzano affirms that "thirty-five years of research provides remarkably clear guidance as to the steps schools can take to be highly effective in enhancing student achievement" (2003, p. 11). The research to which Marzano refers is directed at school-level factors such as policy and school wide initiatives, teacher-level factors such as classroom management, curriculum design, and instructional strategies, and student-level factors such as motivation, learned intelligence/background knowledge, and home atmosphere. The U.S. Department of Education defines scientifically based research as "research that involves the application of rigorous, systematic and objective procedures to obtain reliable and valid knowledge *relevant to education activities and programs* (italics added) (U.S. Department of Education, No Child Left Behind: A Toolkit for Teachers, 2004, p. 6). Research fields exist outside the specific domain of education research which may be highly relevant to advancing student achievement.

One field that holds promise is mind, brain, and education science (MBE) which targets the application of research on the brain and learning/teaching for education. MBE science unites the education, psychology, and neuroscience fields to create usable knowledge to address contemporary issues of student achievement (Tokuhama-Espinosa, 2011). Subdivisions of these three fields are also included in the general scope of creating a research base to enhance learning and teaching. For example, the nascent field of "educational neuroscience is an emerging field that brings together biology, cognitive science, developmental science, and education to investigate brain and genetic bases of learning and teaching" (Fischer, Goswami, Geake, and The Task Force on the Future of Educational Neuroscience, 2010, p. 68). After the inception of educational neuroscience, the term mind, brain, and education science was coined to identify this new academic discipline that "brings together natural, life, neural, and social sciences" (Tokuhama-Espinosa, 2011, p. 14) to help solve the varied and complex problems facing education. Numerous names have been applied to the field of research based learning and teaching over the past 30 years including, "*brain-based learning* (italics in original), (which is a mainly commercial packaging of information about the brain for teachers); *educational* *neuroscience* (which is primarily information about learning grounded in laboratory research but that used more technical terms than teachers are typically comfortable with)…" (Tokuhama-Espinosa, 2011, p. 16). Regardless of the label used, all related fields focus on researching learning while MBE science includes the study of teaching, as well. The most common references to this academic discipline in the literature are educational neuroscience and MBE science; however, prior to the publication of Tokuhama-Espinosa's first book entitled *The New Science of Teaching and Learning: Using the Best of Mind, Brain, and Education Science in the Classroom* (2010), the term educational neuroscience was the most frequently applied and most well recognized for the discipline. For purposes of historical accuracy, I will use both terms in the literature context in which I researched them. While there are more references to educational neuroscience, the terms MBE science is comprehensive and state-of-the-art.

Is it possible to integrate teaching strategies that are aligned with empirically established brain-based principles into middle school teaching paradigms? Please keep in mind that psychology has historically informed education while neuroscience is a new field on the education scene, just learning its foibles and idiosyncrasies. Some critics do not believe that educational neuroscience can inform education at this time, that meaningful interaction between both fields is premature. Other researchers do not share this narrow view and advocate for equal collaboration between neuroscientists and educators to inform each other and continue to advance the new discipline of MBE science. There is a third viewpoint which suggests that while the application of brain research to education is limited at this time, there is no reason not to apply what is known and creatively blend those principles with more commonly held teaching strategies to discover their impact on student achievement (Bruer, 1997, 1999; Fischer & Immordino-Yang, 2008; Willis, 2006, 2007, 2008, 2010). One reason the integration of new knowledge may be difficult is the proliferation of neuromyths in recent years which has led to "bogus recommendations for educational practice based on oversimplifications and unsupported conceptual leaps" (Battro, Fischer, & Lena, 2008, p. 13) often promulgated by the popular press.

Educators must be their own analysts of studies and products that claim to be brain-based and ask questions, examine the research, and know how to interpret the data that supports alleged educational products and programs. "Awareness of new scientific knowledge puts educators in the rightful position of insisting that programs used in their schools reflect what is known about the science of learning and effective learning strategies that are compatible with brain research. (Willis, 2006, p. 104). Educators, therefore, need to be aware of current research and be able to read it knowledgeably. As advances in the field of neuroscience help scientists understand *how* we learn as well as *where* in the brain learning occurs, questions of relevancy to education dissolve as causal links connecting brain function to learning/teaching practice continue to emerge.

Educational neuroscience's place in the laboratory is clear; its place in the field of education is emerging and requires exploration. "The space for working to fill this (scientific) gap is *beyond* (italics included in original) the laboratory and its strict, traditional models of learning. The new "learning space" for the neuroscientist is the classroom" (Battro, Fischer, & Lena, 2008, p. 10)! When the partnership between neuroscientists, psychologists, and educators generates meaningful dialogue, more experimental designs will continue to yield the research that will produce true brain-based teaching strategies. The groundwork for establishing these crucial partnerships is being laid globally in training programs such as the Mind, Brain, and Education program at Harvard University and the Neuroscience and Psychology in Education program at the University of Cambridge in England (Fischer & Immordino-Yang, 2007).

Professional organizations such as the International Mind, Brain, and Education Society and the Learning and the Brain Society are dedicated to providing educators with empirically based information, and provide on-going professional development in the form of websites; on-line chats with renowned brain researchers; conventions, conferences, and summer courses; and a growing library of professional books and journals. More and more educators are learning and sharing empirical brain science some of which can be directly tied into their teaching practice. The opportunities for creating the necessary dialogues are ripe and now is the time to expand the search for research based teaching strategies beyond the limits of education research only.

My professional training and practice as a speech/language pathologist for more than 35 years has included studying brain structure and function relating to human communication in several contexts. Joining my professional background with contemporary classroom practices has been an ongoing personal mission as I have supported the ways teachers instruct and the ways students learn over the past three decades. That union has produced the impetus for this mixed methods study which will investigate teachers' perceptions of increased student achievement resulting from the implementation of brain-based teaching strategies in a public middle school setting (sixth, seventh, and eighth grades). Can classroom teachers and I examine empirical brain studies directly and cull from them research strategies that can be infused in their teaching routines? Can classroom teachers and I assess the effectiveness of such strategies and their impact on student achievement? Will teachers change their teaching practices as a result of their involvement in this project? Using the results of psychologists' and neuroscientists' work with neuroimaging and laboratory based methods may provide educators with new interpretations of brain structure and function to facilitate both teaching and learning.

Additionally, the process of planning, executing, and overseeing this entire project will allow me to test my mettle as an emerging educational servant leader who leads from the trenches.

This study is important because it is in direct accord with the NCLB legislation to include research based teaching strategies in the classrooms of the 21st century. While special education teachers, for example, are highly qualified in their individual content areas according to law, selected teaching strategies and classroom management techniques are determined by their teacher preparation programs and subsequent direct classroom experience and professional development, which is true of general education teachers as well. Anchoring teaching in state-of-the-art research based strategies enhances teaching practices, enables general and special education teachers to join all students' learning needs with unique interventions, and offers teachers the promise of realizing learning outcomes reflective of the fruits of the researchers' labors.

Purpose

The purpose of this action research study was to explore and develop teaching strategies culled from empirical brain research to be used in a middle school setting. An ancillary purpose was to develop my servant leadership through the development of a brain research workshop series, a professional learning community (PLC) to extend the professional development begun with the workshop series, and to assist the teachers in the development and implementation of research based strategies. A series of action cycles were implemented in two phases, both phases containing quantitative and qualitative methods. A concurrent embedded mixed methods design was used, a design in which the quantitative survey data provided a supportive, secondary role in a study based primarily on the qualitative data (Creswell, 2009; Creswell & Plano Clark, 2007; Henry & Kemmis, 1985; Hinchey, 2008; Kemmis & McTaggart, 2005). The primary purpose of this study was to use qualitative methods of observation, interviews, focus groups, and journaling to test the theory of pragmatism which explores solutions to real problems in the world, in this case, the world of education (Creswell, 2009, p. 10). In this study empirical brain-based teaching strategies were implemented to address the problem of student achievement at the Sandersville Middle School and were also attempted to change the participants' teaching practice. A secondary purpose was to gather quantitative survey data to define the teachers' change in teaching practice that they experienced after gaining usable knowledge about brain-based teaching strategies and any changes they observed in their students' achievement at Sandersville Middle School. The rationale for collecting the secondary data was to provide a numerical measure of change to anchor the rich, deep verbal descriptions obtained through the qualitative data (Creswell & Plano Clark, 2007). Due to the small number of teacher participants, percentages were used to determine what amount of change, if any, occurred at the end of the study.

I explored selected brain science topics with general education and special education middle teachers at Sandersville Middle School beginning with a five-part workshop series. The teacher participants and I then used empirical brain research studies to design, implement, and assess teaching strategies to affect learning skills such as increasing attention among middle school students and decreasing affective resistance to learning in this population. The brain-based strategies were assessed through observations, focus groups, individual teacher interviews, and reflection. The research assessed the learning community format as a vehicle of sustainable change through continued professional development; the processes of implementing and assessing brain-based strategies with students to facilitate increased attention and decreased emotional resistance to learning; their impact on student achievement; the teachers' development as students and practitioners of brain science; and my servant leadership.

My role was to provide speech/language services to the designated students in general and special education settings and to support the teachers in a variety of ways, i.e., teaching small groups, modeling lessons with the entire class, co-teaching, providing resources to enhance the teachers' planned lessons. While my role continued throughout the execution of this study, it was expanded to include the researcher's lens through which I observed teachers implementing the brain-based strategies selected to increase student learning outcomes. It also encompassed and embraced the tasks of servant leadership inherent in such an endeavor. My leadership framework was to highlight "that which is in the best interest of the student," which, according to Shapiro and Stefkovich (2005, p. 25) is the foundation for the ethic of the education profession. It was that impetus that defined me as a servant leader who served the needs of others before the needs of self, who sought to serve first, and lead thereafter (Greenleaf, 1977).

Mutually supportive to my leadership style or ethic of the education profession was a very closely aligned theoretical perspective that undergirded the purpose of this study. Connecting research with teaching practice occurred within a democratic, constructivist framework that allowed teachers to participate in the selection of research based strategies, enabling them to enhance academic achievement among middle school students. The significance of this study was defined by the NCLB mandate to employ research based teaching strategies in 21st century classrooms and by the immediate need to increase achievement among students at Sandersville Middle School, given their failure to attain their annual yearly progress goal for the 2009-2010 school year.

Special education teachers are charged with the dual responsibility of adhering to the provisions of each individual student's IEP as well as generalizing their teaching strategies to reach an entire group of students with a variety of classifications and learning challenges. General education teachers are charged with a similar responsibility to differentiate instruction among academically diverse classes. One's teaching practice must be refined and developed beyond teacher preparation courses to address the wide spectrum of student needs and depends on research to discover new ways to stimulate learning among such varied student populations. NCLB provided the mandate and the new field of MBE science provided the research. One goal of this project was to ascertain if a workshop series and professional learning community could create a bridge between empirical brain research and teaching practice among middle school teachers at Sandersville Middle School.

MBE science has begun to investigate various topics that relate not only to generalized learning processes but also to connecting brain-based learning with the field of education. Attention and emotion are two of those topics investigated by MBE science that can benefit classroom teachers. Attention involves attuning to information from our social and learning environment. From all the stimulation in our surroundings, we attend to the exact sliver of input we require at that point in time. "Attention is the portal through which the information flood reaches the brain" (Klingberg, 2009, p. 19). The directive to "pay attention" turns out to be easier said than done for some students.

In a similar vein, an individual's awareness of his/her emotional state coupled with the ability to regulate that state may promote or inhibit a student from engaging in the learning process. Neuroscientists are now able to establish a direct causal link between emotion and cognition, suggesting the interdependence one factor has on the other. Immordino-Yang and

Damasio explain that "…the neurobiological evidence suggests that the aspects of cognition that we recruit most heavily in schools, namely learning, attention, memory, decision making, and social functioning, are both profoundly affected by and subsumed within the processes of emotion; we call these aspects *emotional thought* (italics included in original)" (2007, p. 3). The link between students' emotions and learning must be acknowledged by teachers and students alike if the transfer and generation of knowledge based skills is to occur successfully. To the extent that that is *not* happening within the status quo is a personal and professional mandate to continually seek new teaching paradigms, strategies, supports, and materials to enhance the learning of all students, regardless of their challenges. It is a mandate for the educational servant leader.

Keeping "that which is in the best interests of the student" (Shapiro & Stefkovich, 2005, p. 25) always in mind was the unifying principle that enabled me to bridge the gap between theoretical research and teaching practice. Keeping the students' needs as my guiding light allowed me to illuminate new applications for research that are just beginning take on a practical guise to enhance students' availability for learning. This project extended the care and best interest of the students to include the care of the teacher participants, as well. By serving the needs of both students and teachers, my servant leadership reinforced the trusting relationships that I build day-by-day through my interactions with others. Not having positional power enabled me to be a quiet servant leader, implementing more effective teaching interventions that benefited students and teachers alike. This was accomplished to the extent that I have already created a "power with" relationship with my colleagues (Follett, 1924, as cited in Kreisberg, 1992).

Rationale

Sandersville Middle School's primary problem of partial academic proficiency was visible through the number of classified students we taught and the results of the annual standardized state assessments administered every academic year. One of three middle schools in a large, highly diverse suburban district, the school population of 970 sixth, seventh, and eighth grade students contained the largest concentration of classified students in the district due to its programming variability, flexibility, and coherence. 213 classified students across all grade levels out of a total population of 970 students represented 22% or nearly one-quarter of the school's total population for the 2009-2010 school year. The students were placed in inclusion, resource room, and self-contained classes; all teachers, whether general or special education, were responsible for teaching general and special education students throughout the school day. Among the three middle schools in the school district, these demographics were unique to Sandersville Middle School and formed the foundation for the study's rationale because they could not be changed in any way to address the issue of student achievement.

The teacher participants implemented brain-based teaching strategies designed to change generalized learning skills such as increasing attention and decreasing emotional resistance to learning among classified and general education students. These efforts were directed at continually increasing achievement among all their students. Although decried by many educators as insufficient, inadequate, and sometimes unfair, the standard of academic achievement is currently considered to be individual, grade level, and school wide performance on annual standardized testing in language arts/literacy and mathematics. The achievement gap that existed in language arts/literacy and mathematics among special education students in particular was an on-going visible problem that had yet to be resolved.

Second, education is not just for students, but was for the professional teaching staff as well, which does not have to be advanced through the pursuit of graduate degrees. It takes place whenever there is a conversation related to content areas, teaching strategies, classroom management, behavior, learning disabilities, support systems within the school, and a myriad other topics of interest and need to the teaching staff. The issues of educational neuroscience or brain-based teaching/learning or MBE science struck a familiar chord among some of my colleagues, but none demonstrated more than a casual, surface knowledge of the disciplines. This fact became clear as a result of the pilot study I conducted with several teaching colleagues in October and November, 2009. The teachers reported that they

> have had a lack of exposure to topics such as brain-based teaching and therefore cannot implement strategies that emerge from this research. Lack of knowledge prevents them from connecting research to practice, preventing them from meeting needs such as increasing student attention and decreasing emotional resistance to learning. On-the-job training increased teachers' perceived knowledge and facility with classroom management, therefore, the same approach could be applied to connecting brain based research with teaching practices (Sanders, Teacher Interviews Summary, 2009).

Despite the expressed interest and curiosity, it has remained an unexplored area with, I believe, the untapped potential to reach more students through teachers' knowledge expansion and strategy based paradigm shifts.

There is a third rationale supporting this study. Two dichotomous approaches to the study and implementation of brain research exist in the status quo, which create a gap both in the literature and in the usable knowledge to be incorporated into teaching practices. Usable knowledge is defined by the Harvard Graduate School of Education as connecting research to practice. On the research side of the dichotomy are the empirical studies conducted by neuroscientists for neuroscientists to advance the field of brain science. They are not always user friendly and are written in a scientific language different than that used by educators and others outside the neuroscience field. At least some of the language of education must be incorporated into empirical studies if educators are to dialogue with neuroscientists.

As to the usable knowledge issue, a number of education researchers have written interpretative texts to assist teachers in the understanding and implementation of so called brain-based teaching strategies (Caine, Caine, McClintic & Klimek, 2009; Hardiman, 2003; Jensen, 2005; Jones, 2002; Sousa, 2006). They have not conducted any of the research themselves but report on and interpret the research of others in the field. While each of these texts includes comprehensive reference lists, not all of the specific information within the chapters contains citations, which suggest that the information itself may not come directly from research, but may be an undocumented interpretation. The experts in the field also warn the neophyte to beware of "some irrationally exuberant (and inexact) boosters of neuroscience in education (that) may be found in the popular press" and they cite Connell and Jensen as two examples (Willingham & Lloyd, 2007, p, 147). Classroom teachers who want to increase their own knowledge of brain-based learning and implement ideas from these texts may be relying on information that is not empirical and/or selectively interpreted according to the authors' own understanding of the material. "In typical claims for brain-based education, beliefs about learning and schooling are restated in the language of brain science, but there is no brain research on which those restatements are based" (Fischer & Immordino-Yang, 2008, p. xviii). At least some of the language of empirical brain science must be retained if neuroscientists are to dialogue with educators.

Research Questions

Using the "spirals of self-reflective cycles" that comprise action research developed by Kemmis and McTaggart (2005), I planned, acted, observed, and reflected on various aspects of teaching practice which I have identified as being in need of improvement. The data that was collected from each cycle informed the planning and actions implemented in subsequent cycles after I had engaged reflectively on it personally and with the professional learning community (PLC) members. Their involvement in their own personal reflections as well as the group reflections as part of the PLC were treated as a major contribution to this study's outcomes. Osterman and Kottkamp (2004) take a dim view of new programs purported to create school reform without engaging in reflective practice reminiscent of the double-loop learning required to change values and beliefs of which Argyris (1990) writes. I must heed their caution that

> It is simply not enough to develop a new program, however well designed, if the process of implementation does not provide an opportunity to explore the ways of thinking, seeing, and believing that affect what we do and how we do it. Without this conscious dialogue, even the best solution will not be sustained in the face of continual demand for newer and better solutions (Osterman & Kottkamp, 2004, p. x).

As an agent of change, my ultimate purpose was to affect a degree of change at Sandersville Middle School that was visible, measurable, and sustainable. In conducting action research, reflective practice was considered a powerful change strategy that "empowers them (educators) to assume personal responsibility for their own learning and professional growth"

(Osterman & Kottkamp, 2004, p. 2) and communicate what they have learned with the PLC members first and then the extended members of the Sandersville Middle School staff.

This study sought to answer the following questions about infusing selected principles and practices of educational neuroscience into the teaching strategies of middle school teachers at the Sandersville Middle School to affect their teaching practice:

1. Did the middle school teachers at Sandersville Middle School gain "usable knowledge" connecting brain research to teaching practice? If so, what was the extent of the change in knowledge?
2. Did brain-based "usable knowledge" change middle school teachers' teaching practice?
3. What were the teachers' perceptions of changes in student achievement at the conclusion of this study?
4. Did teachers observe changes in students' attention related to brain-based teaching strategies?
5. Did teachers observe decreased emotional resistance among their students as a result of brain-based teaching strategies?
6. Did the experience of a workshop/PLC format help to create a bridge between empirical brain research and teaching practice among middle school teachers at Sandersville Middle School?
7. Did my leadership role in this project enable the teacher participants to gain usable knowledge in the principles and selected practices of mind, brain, and education science?

Significance of the Study

This study was important because it had the potential to make teachers better educators so that they could teach their students to become better learners. "Better" in this context meant enabling teachers to find ways to help their students take in information, understand it, and apply it meaningfully; it meant helping teachers enable students to increase their attention in learning environments and decrease their negative emotional reactions to learning in order to increase their achievement. Despite the intense efforts of the special education teachers, for example, an insufficient number of students had scored in the "proficient" or above range on the yearly standardized testing that determined if a school has achieved its annual yearly progress (AYP). The results of the 2009-10 school year showed that 60% of the sixth grade special education students scored in the partially proficient range, 20% were proficient, with no scoring information returned for 20%. More than half of the special education subgroup was below proficiency with approximately one third scoring at the proficient level. For the 2008-09 school year, 62.1% of sixth grade special education students scored in the partially proficient range compared to 36.2% of the same population who scored in the proficient range. Nearly twice as many classified students are considered to have failed the state mandated test as passed it. This performance pattern was also seen for the 2007-08 school year as 67.4% of the sixth grade special education students scored in the partially proficient range and only 32.6% scored in the proficient range. The proportion of failing scores to passing scores was more than two to one (NJASK, Preliminary Performance by Demographic Group Report, Spring, 2008).

Teachers are required to adhere to the district curriculum standards, which are aligned with the state and federal standards, whether they teach the general education, special education population or the combined population. They have little control over *what* they teach; they do have control, however, over *how* they teach the prescribed content. New methods of instruction must be pursued and tailored to meet the needs of this classified population if the performance pattern is to shift away from partially proficient performance and move toward proficient performance; and, research must inform general education if that performance pattern is to shift away from proficient performance and move to advanced proficient performance. New strategies, grounded in empirical brain research, may offer a different view of learning strategies that will be applied to content areas resulting in more productive outcomes. A move away from the status quo is necessary if these outcomes are to be realized.

The literature review contained in Chapter Two develops the topic of MBE science from the theoretical to the practical. Recent neuroimaging advances have enabled neuroscientists to "see" into living brains while their subjects are engaged in a variety of tasks, helping them to bridge the distance between neuroscience theory and teaching practice. Some of the pertinent neuromyths that are mistaken for valid brain based teaching are identified and debunked. Chapter Three describes the methodology employed in this mixed methods study from both philosophical and practical viewpoints. Chapter Four includes an analysis of the findings that resulted from the qualitative and quantitative methods employed throughout the project. Chapter Five addresses the conclusions derived from this research as well as implications for further thought, designs, and study of the groundbreaking field of MBE science and its place in the 21st century classroom.

Chapter 2

Literature Review

Since cave dwellers taught their offspring to hunt and gather and Socrates questioned his curious students, educational systems have existed. As humans have evolved over time, educational theories and strategies have also appeared in response to politics, social issues, fiscal concerns, and technological advances. According to popular belief, new information created new knowledge bases from which better teaching and better learning emerged. Education has found itself, once again, approaching a new era of practice, one informed by the diagnostic imaging advancements in neuroscience, the nascent field of educational neuroscience.

The purpose of this literature review is to examine the historical and empirical constructs that anchor the emerging field of educational neuroscience. Discussing and dispelling popular beliefs or myths about brain functioning and its effects on information processing and learning behavior are presented first. A review of bona fide empirical studies connecting neuroscience research to educational practice is a second analytical focus. The final portion of this review is a position statement regarding the possible future of MBE science and the formulation of potential questions educators might ask MBE scientists as they continue the requisite dialogue between the three disciplines. While neuroscience and psychology can certainly inform the field of education, it is truly a two-way street requiring educators to join the discussion and inform neuroscience and psychology, as well.

History

Established on November 7-8, 2003, the International Mind, Brain, and Education Society was formed by a group of neuroscientists, psychologists, and educators who recognized the potential for advancing education practices through the application of knowledge about the brain gleaned from new imaging techniques, such as functional magnetic resonance imaging (fMRI) (Battro, Fischer, & Lena, 2008) as well as joining their efforts to create a strong research based foundation on which to advance learning and teaching. Through such collaboration, research and practice create usable knowledge, that is, research supported strategies that are practically implemented in the classroom to fortify education and provide evidence-based solutions to complex, long-standing problems. "This foundation requires a new approach to connecting research and education, with a two-way collaboration in which practitioners and researchers work together to formulate research questions and methods so that they can be connected to practice and policy" (Fischer, 2009). In order to arrive at evidence-based solutions, the educator will wear the researcher's hat at times and the psychologist and neuroscientist will wear the practitioner's hat to provide parity among the disciplines.

With roots that are traced from the ancient Egyptians and Socrates' Greeks to 21st century classrooms, the history of education contains the history of the MBE movement. The influence of the brain and its workings on teaching philosophy has fluctuated throughout history; its ebb and flow resulting in renewed efforts to place it at the center of education. Its agency has also been observed through its worldwide, interdisciplinary development, "a development that became an integrated effort in the 1990s and a new academic discipline around 2004-2006" (Tokuhama-Espinosa, 2011, p. 72). The reader is referred to Tokuhama-Espinosa's thorough presentation of the historical underpinnings of MBE science's history in her book, *Mind, Brain, and Education Science: A Comprehensive Guide to the New Brain-Based Teaching* (Tokuhama-Espinosa, 2011).

Despite strong support for the development of MBE science, there have been detractors. Some cognitive neuroscientists avow that the connection between neuroscience and information processing is loose at best, resulting in the development of unsubstantiated theories and commercial programs related to errant ideas such as the existence of the "right brain vs. left brain." (Bruer, 1997; Stanovich, 1998). As educators latch onto these commercialized theories that have no empirical basis, neuromyths appear and misinformation begins to be spoken of as scientific truths in classrooms around the world (Goswami, 2004). As educators, psychologists, and neuroscientists join forces, misinformation is brought to light not yet eliminating, but minimizing their impact on teaching and learning practices.

An element of the mind, brain, and education movement that has only recently surfaced is the demand to develop standards around which MBE science will govern itself and prosper or, wither and die before it bears productive fruit that has the potential to create meaningful change. Psychologist Howard Gardner of Harvard University, most well-known for his Theory of Multiple Intelligences (1983), has placed this demand on the new academic discipline from the perspective of neuroethics (Tokuhama-Espinosa, 2011). The ethical concerns raised regarding brain research, the dissemination of inaccurate or incomplete information, criticism within the discipline, its ability to self-govern, to name a few current issues, require a set of standards to be upheld and used as a stanchion, a support providing stability and the potential for further growth and development as a professional field.

In order to establish standards for MBE science, Tokuhama-Espinosa (2011) gathered a panel of 20 experts known as a Delphi panel which is an anonymous exchange of opinions between experts who try to reach a consensus; in this case, she and they sought consensus regarding the information that comprises brain-based education. The Delphi panel's make-up was both interdisciplinary and international, attesting to its potential scope of influence. Information and ideas in education that are allegedly brain-based have proliferated in recent years. In an attempt to organize this large body of information and to create governing standards for the new discipline of MBE science, Tokuhama-Espinosa conducted a meta-analysis of over 4,500 references as part of her doctoral dissertation (2008). The Delphi panel's charge was to work with Tokuhama-Espinosa to organize and categorize that information spectrum which ranged from absolute truth to unfounded myth. They applied four categories identified by the Organisation for Economic Co-Operation and Development (OECD) which was developed by representatives from 30 nations worldwide in their book *Understanding the Brain: Towards a New Learning Science* (2002). The Delphi panel scrutinized the quality of the information and determined into which of the four OECD categories the concepts belonged: what is well established; what is probably so; what is intelligent speculation; and, what is popular misconception or neuromyth.

The OECD spectrum is considered to be "an excellent tool for sorting good information from bad in MBE science because it is an evidenced-based tool agreed upon by MBE scientists around the world" (Tokuhama-Espinosa, 2011, p. 85). The list of concepts and ideas included in this spectrum is fluid and will continue to expand and contract as research advances the existing knowledge base that forms the foundation for MBE science. Concepts in the *what is well established* (italics in original) category are those that are well researched fundamental facts, i.e., connecting new information to prior knowledge facilitates good learning. Ideas in the *what is probably so* group are important ideas in education that may move into the well established group with more research. This would require "unanimous backing from at least one of the three disciplines" in MBE science (Tokuhama-Espinosa, p. 84). Stress, both good and bad, impacts learning is an example of a concept in the *what is probably so* group. *What is intelligent speculation* is the scale's third component which includes brain concepts that teachers want to believe are true but do not have sufficient empirical backing to be well established. More research will either move those concepts to the *what is probably so* group or they will become neuromyths. The bottom of the scale, *what is popular misconception or neuromyth,* includes ideas that are supported by little or no research although they generate an appeal that make them desirable to teachers. "They either reflect the ignorance of their promoters about the brain, or they are knowingly promoted misinterpretations about the brain sold to the public by unscrupulous consultants" (Tokuhama-Espinosa, p. 84). Examples of popular neuromyths are the Theory of Multiple Intelligences and the myth that people are left-brained or right-brained, misconceptions which, while popular and widely held, have never been validated by neuroscience research.

Brain facts that are well established through research and application do not lose their standing as they are considered the foundation of brain-based learning. Research generates the most movement between the ideas that are probably so and those that are intelligent speculation. Most concepts that are considered neuromyths, once they are proven to be fallacies, do not gain respect in the field and should be eliminated from teaching philosophies and practices. However, there are some, such as Gardner's Theory of Multiple Intelligences (1983), which could move to a more respected place on this scale if research proved them to be valid.

Neuromyths

Some "brain-based" teaching strategies, while popular in many classrooms worldwide, have not been validated by the scientific community who refer to them as neuromyths (Atherton, 2005; Bruer, 1997, 1999; Goswami, 2004; Howard-Jones, 2008; Organisation for Economic Co-Operation and Development, 2008; Pickering & Howard-Jones, 2007; Szucs & Goswami, 2007). Without sufficient empirical research to prove their veracity, such strategies gain notoriety through advertising in the media, slick professional packaging, inclusion in educational material catalogues, and user testimonials. Some of the most commonly known neuromyths relevant to education include, but are not limited to, the following: 1) the existence of critical learning periods; 2) the notion that humans use only 10-20% of their brain; 3) the multitasking neuromyth; 4) the left brain vs. the right brain; 5) the existence of the male vs. the female brain; 6) VAK, the sensory modalities neuromyth; and, 7) the theory of multiple intelligences (Atherton, 2005; Beyerstein, 2004; Boyd, 2008, Diket, 2005 ; Gardner, 1983; Geake, 2008; Goswami, 2008; Howard-Jones, 2008; Organisation for Economic Co-Operation and Development, 2008; Tokuhama-Espinsosa, 2010; Willingham, 2004).

Debunking neuromyths. Neuromyths result from various misinterpretations of research that contain nuggets of scientific truth but have limited implications for teaching and learning. Debunking them, therefore, involves replacing misinterpreted, misunderstood, or misanalyzed information with scientific fact. Most neuromyths originate in the popular press which may oversimplify research findings in order to appeal to a wide range of both scientifically sophisticated and unsophisticated readers. The proliferation of neuromyths geared to education has led to the development of some commercial programs and teaching strategies that are not supported by neuroscientific verification or assessment. In reviewing the scientific foundation for these programs and their effectiveness, neuroscientists are debunking the myths to lay the groundwork for developing empirically driven theories and practices for classrooms and to facilitate the dialogue between neuroscientists and educators (Goswami, 2006; Howard-Jones, 2008; OECD, 2002; Tokuhama-Espinosa, 2011).

Critical time period neuromyth. The critical time period neuromyth suggests that if the time frame for learning particular information is missed, that learning opportunity is lost forever.

As with some other neuomyths, this conclusion is the result of animal studies which do not necessarily extrapolate to human beings. Konrad Lorenz's bird imprinting studies figure prominently in this correlation between animal development and human development in terms of critical time periods for behaviors to occur. While optimal periods for certain learning do exist, such as for speech sound development and language skills, they are sensitive periods, not critical. For example, if the time sensitive for learning phonemes, the speech sounds of a language, passes due to chronic ear infections, a young child's ability to develop speech and language skills may be delayed but will still occur. This subtle semantic change casts the idea of critical learning time periods in a whole different light. Neuroplasticity allows for learning to occur at any time during a person's lifespan (Goswami, 2004) and is strong evidence against the existence of strict critical learning periods in an individual's life.

An offshoot of this neuromyth is the idea that children can learn more if they are taught during times of synaptogenesis. The connections between neurons are called synapses. During normal periods of growth throughout the life span, great numbers of synapses are created which are contingent on each individual's experiences. Typically, there is a marked "increase of synapses during infancy, a leveling off during adulthood and a slow decline in very old age" (OECD, 2002, p. 73). The rapid, multitudinous synaptogenesis that occurs from birth throughout infancy has led some to incorrectly infer that the first three years of life are the most decisive for future growth, development, and success. An ancillary process of growth and development, neural pruning, is the process of losing synapses that are not used which begins at about age 10.

Again as the result of animal studies, it was determined that rats who lived with other rats in environments with things such as wheels and tunnels to explore performed better on maze learning tasks because of increased synaptic connections than rats who lived alone in empty cages. The leap to human education results in two faulty assertions. The first assertion is that "educational intervention, to be most effective, should be timed with synaptogenesis (since) the more synapses available, the higher the potential nerve activity and communication, thus making better learning possible" (OECD, 2002, p. 73). A logical, yet incorrect, leap suggests that during the period of early explosive synaptogenesis, children between birth and three years of age should experience an enriched, stimulating environment to facilitate this prime time for learning. The second claim suggests that enriched learning environments can prevent neural pruning and/or enhance synaptogenesis, with either occurrence resulting in better learning. The OECD's (2002) criticism of this neuromyth's derivation stems from the inability to connect animal studies with human studies and "the additional problem of quoting the facts of a pertinent study and then assigning meaning that goes well beyond the evidence presented in the original research paper' (2002, p. 73).

The 10% neuromyth. A second neuromyth suggests that humans use only a mere 10-20% of their brain. The historical origins of this pervasive myth are unclear although several theories have arisen to explain its existence. They include experiments by an Italian neurosurgeon in the 1890s who removed portions of the brains of psychiatric patients to assess behavior changes, an alleged interview with Albert Einstein c. 1920 during a discussion about intelligence and thinking, and the proliferation of self-help manuals in the United States prior to the start of World War II. A more plausible, yet incorrect, explanation came from the 1930s work of Karl Lashley, a researcher who explored brain function through the use of electric shocks. Upon observing no effect from the shocks in certain areas of the brain, Lashely concluded that those areas had no function and the term "silent cortex" came into being. Further research proved that Lashley was incorrect and the "silent cortex" was a gross misnomer. A more recent explanation for the myth is the discovery of the 10:1 ratio of glia cells to neurons. At this writing, glia cells are known to provide support to neurons which are responsible for information processing and communication with other parts of the brain. With such a checkered past, it is easy to understand the impact the 10% myth has had on education (Boyd, 2008).

Neuroimaging techniques provide clear evidence of continuous, dynamic neural activity. "…even when any of our brain cells are not involved in processing some information, they still fire randomly (Geake, 2008, p. 127). Beyerstein documented in Scientific American (2004) that human evolution does not create wastefulness or excess. If humans use only 10% of their brainpower, that means that 90% is going to waste. Brain-mapping clearly demonstrates that all areas of the brain are active. The results of direct neuroscience research prove that 100% of human brain capacity is used at all times. Neuroplasticity continues to factor into this mythbusting equation. As the British researcher John Geake states, "But what plasticity requires is a dynamically engaged brain, with all neurons firing (Geake, 2008, p. 128). He goes on to explain that if an individual is using only 10% of his/her brain, then that person is in a vegetative, near death state. Human beings not afflicted with illness or injury use 100% of their brains 100% of the time.

The multitasking neuromyth. The digital age has brought with it a digital dilemma. In this new age of near instant information gratification, to what bit or byte should a person attend first? And how do you choose? And why am I forgetting so much more than I used to forget? When it comes to paying attention, multitasking is a myth. According to Klingberg, "Multi-tasking has long been a well-known strategy adopted by the over performing and the impatient for getting more things done more quickly" (2009, p. 69). While the interconnected design of the human brain allows us to store information in multiple locations at once and to connect new information to several stored memories simultaneously, it does not allow us to attend fully and process incoming information from multiple sources at the same time. Its blueprint specifies that one cognitive operation may be efficiently processed at a time in a sequential, not simultaneous, manner (Medina, 2008; Restak, 2009, p. 199). Divided attention results in incomplete information reaching the brain while some is distorted and some is simply forgotten.

Several negative consequences result from attempts to multitask. First, when we attempt to multitask, it takes longer to do each task and with less efficiency because a neural network in the frontal lobes creates a "central bottleneck of information processing that severely limits our ability to multitask," according to neuroscientists from Vanderbilt University, particularly when decisions must be made. Second, when workers answer e-mail or instant messages, they require upwards of 15 minutes to re-attend to the task at hand. This activity is distracting and disruptive of sustained activity, resulting in significant loss of productivity. Third, multitasking creates stress. By attempting to perform two competing tasks simultaneously, the brain is put into conflict with itself. This phenomenon increases with age. Learning to concentrate and to focus on the task at hand will prevent this source of stress from enabling us to become confused, lose pertinent information, and forget what needs remembering (Restak, 2009).

Multitasking is also influenced by working memory capacity and working memory load relative to the task at hand, the amount and type of distractions that surround us, response times which decrease with age and amount of distraction, and multiple tasks attempting to access the same brain areas simultaneously are some of the factors preventing us from multitasking successfully (Klingberg, 2009; Medina, 2008; Restak, 2009; Willingham, 2009). Despite the definitiveness with which these researchers decry our ability to multitask, the winds of change may begin to blow when the results of a 2008 study examining expanding working memory capacity are discussed later in this literature review.

Learning styles neuromyths. Among the neuromyths which directly pertain to education, there are four that have exerted a significant influence over the teaching profession in recent years, the male brain vs. the female brain, the right brain vs. the left brain, VAK learning styles, and the theory of multiple intelligences. Although supported by a dearth of empirical research to validate their effectiveness, they have a logical and an emotional appeal that intuitively feels right to many teachers. This gut feeling is often reinforced by school district sponsored professional development workshops subscribing to their worthy consideration and inclusion in teaching practice. It is extremely important to emphasize at this juncture that educational neuroscience is an infant science compared to other branches of brain science, psychology, biology, and education. Although barely 20 years old, its presence and potential power is making itself known in the laboratory, the neuroimaging scanner, and the classroom. That suggests that the neuromyths of today may become undisputed facts of tomorrow. Time and further research will separate reality from fantasy and popular folklore.

The right brain/left brain neuromyth. The brain laterality neuromyth implies that a right brain/left brain learning differential exists and that it is important for educators to determine if students are "right brained" or "left brained" so that they can be taught accordingly. While areas of hemispheric specialization do exist, such as language lateralizing to the left hemisphere and aspects of facial recognition lateralizing to the right hemisphere, one hemisphere does not become inert while the other exclusively controls specific areas of functioning or learning. Goswami (2006) believes that this neuromyth originated from an over-literal interpretation of hemispheric lateralization as we have come to think of the left hemisphere as the logical, verbal one and the right hemisphere as the creative, visual one.

In the 1960s, Roger Sperry and his colleagues performed what have become known as the "split brain" studies for which he won the Pulitzer Prize in 1981. He studied patients who had had their brains surgically split in half through the corpus collosum, the dense fiber mass connecting both hemispheres, in order to control life threatening epilepsy. By asking his subjects to identify visual stimuli that were presented to the left or the right hemisphere, Sperry determined that the left hemisphere analyzed the information and spoke better than the right hemisphere. The right hemisphere could only speak simple words or phrases but was better at spatial orientation and providing an emotional context for language. As important as these experiments are to our current understanding of the brain and how it functions, it also added substance to the neuromyth. After many unsuccessful attempts to categorize hemispheric functionality and with better data available through neuroimaging, researchers concluded that due to the intricate network of cross connections in the corpus collosum, the hemispheres communicate with each other to accomplish all neurological thinking and learning tasks (Goswami, 2004; Howard-Jones, 2008).

Daniel Willingham, a cognitive scientist from the University of Virginia, comments that despite the efforts of neuroscientists to eliminate the myth altogether, the concept of right brain vs. left brain learning persists to the 21st century. Websites and instructional programs based on this false idea of hemispheric lateralization can be found in contemporary literature leading some to conclude that school is designed for left brained students, an extension of right brain v. left brain neuromyth. "Some educators observed that when one compared the specialties of each hemisphere to what is emphasized in schooling, the right brain seemed to be getting short-changed" (Willingham, 2006). The core subjects of reading, writing, and mathematics seem to fit with the logical processing of the left hemisphere while the right brain's artistic and creative pursuits are minimally present, if at all, during the school experience. The logic pales, however, in light of our knowledge regarding neuroplasticity, the communication between hemispheres, and the existence of interconnected neural networks governing brain functions such as thinking and learning which are found in neural networks located throughout the brain. John Geake (2008) debunks the myth when he states that "the central characteristic of brain function which generates its complexity is neural functional interconnectivity…Cerebral interconnectivity is necessary for all domain-specific learning…Neuromyths tupically ignore such interconnectivity in their pursuit of simplicity."

*Male brains vs. female brains***.** This concept is another over generalized reference to cognitive styles of learning rather than to verifiable biological differences in brain development or function (Goswami, 2004; Howard-Jones, 2008). While the popular press explains that *Men Are From Mars and Women Are From Venus* (Gray, 1993) and *Why Men Don't Listen and Women Can't Read Maps* (Pease & Pease, 2001), none of these pithy differences can be explained through neuroscientific investigation. No study to date has shown gender-specific processes in building neuronal networks during learning and therefore is classified as an unsubstantiated belief, or neuromyth, according to Tokuhama-Espinosa's (2010) classification system.

*VAK: The sensory modalities neuromyth***.** Are you a visual, auditory, or kinesthetic learner? This theory proposes that by discovering students' learning style preferences and teaching to those alleged strengths, learning will be enhanced. The extensive backing that this myth has among educators and parents comes from the observed learning differences that exist in any given group of students which, popular folklore explains, must be the result of different styles or ways to learn. Among the myriad of inventories on the market which claim to identify learning styles in many and various ways, the simplest and perhaps most well known references are to visual, auditory, and kinesthetic sensory modalities, or VAK. This view is prevalent worldwide with some schools in the UK requiring children wear badges on their shirts identifying them as visual, auditory, or kinesthetic learners (Geake, 2008, Goswami, 2006, 2008).

The basic flaw in the VAK myth is that it is counter to the interconnectedness of the countless neural networks in the brain that exist to facilitate learning, memory, and information recall. Input from one sense is not processed independent of input received from another sense; input from multiple senses is processed simultaneously as it is received by the brain. fMRI research demonstrates the supra-additive effect of processing more than one sensory modality at a time. During a typical classroom lesson, students often see and listen to information at the same time. Simultaneously seeing and hearing the same information promotes better learning than seeing the information first and then hearing about it. Multi-sensory teaching strategies are effective because input modalities from the five senses are interlinked in the brain to enhance both information processing and learning.

If the brain did process sensory information separately and not interconnectedly, fMRI studies would probably reflect single neural centers in each hemisphere that respond to visual information (the occipital lobe), auditory information (the temporal lobe), and kinesthetic information (the parietal lobe). However, multiple areas of the brain react when different types of sensory stimulation are presented (Posner & Rothbart, 2007; Restak, 2009; Willis, 2007, 2008, 2010). Other observations inconsistent with this neuromyth have also been demonstrated. Since blind individuals read kinesthetically and not visually, their parietal lobes should respond upon fMRI study. However, Braille is represented in the visual cortex of blind children, the same area in the brain used by sighted children to learn written language, that is, reading and writing. Kriegseis et al. (2006) demonstrates that blind people create the same mental spatial maps of their environments as sighted people create. Even though their information comes from tactile and auditory information, the brain uses that information as if it was from visual input.

It is a well established fact that all people use the sensory VAK modalities to take in information according to the research included in Tokuhama-Espinosa's categorization system. There is also strong evidence that individuals use different processing strategies at different times depending on the learning context suggesting that one's preferred learning modality is fluid and adapts to different learning tasks and contexts (2010, p. 96). A student's ability to strategize about which modalities to use is less well documented, putting it into the intelligent speculation category until further research reclassifies it as a well established fact or a neuromyth. This leads one to speculate whether the sensory modality learning preferences are naturally occurring and fixed or if individuals can intentionally develop their sensory modalities to fit the demands of diverse learning contexts.

The logical pull behind the feeling that students will learn best when taught in their preferred sensory modality or learning style is strong. Another viewpoint suggests that while teaching a child in his/her preferred modality does not increase educational achievement, students will learn more when taught in the content's best modality. Information should be presented auditorally, visually, or physically manipulated when its meaning is best understood in that modality. That is perhaps how students can be taught to strategize about what sensory modality is the most effective for a given learning experience. While we do store visual, auditory, and kinesthetic information, memories are created by thinking about what those representations of a learning experience mean. The meaning that is attached to the sensory input, regardless of what kind of input it is, is what becomes stored as a meaningful memory for later retrieval or connection to new input (Willingham, 2005).

Tokuhama-Espinosa's (2010) meta-analysis of educational neuroscience research classifies the sensory modality (VAK) theory as intelligent speculation which she defines as "concepts or beliefs that…tend to be concepts that we want to believe are true but that just don't have the science behind them to support the weight of their claims" (p. 53). While not a verifiable neuromyth at this time, according to her categorization, its validity has not yet been established or disproved with studies both proving the hypothesis and others firmly disproving it.

*Theory of multiple intelligences***.** Of all the neuromyths identified in the literature, the most compelling is Howard Gardner's theory of multiple intelligences (MI) (Gardner, 1983). Dissatisfied with the constrictive one dimensional psychometric assessment of human intelligence, Gardner expands the notion of intelligence into eight separate and independent categories through observation, logical inquiry, and the "synthesis of large bodies of empirical work from a variety of disciplines" (Gardner & Moran, 2006). They include linguistic, logico-mathematical, spatial, musical, bodily-kinesthetic, interpersonal, intrapersonal, and naturalist intelligences. Anyone who acknowledges the differences that make us unique human beings, especially those related to how we learn, understands the appeal of this perspective on intelligence and learning. Understanding the appeal however, does not imply uninformed, blind acceptance of its tenets which may explain the theory's widespread visibility in education.
The main argument levied against the MI is its lack of empirical evidence. The literature is replete with that observation by those seeking to support or repute its validity (Allix, 2000;

Atherton, 2005; Diket, 2005; Duncan, 2001; Geake, 2008; Posner, 2003; Sternberg, 1994; Sternberg & Grigorenko, Tokuhama-Espinosa, 2010; 2004; Waterhouse, 2006; Willingham, 2004). The lack of evidence makes the MI theory impossible to validate, yet the debate itself seems to keep the theory alive and well. Gardner himself sought validation from the scientific community which was not forthcoming (2004) and acknowledged MI's unpopularity with traditional psychologists because they require "psychometric or experimental evidence that allows one to prove the existence of the several intelligences (p. 214), evidence that he was against and would not pursue by conventional means himself. Though several parts of the theory have found support in cognitive neuroscience, Diket contends that there is no neurological confirmation for establishing educational practices around the multiple intelligences theory as a whole. Arguments are raised against Gardner's selection and defense of criteria for determining the eight intelligences as they differ from the criteria defining *g*, the general intelligence that is identified by IQ testing; against his view that each intelligence operates by virtue of its own neural mechanisms, denying the brain's established interconnectivity; against the lack of hard data describing what happens in those classrooms where MI theory is implemented; against the semantic, connotative barrier raised by using the term intelligences instead of talents or abilities (Waterhouse, 2006; Willingham, 2004). Gardner's theory exists in opposition to the well established neuroscientific evidence of the brain's interconnectivity through the existence of its numerous neural networks, suggesting the presence of one multifaceted intelligence, not several. In Gardner's view, "MI theory demands that linguistic processing, for example, occur via a different set of neural mechanisms than does spatial or interpersonal processing (1999, p. 99).

Despite the critics, Gardner's basic claim that the human brain is multifaceted remains unchallenged and has enabled educators in particular to re-think the concepts of intelligence and intelligent behavior in terms much broader than mere numerical representations (Diket, 2005; Medina, 2008). While the theory in toto is empirically lacking, it has opened the minds of many, scientists and educators alike, to new possibilities and discussions of concepts such as differentiated instruction to address students' unique and varying learning profiles (Gray & Waggoner, 2002; Kapusnick & Hauslein, 2001). The theory of multiple intelligences may technically qualify as a neuromyth, but it maintains its appeal despite severe criticism and maintains a following whose proponents are zealots who seem to be impossible to dissuade.

Neuroplasticity

How, then, does neuroscience research connect to educational practice? As happens in all fields supported by research, new information replaces existing information to advance the field. Until recent modern history, scientists believed that the brain was unchangeable once it was fully formed in childhood. When brain cells became injured or died, they could not regenerate or be replaced (Doidge, 2007). However, with the discovery of new imaging techniques like fMRIs, the structures and functions of the living brain could be identified and observed in action (Columbia University Medical Center, 2008). This technological breakthrough led to the discovery that changed the way researchers understood brain function forever.

The brain is not hard-wired and static, but malleable and plastic, hence, the term neuroplasticity (Doidge, 2007). Learning changes the brain's structure and function and creates new pathways to connect structures in different ways (Bransford, Brown, & Cocking, 2008; Wolf, 2008), causing those structures to do things they had not done before. It is the brain's neuroplasticity that allows it to experience novel, creative thinking as well as to create new neural pathways between damaged and undamaged areas to restore some degree of functioning to an individual who has perhaps suffered a stroke. Neuroplasticity enables humans to successfully engage in lifelong learning.

Animal experiments have led to the expansion or the change in our neuroscientific knowledge base since scientists first began to map the brain. A long series of experiments with monkeys established irrefutable proof that the brain is adaptable, and that structure and function can be reassigned to carry out the neural activity necessary to respond to stimulation such as movement. These empirical studies involved surgically cutting nerves, removing digits, sewing two digits together and then mapping the monkeys' brains to determine the effects. In all the experiments, the brain did not respond when the affected cortical area was stimulated, but did respond normally when adjacent areas in the brain were stimulated despite the alteration in the anatomy. Neurons in the brain took over the space created by the damaged nerves and used it to process different information. After amputating the middle finger, the brain map for the amputated finger had disappeared but the maps for the adjacent fingers had taken over the space for the amputated middle finger. This proved that the brain is plastic, malleable and dynamic (Merzenich, Kaas, Wall, Sur, et al., 1983; Merzenich, Kaas, Wall, Nelson, 1983; Merzenich et al., 1984).

Fortunately, this pure science data transfers to the human brain as well as to the monkey brain. Learning and practice change the brain, enabling it to develop or regain functions that were either missing or damaged. Some deaf individuals can hear through the development of the cochlear implant which relies on the brain's ability to "take over" functions not present at birth through electrical stimulation created by the implant (Doidge, 2007). Lengthy remedial instruction modifies the brains of dyslexic students allowing the "reading centers" in their brains to comprehend sentences, not just words (Myler, Keller, Cherkassky, Gabrieli, & Just, 2008).

Listening to filtered speech changes the way the brain hears, improving the receptive/expressive language ability of children who complete the *Fast ForWord* computer program (Scientific Learning, 2003).

The hard wired machine/computer metaphor no longer applies to the brain and its functioning. The revolutionary concept of neuroplasticity has opened doors to possibilities that were previously thought to be nonexistent. While it has expanded our thinking about thinking, it cannot be viewed as the "magic bullet" to remedy the world's ills, but as a way to create possibilities for the continued application of brain power.

Hemispherectomies and brain plasticity. One of the most dramatic demonstrations of the brain's ability to repair and reconfigure itself is found in the case study of two adolescent males, each of whom suffered severe localized brain seizures as children resulting in the surgical removal of a hemisphere of his brain, a hemispherectomy (Immordino-Yang, 2007; 2008). Each boy had a different hemisphere removed, suggesting that different brain controlled activity would be affected. They were compared to a matched group of typical peers on several tasks that were educationally and socially based as well as a task of prosody or speech melody which involves bilateral processing of the brain (Immordino-Yang & Damasio, 2008). The anticipated differences in performance between the two boys did not occur and each boy demonstrated skills, such as identifying melodic changes in speech and sarcastic tones of speech, that should have been impossible for them to accomplish given their altered anatomy. Each boy was able to identify the melodic patterns and to identify vocal sarcasm. Immordino-Yang suggested that the boy with a left hemisphere relied on a cognitive strategy for processing the linguistic aspects of social communication while the boy with the right hemisphere relied more on an emotional strategy. In essence, each boy changed the tasks into new ones that suited his strengths, a dramatic demonstration of brain plasticity.

Cases of hemispherectomies in life and in the literature are rare, but they do exist, often as a radical medical response to seizure disorders that have no alternative treatment. A study of the human auditory pathways included two adults who had each had the left hemisphere excised to stop seizure disorders and 15 neurotypical adults, all of whom demonstrated hearing within normal limits (Paiement et al., 2008). Its purpose was to determine if the brain reorganizes its ability to detect sounds ipsilaterally (the same sound presentation side) and contralaterally (the opposite sound presentation side). In typical listeners, the contralateral pathway responds more strongly to auditory stimulation due to its increased number of nerve fibers and fewer synapses to reach the auditory cortex than does the ipsilateral pathway (Paiement et al.). The control groups responded to complex tones presented to one ear, monaurally, and to both ears, binaurally, as expected; the hemispherectomized subjects' response was mixed. fMRI results demonstrated balanced cortical activity in normal control subjects when sounds were presented binaurally, with the hemispherectomized subjects' responses lateralized to the right side. For the monaurally presented tones, the normal subjects demonstrated greater cortical stimulation in the contralateral hemisphere as was expected. The hemispherectomized subjects, however, demonstrated greater ipsilateral stimulation, suggesting that a functional reorganization occurs after hemispherectomy (Paiement et al.). The exact implications of this reorganization are reported to require further study and analysis to determine their full meaning. What is clear, however, is that the plastic brain reorganized itself to function as a whole brain might function given the normal hearing levels of both hemispherectomized subjects.

A study of 30 hemispherectomized British children, (17 left, 13 right) developed the concept of neuroplasticity further by demonstrating that there are limitations to this reorganizing capability (Liegeois, Cross, Polkey, Harkness, & Vargha-Khadem, 2008). Measures of receptive and expressive language assessed the viability of core language components, memory, and verbal intelligence. The seizure disorder onset (pre/perinatal v. postnatal) and hemispheric side of pathology (right v. left) were the specific variables under review. Patients with postnatal right hemispherectomies demonstrated the highest language scores and short term verbal memory. Brains that had a period of normal development, even if only until birth, retained the stronger language and memory skills.

The Story of *Fast ForWord*. An application of Merzenich's (Merzenich et al., 1996; Merzenich, Kaas, Wall, Sur, et al., 1983; Merzenich, Kaas, Wall, Nelson, et al., 1983; Merzenich, 1984) extensive work demonstrating that the brain is not a compartmentalized machine, but a living, learning organ capable of reorganizing itself when necessary or when taught is the Fast ForWord language/reading development program. Merzenich collaborated with researchers from Rutgers, The State University of New Jersey to develop a treatment for individuals with language-based learning impairments (LLIs) which ultimately included struggling readers as well.

The LLI students demonstrated temporal processing deficits indicated by their weak ability to identify brief phonetic elements presented in speech contexts as well as identifying and/or sequencing brief duration acoustic stimuli presented in quick succession (Merzenich et al., 1996). Improvements were noted after daily participation in two computer generated circus game formats after a 20 day period. Expanding on these results, the group devised a second study to train LLI children to recognize fast phonemic elements in ongoing speech that have durations in the range of a few tenths of milliseconds, a critical time frame over which many phonetic contrasts occur (Tallal et al., 1996). The speech stimuli were temporally modified, that is, filtered, by lengthening the duration of the speech signal by 50% to facilitate identification by LLI subjects and presented in a circus game format. In each study, subjects trained with the acoustically modified speech and computer games three hours every day, five days a week, for six weeks. Statistically significant improvements occurred at the study's conclusion and six weeks later in a follow-up assessment. Intensive training coupled with cortical plasticity changed the auditory cortex' ability to detect brief sounds and phonemes, enabling LLI subjects to then identify them.

The collaborators formed Scientific Learning, Inc., a company whose mission was to develop motivating games to train LLI students to listen for bits of acoustic information that they were missing due to the speed with which it occurs in spontaneous speech. The initial product, *Fast ForWord Language (*Scientific Learning Co., *1997)*, comprised a series of seven animated games with five levels of acoustically modified speech, beginning with the most filtered speech and proceeding through four levels until the student reached the fifth level which consisted of speech produced at temporally normal speeds. Eighty percent accuracy was required before a subject could advance from one level to the next.

The original research was conducted with LLI subjects. *Fast ForWord* was marketed as a product to create a strong foundation for reading and learning (Scientific Learning Corporation, 1997). A comparative study was undertaken to assess the outcomes of *Fast ForWord (*FFW) and Orton Gillingham (OG) training (Hook, Macaruso, & Jones, 2001).The results were mixed in that both FFW and OG groups made similar gains in phonemic awareness. The FFW group demonstrated strong gains in speaking and syntax at the conclusion of the intensive program, but the gains were not maintained over two years, which was a claim Scientific Learning Corp. made about the product. The OG group gained word attack ability which is a skill that is not part of the FFW research design, therefore, those subjects made no gain in word attack skills. Significant differences were not demonstrated between the two groups over the study's two year period.

While the basic research supporting neuroplasticity and the temporal deficits of LLI students is strong, the result of that collaborated effort has not been as solidly demonstrated. Several studies indicated that while the use of this particular computer program may improve some aspects of students' language skills, the gains do not translate into a broader measure of language acquisition or to actual reading skills, as Scientific Learning Corporation advertises (Borman, Benson, & Overman, 2009). Although it appeared to be well-grounded, the efficacy of the *Fast ForWord* programs has yet to be empirically established by the scientific and education communities.

Reading and Dyslexia

The phenomenon we know as the reading process is defined, discussed and analyzed in enough tomes to fill a library, its development evolving over time. Contemporary research and discoveries related to brain function and how the brain "reads" continually expand our knowledge base which should also inform and influence reading didactics. A simple, yet elegant definition of reading is "speech at the level of print" (Mody, 2004). Consider how your brain responds when your eyes travel over a line of print in an unknown language or an unfamiliar alphabet arrangement of known letters or the pictogram structure in many Asian languages. Your eyes move quickly and smoothly over the line without any interruption because you have no basis for comprehending what your eyes see, symbols that are a meaningless arrangement of shapes. Now consider how your brain responds when your eyes travel over a line of English print or any other language with which you are familiar. The "voice in your head" is automatically activated as your brain engages the meaning associated with the shapes on the page. It is a reflexive action that occurs once the brains learns how to read. This is one of the most basic demonstrations of the connection between language (phonology and semantics) and reading.

As new hypotheses emerge and our understanding expands, teachers have the means to develop more powerful and more specific strategies to teach all students the reading process. For example, neuronal recycling is a theory which develops the concept of cultural neuroplasticity, a new explanation of the mysterious reading process (Battro, 2008; Dehaene, 2008). The research is ongoing, continuing to advance and develop new theories, anticipating the eventual development of more precise approaches to pedagogy and remediation.

Dyslexia is a language-based learning disability affecting 15-20% of the population, or one in five students, according to the International Dyslexia Association (International Dyslexia Association, n.d.). Among the students with specific learning disabilities, 70-80% demonstrate deficits in reading, according to the same source. The pervasiveness of reading disabilities is staggering, affecting nearly equal numbers of males and females as well as those from different ethnic and socio-economic backgrounds. It is a disability that does not discriminate and does not lend itself to remediation easily; therefore, dyslexia can be thought of as a mystery wrapped in a conundrum contained within an enigma and held together by a quagmire (source unknown). This statement is offered not to minimize the seriousness of the condition but to highlight it. Reading disabilities are highly resistant to remediation as the incidence numbers indicate.

Neuroscientific study has expanded the knowledge base that encompasses all reading disabilities, specifically through the use of advanced imaging techniques such as functional magnetic resonance imaging (fMRIs), diffusion tensor imaging which is a form of fMRI, evoked-response potential (ERPs), and magnetoencephalography (MEG). fMRIs are the least invasive and hence, most frequently used imaging study in current use (Mody, 2004). Studies of individuals' brains are undertaken while the subjects are actively engaged in reading and writing activities. The structure and functional organization of the normally functioning brain is more completely understood as a result of these studies.

Imaging studies identify less activation in specialized cortical areas of the brain in dyslexic readers than in normal readers, particularly in the left hemisphere. Researchers who detected differences in the parts of the brain controlling visual aspects of reading as opposed to auditory centers, for example, claim that the areas they each have identified are the ones directly linked to reading impairments. Others suggest that the brain differences are more widespread throughout the brain, resulting in various learning strengths and weaknesses. Arguments exist that interpret the inactive or less active cortical centers in fMRI studies of dyslexic readers as the result of poor, inaccurate reading, not as the cause of the reading disability as many researchers postulate (Catts & Kamhi, 2005).

One of the strongest prognostic indicators that has resulted from advanced imaging studies of poor readers demonstrates that with enough remediation, increased activation in key cortical centers occurs which correlates with improved reading ability. Sentence comprehension tasks require higher level processing than word recognition tasks. Studies suggest that intensive reading remediation, 100 hours minimum, results in improved brain functioning in both higher and lower level reading tasks both immediately after the remediation period and one year later

(Meyler, Keller, Cherkassky, Gabrielli, & Just, 2008; Rimrodt et al., 2008). The left hemisphere which is directly involved in phonological processing as well as areas in the right hemisphere were more active in a group of 8-112 year old children with dyslexia after completing the *Fast ForWord* program. The imaged changes in brain function correlated to improvements in receptive and expressive language, phonological processing, and reading ability (Temple et al., 2003).

The common thread that runs through the reading disabilities research is that more research is necessary. More questions than solutions guide the research and practitioner communities alike. Identifying the type of reading disability a child might have with pin point accuracy which then suggests the appropriate remediation technique and its duration is not yet possible even with the use of advanced imaging techniques. This is a critical area in which neuroscientists must collaborate with educators if the gap is to be closed and dyslexia is to be brought under control.

Mirror Neurons

The brain is as old as the first living creature that swam or crawled out of the primordial soup eons ago. The field of neuroscience is approximately 150 years old, an infant field in the scientific world. Knowledge of the anatomy and functional organization of the brain has been ongoing from its inception. The most recent brain cell discovery in the 1980s, referred to as mirror neurons, brings us another step closer to understanding who we are and how we interact with others. Very simply stated, mirror neurons enable an individual to observe the actions of others and experience the same neural firing of comparable mirror neurons without performing the action itself. It allows one to cortically mirror actions of others; the context in which those actions occur provide insight into the intentions of the actor. Social cognition and interaction may have a neurobiological basis in mirror neurons which can be measured and viewed through advanced imaging techniques (Iacoboni, 2008).

The discovery of mirror neurons may ultimately serve the educational needs of students with autistic spectrum disorder (ASD). The current theory is that mirror neurons are dysfunctional in the brains of those with ASD, thereby preventing their brains from firing in concert with the actions of others, shutting off their ability to "read" the other person and have a tacit knowledge of that person's intentions. The ability to know what another person is thinking or how he will respond or what action might occur or what his facial expression reflects is known as having a theory of mind (ToM) (Iacoboni, 2008). A neurotypical person with an intact ToM understands that another person has a perspective that may or may not be similar to his own and will make the mental and social adjustments necessary to maintain a social interaction. Mirror neurons, perhaps, create perspective taking ability and ToM. Iacoboni contends that mirror neuron activity can be increased through imitation of the autistic person's actions, mannerisms, and vocalizations as a way to get their attention and then to move the autistic person toward reciprocal imitation of another's movements and vocalizations. The strategy of imitating the behaviors of those with ASD is not a new one, however, the justification for this type of strategy, that of increasing the firing of mirror neurons to develop a more neurotypical ToM, is revolutionary and promising.

The Affective Domain

> The key to creating usable knowledge in mind, brain, and education is not simply to apply neuroscientific evidence but to proactively study the relations of brain to learning and behavior. People should not jump from brain findings to new models of education without research that directly examines the ways that children learn in school and in

everyday life, including how their learning relates to their brain functions (Battro, et al., 2008, p. 13).

The relationship of the brain to learning and behavior is a multifaceted set of complex interconnections that are also shaped by the environment. The ebb and flow of this relationship is a uniquely personal experience that occurs within the guidelines imposed by biology, human development, and maturation. The end result is the lifelong pursuit of usable knowledge constructed through a myriad of experiences. The gateway to this limitless array of experiences is entered through one's emotional state or affective domain and one's attentive state or ability to engage in the experience (Battro, Fischer, and Lena, 2008; Caine, Caine, McClintic, and Klimek, 2005; Damasio, 1994; Immordino-Yang and Damasio, 2007).

Judy Willis, M.D., first practiced clinical neurology for 15 years, then pursued her teaching credentials and a master's degree in education, taught in elementary and middle schools for ten years, and currently conducts professional development workshops teaching teachers how to apply the mind, brain, and education research to classroom teaching strategies. She is therefore uniquely qualified to connect the fields of neuroscience and education in a practical, neuro-*logical* (emphasis included in original work) (Willis, 2010), scientific manner. As a classroom teacher, she emphasized the importance of teaching students of all ages about the brain, how it works, and how they can work their brains. She enabled her students and the teachers with whom she now interacts through professional development to grasp the significance of emotions, stress, and anxiety in the classroom and its impact on learning. The following is a condensed description of the physiology of emotion and learning.

Information from the senses is received through receptors in the brain to be processed, coded into patterns, and stored as memories. However it must pass through two filters in order for the information to be recognized and processed for storage or not, which either facilitates or inhibits learning. Sensory data first enters the reticular activating system (RAS) located in the brainstem. From the billions of bits of sensory information available for processing, only about 2,000 bits can pass the RAS filter per second (Willis, 2010, p. 166). A forced choice over which you have some control occurs at this point. If you are calm and your stress is under control, you may attend to that information that you want to pass through the RAS to the prefrontal cortex (PFC), the thinking brain, for reflective processing and storage. If, however, you are in a state of anxiety or stress brought on by any one of many factors, the RAS directs the sensory data to the more automatic parts of the brain. These systems, anchored in the brain's primordial need to ensure survival in times of perceived danger, stress, anxiety, or boredom force a fight, flight, or freeze reaction over which you have no control. In the classroom, these reactive responses are identified as oppositional acting out/class clown behavior, requests to leave the situation and go to the nurse/the lavatory/the locker, doodling, and a "deer in headlights" look, among others.

Once sensory data has successfully passed through the RAS, it is directed to sensory cortex areas in the lobes of the brain for further processing. The next processing phase occurs when the sensory cortex areas sends the RAS approved data on to the limbic system's filters, the amygdala and the hippocampus. Willis (2010, p. 169) describes this as the place "where emotional meaning is linked to information." If you are confused, anxious, inattentive, angry, sad, or bored, the amygdala will automatically send the information to the reactive brain for a fight/flight/freeze. This emotional filter reacts to the perceived threat, the stress, by initiating a survival response; the amygdala attracts nutrients and oxygen which blocks the flow of information to the thinking PFC. If, however, you are attentive, relaxed, alert, and calm, the amygdala will send the information to the hippocampus for long-term memory storage in the reflective PFC. The new information is sent to existing neural networks that store previously created memories related to the incoming data, thereby connecting new information with a previously learned body of knowledge. In this positive emotional state, the neurotransmitter dopamine is also released, which strengthens learning and memory and reinforces your ability to recall and recreate that same emotional state for future learning experiences (Willis, 2010, p. 165-174).

Emotions are the force that both unifies the mind and body into a complete, interrelated, interdependent system and directs learning. LeDoux (1994) verified that "emotions drive attention, create meaning, and have their own memory pathways." The term "emotional thought" was coined to describe the elements of learning that include attention, memory, decision making, and social functioning (Immordino-Yang and Damasio, 2007). Ignoring the impact of emotion on learning sterilizes the learning experience and weakens the learner's ability to make strong, lasting connections that anchors the learning to his/her emotional center. The concept of emotional intelligence about which Goleman (1995) wrote is finding empirical support in the work of contemporary educational neuroscientists.

A concept that runs parallel to Willis' teaching students about their reactive and reflective brains as a way for them to understand how emotions and stress can enhance or impede the learning process is teaching students the difference between the growth mindset and the fixed mindset. Stanford University professor Carol Dweck uses these terms to explain the difference between the belief that intelligence is static and unchangeable and the belief that intelligence can be developed (2006). These polar opposite mindsets define those who choose to see effort as useless compared to those who choose to see effort as the path to mastery, for example (p. 245). Dweck has created a computer program designed to teach middle school aged students about their brain, its care, and growth through a series of four animated interactive modules which lays the foundation for creating growth mindsets among this population. The "Brainology" program offers students and teachers practical, easily usable information about their brains and how to apply it to their various learning tasks. The only lesson to be learned is simple, yet life changing; you can change your mindset. The fixed mindset is similar to the reactive brain that causes students to fight/flight/freeze when faced with academic challenges whereas the growth mindset resembles the reflective brain in which sensory input that passes through the brain's emotional filters enters the prefrontal cortex where it is processed, stored, and retrieved as learned memories. The affective domain is the foundation on which the cognitive domain is secured, grows, and develops. This symbiotic relationship must be continually renewed, refreshed, and reinvigorated as challenges present themselves throughout the life span.

Attention

How many times during the course of a school day do teachers say and students hear, "Pay attention!" "Focus!" This exhortation, expressed in a variety of ways, has become the mantra of our multi-tasking, stimulus driven, interactive global society. While fundamental to learning in school, the ability to establish and sustain attention varies among individuals and tasks (Caine et al., 2005; Posner, Rothbart, & Rueda, 2008). Attention exists as a neural network in which numerous areas of the brain interface and coordinate with each other to accomplish the desired attentional functions of alerting, orienting, and executive control (Jensen, 2005; Posner Rothbart, & Rueda, 2008).

> Alerting is defined as achieving and maintaining a state of high sensitivity to incoming stimuli; orienting is the selection of information from sensory input; and executive

control involves the mechanisms for monitoring and resolving conflict among thoughts, feelings, and responses (Posner, Rothbart, & Rueda, 2008, p. 152).

Information that is not attended to is also part of this neural network. Individuals must choose between ignoring what is in the background or including it in the learning process. "Directing your attention at something is analogous to selecting information, as you give priority to only a small part of all the information available" (Klingberg, 2009, p. 19). In education, those who struggle to ignore what is in the background and include it in their attentional focus are said to have a problem with figure-ground; that is, separating the primary information, the figure, from the surrounding stimuli, the ground. An example of this daily occurrence in classrooms around the world is the teacher's voice (figure) being heard above the typical ambient noise and conversation in a classroom (ground).

As LeDoux (1994) determined that emotions drive attention, "attention is the portal through which the information flood reaches the brain" (Klingberg, 2009, p. 19). This is the causal link through which learning is constructed; emotions drive attention and attention drives information flow to the brain. If this cause and effect relationship is interrupted for any reason, learning is impeded. Numerous other variables may interfere with learning occurring after this point in the chain, such as issues with information processing or memory, but knowledge can only begin to be constructed if the learner's emotional state and attention allow information to reach higher cortical levels for the learning process to continue. The importance of this emotion/attention relationship cannot be overstated. "The more attention the brain pays to a given stimulus, the more elaborately the information will be encoded – and retained" (Medina, 2008, p. 74). But how do we control attention so that we can concentrate on that desired or required stimulus?

Working Memory. Attention is controlled through working memory. For example, you go to the refrigerator to get eggs for a new recipe that you are making. As you open the door, the phone rings, the dog barks, you hear the kids screaming, and you think about the PTA meeting after dinner. You stare into the refrigerator at the array of food items stored there competing for your attention. The neurons in your brain also compete for which are to be activated in order for you to control your attention. You stare blankly into the refrigerator, distracted by your environment and wondering what you are looking for, close the door and return to the counter empty handed, having forgotten your intent. You look at the recipe and the on-hand ingredients and the word EGGS! literally slams into your brain as you have regained your focus of attention. Repeating the word "eggs, eggs, eggs" over and over to yourself, you go back to the refrigerator, rehearsing your focus until you grab the eggs and resume the task at hand.

The results of animal and human computer studies in which subjects are required to remember with and without prompting where targets are expected to appear on the screen activate one of the three kinds of attention, controlled attention, stimulus-driven attention, and arousal. Subjects had to keep the positional information in mind, in working memory, to complete the task. By measuring subjects' reaction times, researchers quantified the different kinds of attention indicating that each of the three attention systems are independent of each other. A person may experience a problem in one attentional area and not in the other two. This finding has learning implications for students with ADHD, especially in the area of attentional control, as research has demonstrated (Lawrence, Houghton, & Tannock, 2002; Posner, 1980; Klingberg, 2009). The results of Posner's seminal work set the stage for our current understanding that "working memory is essential for controlling attention. We have to remember what it is we are to concentrate on" (Klingberg, 2009, p. 39).

Working memory is also a key element in our ability to solve problems. This is where the extreme importance of having a strong working memory is highlighted. Richard Restak, M.D., a renowned neuroscientist and neuropsychiatrist, states that “working memory involves the most important mental operation carried out by the human brain: storing information briefly and manipulating it” (Restak, 2009, p. 67). He likens it to toggling between documents on your computer. You balance several thoughts in mind (working memory) at the same time and shift back and forth at will between the thoughts while holding the information in mind. When solving problems, the parts of the problem are held in working memory and manipulated. The term, working memory, was coined in the 1960’s by Karl Pribram, but psychologist Alan Baddeley is usually credited with defining it. According to Baddeley, “The term working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning” (Baddeley, 1992, p. 556). What are you really doing, then, when you hold information in mind and manipulate it? You are thinking. Working memory is the place in the mind where thinking happens and thinking occurs when you combine information from the environment and long-term memory in novel ways. It is Willingham’s position that that combining happens in working memory (Willingham, 2009). Working memory is a temporary storage area for thinking that lasts from seconds to minutes. Some information, but not all, passes through working memory into long-term memory to be retained for long periods of time, even a lifetime. Such information, through practice and verbal rehearsal, can become automatically retrieved on demand so that it does not have to be continually processed by working memory, i.e., the alphabet, the multiplication tables, PIN numbers, and passwords, for example.

Working memory, however, has a severe limitation known as working memory capacity. It fills up quickly and becomes so crowded that a person is unable to hold all of the information it needs to at one time. Consider a mental math problem such as 43 x 67. While you have the ability to do the calculations, you do not have the ability to hold all the information in mind, toggle back and forth between multiplying, adding, and holding number places and then come up with an accurate answer. Our working memories cannot hold that much information at one time to complete the task. Overloads of working memory are caused by things such as multistep directions, chains of logic more than two or three steps long, mental math, applying newly learned information to new material, and background noise to suggest a few. On average, an adult can hold seven units of information in working memory at a time, give or take three or four units (Miller, 1956). Working memory loads can fill working memory capacity, impeding thinking, concentration (i.e., multitasking attempts), and problem solving. Until recently, researchers in the fields comprising mind, brain, and education were of the opinion that a person was born with whatever working memory capacity they would have for their lifetime. In 2009, cognitive psychologist Daniel Willingham from the University of Virginia wrote, "As far as anyone knows, working memory is more or less fixed – you get what you get, and practice does not change it" (Willingham, 2009, p. 83). So, the essential question then becomes, can working memory capacity be expanded through training?

In order to answer that question, I must introduce a new topic, intelligence, and then return to the discussion of working memory capacity expansion. Raven's matrices is a problem task used by psychologists to assess general intelligence in which the subject looks at a three-by-three matrix of eight symbols, figures out the rules that determine how the symbols change, concludes what the missing symbol is, and selects it from a group of choices. Determining the solution to such a reasoning based task is dependent on how much information can be held in working memory. In 2002, SuB, a German psychologist summarized the results of his research by stating, “At present, working memory capacity is the best predictor for intelligence that has yet been derived from theories and research on human cognition” (p.284). Further substantiation is offered by researchers at the Georgia Institute of Technology who demonstrated a correlation between working memory tasks and problem solving ability in the area of fluid intelligence which is connected to abstract reasoning and problem solving. It has also been suggested that measures of working memory constitute the new intelligence testing. (Alloway, 2011). Restak’s view is that working memory capacity is correlated with both general intelligence and performance on intelligence tests (Conway, Kane, & Engle, 2003; Restak, 2009; SuB, 2002). What impact does this knowledge have on expanding working memory capacity?

As early as 1963, psychologists determined that general intelligence can be viewed as two constructs, crystallized intelligence and fluid intelligence. Crystallized intelligence is the recall of specific factual and procedural information including background knowledge; fluid intelligence includes abstract reasoning, working memory, and the innate ability to solve novel problems that involve more than just information retrieval from memory (Ackerman, 1996; Cattell, 1963; Rolfhus & Ackerman, 1999). Marzano (2003) cites eight studies from 1976 to 1999 in which crystallized intelligence was found to correlate highly with academic achievement, more so than fluid intelligence, leaving the reader to question the impact of fluid intelligence on learning.

In 2008, five years after Marzano (2003) published his analysis of the earlier crystallized and fluid intelligence studies and equated crystallized intelligence with learned intelligence/background knowledge, another groundbreaking study was published in the

Proceedings of the National Academy of Science. Neuroscientists Jaeggi et al. (2008) demonstrated that fluid intelligence, the ability to reason abstractly and solve problems independent of general knowledge, is trainable to a significant and meaningful degree. It is trainable through the expansion of working memory capacity, which was previously not thought possible by the research community. Working memory is the ability to hold information in mind for a brief period of time, manipulate it, connect it to new information, and formulate an appropriate response. "It is only in fairly recent years, relative to the age of the field, that so-called 'working memory' has come to be viewed as a key determiner of fluid intelligence" (Sternberg, 2008, p. 6791).

The researchers in the Jaeggi study expanded working memory capacity by training subjects using a demanding working memory task called the dual *n*-back task. The description of the task is as complex as the task itself, so I will use the words of the researchers themselves to explain its construction.

> In this task, participants saw two series of stimuli that were synchronously presented at the rate of 3 s per stimulus. One string of stimuli consisted of single letters whereas the other consisted of individual spatial locations marked on a screen. The task was to decide for each string whether the current stimulus matched the one that was presented *n* items back in the series. The value of *n* varied from one block of trials to another, with adjustments made continuously for each participant based on performance. As performance improved, *n* incremented by one item; as it worsened, *n* decremented by one item. Thus, the task changed adaptively so that it always remained demanding, and this demand was tailored to individual participants (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008).

Transfer from this working memory task to fluid intelligence testing did occur by expanding the working memory capacity of the participants, and in the researchers' opinion, the dual *n* back training may have effectively controlled attention resulting from the constant need to shift attention as each new stimulus was detected. Part of the significance of these findings is that fluid intelligence was previously thought to be fixed and unchangeable. They also suggest that tasks that measure fluid intelligence pick up on other skills such as multiple task management even though their training paradigm was not sensitive to this task. This dual *n* back task required the participants to manage two *n* back tasks simultaneously. Recall that multitasking is currently viewed as a neuromyth with no empirical research to support its existence as part of our cognitive repertoire - until now. This research in 2008 opens the door to further studies which may expand our current body of neuroscientific knowledge to include multitasking as part of our cognitive processing abilities. Please recall Willingham's statement in 2008 that working memory capacity is not expandable. The closeness of the Jaeggi et al. study to the publication of Willingham's book perhaps made it impossible for Willingham to know of the critical contribution to the field Jaeggi et al. had made, making Willingham's statement somewhat obsolete. Studies of this type are cutting edge, state of the art research which may prove to revolutionize the field by discovering that which was previously unknown.

Expanding WM capacity, therefore, expands fluid intelligence by increasing the learner's ability to hold information in mind and apply it to a variety of reasoning tasks. Using tasks such as forward and backward digit span repetition and the *n*-back task are considered good measures of WM and can be practiced in the classroom by the teacher, the speech/language pathologist, the school psychologist, or related school personnel. Computer based *n* back tasks are available are online as provided by John Jonides to this author in an on-line chat sponsored by the

Learning and the Brain Society. Increasing WM will, over time and with practice, positively affect students' fluid intelligence according to the Jaeggi et al. study (Jonides, on-line chat, 3/2010).

While in its infant stages of development, the discipline of MBE science includes a vast, varied comprehensive body of literature. New research yielding new knowledge exists on a long standing foundation of knowledge from biology, psychology, cognitive psychology, experimental psychology, neuroscience, cognitive neuroscience, and education to name just a few. Teachers benefit both personally and professionally from keeping abreast of information that has the potential to influence their teaching practice. It is possible for teaching practice to be influenced by the MBE science research of yesterday, today, and tomorrow, because a new study may be published literally tomorrow revolutionizing the teaching profession as our knowledge of the brain continues to advance, i.e., the expansion of working memory capacity as per Jaeggi et al (2008). Part of this study is to inform educators as to the state of the art and the science of any knowledge base that has the potential to influence their practice. As an educator in the trenches, I have chosen to explore how to provide my colleagues with access to the body of knowledge that comprises mind, brain, and education in a meaningful, and hopefully, lasting way. My view from the balcony at Sandersville Middle School suggests that I possess leadership qualities that can merge traditional teaching practices with state of the art educational neuroscience to enhance the learning and the teaching for those in my middle school community through the establishment of a specialized professional learning community.

Professional Learning Community

I have chosen the construct of the professional learning community (PLC) as the vehicle to drive both this study and the development of second order change among the teacher-participants at Sandersville Middle School. Lasting change occurs when one's perceptions, knowledge, beliefs, and values are examined, analyzed, and reconstituted into a new set of beliefs and values upon which a person acts. In an environment of second order change, the followers' attitudes and beliefs are developed so that they become the promulgators of the desired change, in this case, implementing teaching strategies derived from empirical brain research. It is not imposed from without (first order change), it emanates from within, resulting from the knowledge derived from the initial action of this study, the workshop series, in concert with ongoing, bi-weekly professional development related to brain research and education. The intent is for the teacher-participants to arrive at a new belief system regarding their teaching practice through information dissemination, the collaborative creation of research based strategies, and the ability to tailor particular brain-based strategies to the specific needs of their students (Argyris, 1990; Senge, 1990, 1999).

While the targeted focus of traditional PLCs is student learning, the collaborative teaching teams that comprise a school's PLC continually attempt to answer a series of questions highlighting that focus. According to DuFour, DuFour, Eaker, and Many (2006) they include questions such as: What should students know as a result of this unit of instruction? How will we know when each student has acquired that knowledge and the requisite skills that accompany it? What will we do when some students do not learn? What will we do when some students have achieved the intended outcomes? It is clear that the primary goal of student learning is the content being taught and that any accompanying skill based learning is secondary. The premise of this study is that teachers can enhance student learning by implementing teaching strategies drawn from the field of educational neuroscience or mind, brain, and education science. The review of that literature indicates that those strategies are skill based, not content oriented. How can we reconcile this apparent contradiction between the goals of PLCs and the goals of brain based teaching strategies? By acknowledging that all academic content has a skill based infrastructure that must be continually developed as the foundation for learning any content, teachers can strategically develop the whole student and gather more specific information when considering the critical questions posed earlier. Perhaps all that is needed is one additional key question that PLC members should include in the analysis of their teaching effectiveness/student outcomes. What teaching strategies can I implement to support *how* my students will learn (the learning skills) *what* they need to know (the content) from this unit of instruction?

For example, neuroimaging demonstrates that rote memory, the memorization of isolated facts through repeated rehearsal, is a weak foundation on which additional content and knowledge creation is often based. While necessary to a very limited degree, rote memory is considered to be the most common memory task required of students in primary and secondary schools. These isolated, unconnected bits of information, such as vocabulary words, are stored in remote areas of the brain that are difficult to retrieve when needed due to the scarcity of nerve pathways leading to those areas. Through the implementation of teaching strategies that connect factual information through patterns that are contextually relevant to each other and to students, a solid infrastructure is created upon which meaningful, easily connectable, and retrievable knowledge may be built (Willis, 2006, 2007, 2008, 2010). Implementing teaching strategies that build the foundation on which content is layered couches the critical questions PLCs regularly ask themselves in a very different light, giving teachers an expanded skill set to respond to those questions with laser-like precision.

There are those in the PLC movement who are moving beyond advocating the necessary structural changes that constitute PLCs and looking "to address culture as a critical part of the improvement process" because of its powerful influence in the school environment (DuFour, DuFour, Eaker, & Many, 2006; Marzano, Waters, & McNulty, 2005). I sense a cultural shift is occurring in the learning/teaching atmosphere in Sandersville Middle School. Shortly after the 2010-11 school year began and the results of the 2009-10 New Jersey Assessment of Knowledge and Skills were compiled and revealed, it was announced that Sandersville Middle School was, once again, a failing school, as its annual yearly progress (AYP) was not achieved in four subgroups by large margins. Seventy-two percent of each subgroup was required to score at the proficient level in order to establish AYP for the 2009-10 academic year. The bigger issue is this: for the next three years, the passing percentage for public schools nationwide is 86% and 100% in 2014. The principal of Sandersville directly confronted the issue at the initial faculty meeting of the 2010-11 school year. His direction to the staff was not to become paralyzed by our current failing status, but to put our collective efforts and energy into fostering and demonstrating student growth. The significance of that directive is that perhaps now is the time to evaluate other ways to enhance our culture and to consider new strategies to teaching our mixed general and special education population. Shoring up *how* students learn, *what* they need to learn creates an internal focus within each PLC on specific steps teachers can take to increase student learning outcomes with an accompanying expectation that sound learning requires multifaceted practice as part of the daily classroom routine.

The outcome of this study's specialized PLC may be to expand the established educational neuroscience initiative to provide professional development to the entire staff of Sandersville Middle School. Investing in strategies related to student attention and emotion may yield outcomes exceeding mere skill development. It is an investment that may enable teachers to make meaningful connections between how to learn effectively and developing a content related knowledge base upon which students can build.

Leadership Theory

Becoming a leader who leads from the trenches with no positional power is bottom-up leadership. While not doomed to automatic failure, it does require finesse, the establishment and maintenance of solid relationships, reciprocal trust between the leader and those who follow, sharing knowledge, and courage. My ability to emerge from the trenches as a viable leader is one of the lynchpins undergirding the success or failure of this study (Fullan, 2001, 2007).

In addition to sharing space in the trenches, the teacher-participants and I share a common philosophical viewpoint of teaching middle school age students that is translated into the daily actions of our professional lives. That which is in the best interest of the student is the fundamental principle underpinning my leadership platform and the teaching philosophy that I share with my colleagues. Shapiro and Stefkovich (2005) identify it as the underlying premise of the ethic of the education profession. As such, it is the maxim which causes me to self-identify as a servant leader. The state of flow produced by the implicate order of the natural world is present in the relationship of the servant-leader to those whom he/she serves (Greenleaf, 1977; Jaworski, 1998). This is evident in both my professional interactions with students, teachers, parents, Child Study Teams, and administrators and my personal interactions with my family. My servant leadership is defined by an umbrella of additional supporting principles, the three R's, which are practical tools to bring the theory to life and give it substance. Responsibility gives me moral purpose; relationship connects me with others; and, reflection permits me to construct meaning and value my own personal and intellectual growth as well as those in my care. Former mayor of New York City, Rudy Giuliani, expresses his use of a similar inner compass. On his desk is a sign that states, "I'm responsible," (Giuliani, 2002, p. 96); he reveals his appreciation of and need for relationship in chapter five which is titled, "Surround Yourself with Great People" (p. 98); and, his leadership platform is written as a personal, yet very public reflection of his service to New York City's citizens during the most trying of times.

Leadership and the theories we develop to explain them do not exist in vacuums. They can share similar characteristics, are open to interpretation, and can sometimes be identified by a variety of names. The ethic of the profession is the compilation of three ethics which surely affect my leadership. The ethic of critique and ethic of justice come from critical theory and force leaders to engage in democratic leadership as they face the difficult social and ethical dilemmas of our society, especially as they exist in our schools and affect our students. The ethic of care, concern, and connection provides a nurturing perspective from which moral decisions can be made in the true spirit of feminist leadership (Noddings, 2003; Sernak, 1998; Shapiro & Stefkovich, 2005). Each of these theories is intimately related to the others so much so that perhaps discussing them as separate constructs is a mere academic exercise; perhaps in reality, they exist as one entity with multiple parts or phases that surface when the need arises.

Transformational leadership is often identified as the epitome of what a "good" leader does, that is, changes others. I have a healthy fear of becoming a transformational leader because of the enormous responsibility attached to "changing" others and because transformational leaders can be one breath away from abusing power. Yet, I, too, seek to include this form of leadership in my platform. If it occurs naturally, I am in a synchronous flow with others, engaging in Argyris' (1990) Model II theory-in-use which redefines personal and organizational values and beliefs. It can occur coercively, as with those who subscribe to Theory X theory-in-use. It can also occur through prescriptive interventions, such as surgical hemispherectomies to control severe epilepsy or the *Fast ForWord* listening program to enhance language and reading skills. It takes responsibility, relationship, and reflection to be a transformational leader in a school setting, maintaining the interest of the student as the focal point and, at the same time, enabling the student to become more of a stakeholder in the educational process. Transformational leadership demands the leader exercise great caution, adhere to the ethic of the profession, and lead in the service of others first. It is not for the weak or fainthearted (Argyris, 1990; Bolman & Deal, 2003; Burns, 1978; Couto, 1993; Fullan, 2001; Leithwood, 2007).

The Future of MBE Science

Does MBE science, then, belong in the classroom, and is the classroom an appropriate venue for MBE scientific inquiry? Despite the concerns of some nay sayers in the neuroscience camp, the brain is the seat of human learning. Since the promotion of learning is the school's mission, then the logical conclusion is that a cooperative interaction between neuroscience, the study of the anatomy and functional organization of the brain, and education, the institution that supports and advances human learning, should exist. The establishment of a common language is necessary to facilitate meaningful dialogue between the two fields. It is in meaningful dialogue that questions may be posed, theories formulated, studies designed, and results analyzed for neuroscientists, psychologists, and educators alike. The practice of all professionals can be informed through interaction with the others, especially if all the mirror neurons fire as they should. As the intentions of the contributors become clearer and information is exchanged, the research will become laser focused on the pertinent issues with neuroscientists gaining a more complete knowledge of the brain and its capability and educators using that knowledge base to inform their pedagogy for the advancement of all students.

Several additional areas of focus have been suggested as the cornerstones on which to build the field of MBE science (Goswami, 2008; Szucs & Goswami, 2007). Documenting the typical cortical pathways for learning that is not possible using behavioral methods alone is one of the key outcomes of educational neuroscience. A deeper understanding of neuroplasticity, the brain's capacity to change as learning occurs and to reorganize itself by forming new neural connections, can lead to enhanced theories and paradigms of learning. Identifying neural markers of educational risk through advanced imaging techniques will connect that knowledge to educational performance, enabling teachers to provide earlier diagnosis and earlier intervention when necessary. Neuroscience can provide the research methods to resolve issues in education that cannot be answered through behavioral means, such as the debate regarding learning styles or the "right" brain vs. "left" brain discussions (Szucs & Goswami, 2007).

If the field of educational neuroscience is to go forward, it is in the best interests of educators to be assertive and not passive as they begin to engage with neuroscientists in the information exchange that will launch the joint endeavor. At the moment, it is a solitary endeavor, with the neuroscientists taking the initiative. As much as educators need to be informed about brain structure and functional organization, neuroscientists need to be informed about reading to learn, not just learning to read, combining reading and numeracy to solve and explain math word problems, the effects of classroom noise on neural plasticity, and student motivation to learn, to name a few areas of potential collaborative research.

The multivalent research interests of neuroscientists have taken them in varied directions as technology has created new frontiers for exploration. These interests have not always followed the "scope and sequence" approach favored by education researches and practitioners. As new knowledge is gleaned from neuroscience, educators attempt to force a fit wherever it seems appropriate, whether a solid, logical, proven foundation has been established or not. What new connections might be possible if education researchers looked at the developmental progression of the disparate skills that encompass learning and fit the existing functional neuroscientific research findings to the science of learning instead of vice versa? Student attention and affective resistance to learning are two foundational elements that enhance or inhibit learning in typical group learning situations. They feed directly into memory, information storage and retrieval, constructing new knowledge from past knowledge, and the higher order thinking skills demanded by global competition and a global economy. This study will examine elements of learning in terms of the functional neuroscience that explains, supports, and develops them, while at the same time, suggesting strategies to strengthen deficiencies and enhance the learning potential of classified students. The project's mixed methods design will attempt to establish a foundation from which the teacher participants will expand their usable knowledge of functional, educationally relevant neuroscientific principles, and collaboratively develop, implement, and evaluate the effectiveness of brain-based strategies to enhance student performance.

Chapter 3

Methodology

Problem Statement

A federal government mandate clearly directs public school districts to employ research based teaching strategies in their ongoing pursuit of increased academic achievement in the areas of early childhood education, reading, mathematics, character education, dropout prevention, and English language learners (ELL) education on a local, national, and global scale. Congress included this provision in their authorization of the No Child Left Behind (NCLB) Act of 2001 (U.S. Department of Education, 2006, 34 C.F.R. 300.15 et seq.). NCLB defines scientifically based research along two dimensions; research that is rigorous, reliable, and relevant to education activities and programs, and that is the result of experimental designs that have been reviewed and accepted by a peer-reviewed journal or approved by a panel of independent experts (No Child Left Behind Act of 2001, 20 U.S.C. § 1411(e)(2)(C)(xi)). While the directive's intent seems clear, educators, from superintendents to classroom teachers in neighborhood schools, struggle to work within its legal scope. Identifying programs, materials, and teaching strategies that are aligned with the mandate's provisions can be a confusing, convoluted undertaking that is not easily accomplished.

Cognizant of the difficulties its mandate created, the U.S. Department of Education (DOE) has developed several solutions to the problem. The DOE's Institute of Education Sciences (IES) created the What Works Clearinghouse website in 2002 along with three technical assistance centers located around the country as conduits connecting education research to practice. The criteria for acceptance by the clearinghouse are stringent and the language used to evaluate scientifically based education research indicates that the analysts who assess them are biased toward traditional quantitative studies with large experimental, control/subject populations. It appears that the potential benefits of research-based instructional programs that are the results of methodologies such as action research are not considered by the clearinghouse due to methodology alone. Are the more subjective elements of learning that result from using new programs, strategies, or materials traded off in favor of a numbers based outcome alone? Is it possible that factors such as these prevent educators from considering the larger, more comprehensive realm of research and its potential impact in their classrooms daily?

This practical action research project explored the inclusion of empirical brain research as a pedagogical foundation on which to change the teaching practice and increase the craft knowledge of a group of middle school teachers. Hinchey explains that craft knowledge is "what teachers know about teaching based on their classroom experiences" (2008, p. 39). This tacit knowledge is the antithesis of empirical findings such as those supported by the What Works Clearinghouse and its legitimacy as a proven, reliable research base has yet to be firmly established and accepted by the quantitative research community. As action research continues to gain legitimacy among researchers, the fruits of those labors should become recognized as valid, reliable, and worthy of consideration by the research and education communities. The contribution of this study is to enable teachers to "gain more control of (their) practice, to change what counts as 'knowledge' of teaching practice, to help build a body of craft knowledge," (Hinchey, 2008, p. 40) and to move it into the realm of empirical research.

One way that a teacher's practice may be limited is his/her reliance on an incomplete body of knowledge. The implementation of erroneous or misinterpreted information that is thought to be factual is an inherently greater teaching flaw. The transfer of information from educational neuroscience to laymen (teachers) who do not share the same foundational knowledge as neuroscientists has occurred in recent years. Identified in the literature as "neuromyths," they are a collection of pseudo-factual concepts that have become synonymous with brain-based teaching (Battro, Fischer, & Lena, 2008; Bruer, 1997; Diket, 2005; Gardner, 1983; Goswami, 2008; Howard-Jones, 2008; Organisation for Economic Co-Operation and Development, 2007; Pickering and Howard-Jones, 2007; Szucks & Goswami, 2007). This is where the strongest comparison can be drawn between bridging the gap between education research and teaching practice and bridging the gap between neuroscience research and teaching practice. Just as a need exists for the federal government to provide assistance in the interpretation and implementation of education research, so, too, is there a need for neuroscience/brain-based research to be translated into understandable, useable knowledge to inform teaching practice. The need to connect valid neuroscience research and knowledge with teaching practice to enhance student learning has led to the framing of the following research questions.

This action research study sought to answer the following questions regarding infusing selected principles and practices of educational neuroscience into the teaching strategies of middle school teachers at the Sandersville Middle School to affect their teaching practice.

1. Did the middle school teachers at Sandersville Middle School gain usable knowledge connecting empirical brain research to teaching practice? If so, what was the extent of the change in knowledge?
2. Did brain-based usable knowledge change middle school teachers' teaching practice?
3. What was the teachers' perception of changes in student achievement at the conclusion of this study?

4. Did teachers observe changes in students' attention related to brain-based teaching strategies?
5. Did teachers observe decreased emotional resistance among their students as a result of brain-based teaching strategies?
6. Did the experience of a workshop/PLC format help to create a bridge between empirical brain research and teaching practice among middle school teachers at Sandersville Middle School?
7. Did my leadership role in this project enable the teacher participants to gain usable knowledge in the principles and selected practices of mind, brain, and education science?

Research Design

The prime objective of this research design was to introduce empirical, brain-based research to general education and special education teachers in my middle school setting. I also attempted to influence their teaching practice as a result of a five-part brain-research workshop series and ongoing professional development as part of the teachers' participation in a voluntary professional learning community (PLC). I chose a concurrent embedded mixed methods approach to this practical action research study to address my research questions. In this approach, the qualitative data is primary while the quantitative database is secondary and supportive to the primary qualitative data (Creswell, 2009; Creswell, 2007). The cyclical design of action research afforded the participants and me the opportunity to adjust this process in response to the ebb and flow of life in a middle school, to teacher and student response, and to the impact of empirical brain research in a public school learning environment. This information was included in the application for approval of the project that was filed with the Institutional

Review Board at Rowan University. Prior to the start of the study, permission was granted by that board to conduct the research as it was therein described.

The Organisation for Economic Co-Operation and Development (OECD) promoted the position that "any educational reform which is truly meant to be in the service of students should take into account neuroscientific studies and research, while maintaining a healthy objectivity" (2007, p.124). The pragmatic underpinnings of practical action research implemented through a PLC is one way to establish and maintain the objectivity required to thoughtfully and meaningfully assess the outcomes of implementing brain-based strategies.

The empirically derived brain-based principles that had the greater impact on teaching practice are those which have the potential to be the most generalizable from learning environment to learning environment among the group of teacher-participants who shared some of the same students. If they were determined to be the most generalizable, they were the most reinforceable from setting to setting, and therefore, the ones that yielded the most observable outcomes for teachers and students alike. Those principles should not be related to specific curricular content but to learning strategies that are applicable over a range of academic and social activities. Principles related to increased student attention and decreased emotional resistance to learning were the focal components of this research-to-practice program.

Most historians credit Kurt Lewin and John Collier with the development of action research in each of their respective fields in the 1940's, while Stephen Corey was the first to apply the concept to education (Hinchey, 2008; Kemmis & McTaggart, 2005; Masters, 2000). One of the purposes of action research is to enable the educator to identify a problem in her practice and, as an agent of change, cycle through a series of steps several times until the problem is improved, resolved, or redefined. Creswell and Plano Clark, (2007) define mixed methods research as "an approach to inquiry that combines or associates both qualitative and quantitative forms…it also involves the use of both approaches in tandem so that the overall strength of a study is greater than either qualitative or quantitative research" (as cited in Creswell, 2009). As a research method, it has been described as a creative research form that does not impose limitations on the researcher as strict adherence to either qualitative or quantitative methods alone does. It is able to address the essence of the research, that is, the research question(s) more eclectically and with an eye to using all available, appropriate means to obtaining practical answers to those questions (Johnson & Onwuegbuzie, 2004).

In discussing research design, Creswell (2009) described the joining of three components: the philosophical underpinnings of the researcher, which he refers to as philosophical worldviews; strategies of inquiries; and exact methods. Johnson and Onwuegbuzie (2004) paired mixed methods research with pragmatism as its philosophical partner. They, along with Creswell, looked to the classical pragmatists, such as John Dewey and William James, whose foci were on problem solving actions and practical outcomes. Reduced to its simplest terms, the pragmatic method enabled researchers to "choose the combination or mixture of methods and procedures what works best for answering your research questions" (Johnson & Onwuegbuzie, p.17) instead of being restricted to using only those that fit the qualitative or quantitative paradigm which might leave research questions unanswered.

My project employed a concurrent embedded mixed methods strategy which is an approach to inquiry in which qualitative and quantitative data is collected within the same timeframe or cycle, but is independent of each other (Creswell, 2009; Creswell & Plano Clark, 2007; Johnson & Onwuegbuzie, 2004). For example, the pre- and post-workshop surveys administered during Cycles I and IV attempted to quantify the amount of usable knowledge about educational neuroscience or the shift in attitude about this research field that occurred as a result of the workshop itself. The interviews and focus groups that were conducted at the workshop's conclusion added richness, depth, and a more complete interpretation of the numerical data obtained from the surveys. The quantitative data supported the primary qualitative data and added to its comprehensive interpretation since each method alone contributed only a partial answer to the appropriate research questions.

Data Sources and Data Collection Strategies

Data was collected at Sandersville Middle School, part of a large, suburban school district in southern New Jersey. The school had a student enrollment of approximately 970 sixth, seventh, and eighth grade students for the 2009-2010 school year. One of three middle schools in the district, Sandersville educated the largest population of classified students (213/970 or 22%) with programs ranging from full inclusion to double period resource room replacement, to self-contained classes, with any appropriate variation of programming occurring as mandated by student IEPs. This meant that all teachers, both general and special education, taught the entire population with many classes representing the entire spectrum of student achievement.

The entire professional and administrative staff were invited to attend a five-part brain-based/educational neuroscience workshop series to engage as many teachers and administrators as possible in debunking neuromyths, in discussing applicable neuroscience research topics, and in considering the inclusion of strategies derived from empirical brain research in their teaching practices. A convenience sample of from 6 to 12 attendees that were representative of the larger workshop population were invited to participate in a focus group to engage in continuing conversation about the empirical brain-based topics; individual attendees, including some teacher participants, were asked to participate in face-to-face interviews with the investigator to discuss the relevance of the workshop information and to explore the potential for developing and implementing brain-based teaching strategies in their teaching practice (Corbin & Strauss, 2008; Creswell, 2007; Miles & Huberman, 1994; Patten, 2001). With the empirical brain research as a foundation, all workshop attendees were invited to participate in the subsequent cycles of this study through their involvement in a specialized professional learning community which included continued professional development regarding the brain and learning, the selection of appropriate strategies, their implementation, discussion and continued evaluation of the strategies as well as of the project as a whole.

Mixed methods were implemented throughout the duration of the project. A quantitative survey was administered both before and after the brain research dissemination workshop series to assess the degree of change in the participants' knowledge base regarding the topic. The participants were also surveyed prior to the start of the 2010-11 school year when they implemented the brain-based strategies with a new group of students as well as at the conclusion of the implementation phase of the study. A variety of qualitative methods were employed during the cycles of this action research study. The PLC met approximately bi-weekly to extend the professional development phase of the study and to continuously assess the brain-based strategy implementation phase, injecting the objectivity suggested by the OECD (2007) and the necessary adjustments required by practical action research. Its members determined the ebb and flow of on-going research actions through their interactions with each other, with me, and with their students. This group interaction was intended to add depth and breadth to the project's assessment and to the teachers' personal reflections about the strategies' effectiveness as they became integrated into their teaching practices. I planned and the conducted the empirical brain research workshop series, the PLC meetings, the individual teacher interviews, all survey preparation and administration and maintained a reflective journal throughout the course of the project.

Action Research Implementation

Once a problem is identified in action research, the next phase in the process is to design and implement appropriate interventions to address the problem, attempt to resolve the issues at hand, and change the status quo. Referred to as an action research spiral by Henry and Kemmis (1985), this systematic inquiry sequence of "plan, act, observe, reflect, revise plan, act, observe, and reflect" repeats itself until some outcome is achieved, albeit not always the anticipated result. As a process of cyclical, systematic inquiry designed to improve or change a situation, action research has several identities. Critical or emancipatory action research addresses issues of social justice; participatory action researchers also seek a more democratic and just society through a group effort that may address issues that are more generalizable than local; collaborative action research involves a number of researchers collaborating to address a local problem. This study was practical action research which was undertaken to identify a problem area, and systematically worked to improve the situation by implementing a change strategy, after planning, acting, observing, and reflecting in a series of repetitive cycles until the change was affected (Hinchey, 2008). The change strategies for each cycle of research undertaken were dependent on the results of the previous cycle. The researcher planned for the interventions to be utilized during Cycle I and anticipated possible interventions for use later in the study which were tailored to the actual results obtained in the research cycles. My study may be characterized as practical action research as its goal was to connect empirical brain research to the practice of teacher-participants as they sought to increase attention and decrease emotional resistance to learning among their students.

Cycle I. An invitation was extended to all members of the teaching and administrative staff to attend a five-part workshop series in February, 2010, for the dual purpose of expanding their knowledge base regarding empirical brain research and informing their teaching practice. Another targeted goal was to identify and debunk popularly held neuromyths which have made their way into some educational circles and perhaps influence teaching practice. The workshop sessions were scheduled to take place both before the school day began and at the end of the school day so that they would not interfere with teachers' contracted responsibilities within the official school day. For their convenience, workshop participants had the choice of which workshop sessions to attend as the same information was presented at each A.M. or P.M. session.

The first session of the workshop was conducted by Russell Buono, Ph.D., a neuroscientist from the Veteran's Administration Hospital in Coatesville, PA, who conducts informative demonstration sessions such as this one as part of the veteran administration's outreach philosophy. Dr. Buono was accompanied not only by a wealth of knowledge regarding brain structure and function but by several preserved human brains, both typical and diseased, a spinal cord, and a dura mater or brain covering. The participants were invited to join Dr. Buono at his presentation table, don latex gloves, and examine the specimens first hand if they chose to do so. Dr. Buono's knowledgeable yet listener friendly presentation made it easy for the teachers to ask questions, make comments and observations, and interact easily with the content and the specimens. The session was videotaped for later review and discussion.

I conducted the four subsequent sessions and supported the presentations with powerpoint outlines, copies of the empirical research studies presented in each session, and examples of books and materials related to the topics under discussion. The topics included neuromyths, attention, emotion, math, neural branching, and working memory strategies. The sessions were all interactive, with the participants asking questions, making observations, connecting to their teaching experiences, and reacting with several “AHA!” moments. The most frequently offered observation about the entire series was the comment that the entire school community would benefit from the information presented throughout the workshop.

A pre-workshop Likert scale survey (Appendix A) was administered after having obtained written informed consent from the workshop attendees prior to the first workshop session to assess participants’ prior knowledge of educational neuroscience. Informed consent was given for the pre-workshop survey and the post-workshop survey with the participants made fully aware that the surveys were part of the data collection procedures employed in this dissertation research (Patten, 2001). The workshop series occurred one day a week for five consecutive weeks. At its conclusion, a post-workshop survey (Appendix B) was administered to assess the degree of measurable change, if any, in the teachers’ newly gained knowledge (Patten, 2001). Volunteers from the workshop were sought for two purposes: to participate in a focus group to be held after the workshop series concluded (Appendix C), and to become participants in the study for its duration. Nine teachers volunteered to participate in the study. The focus group was brought together for questioning and further conversation about educational neuroscience, to encourage participant interaction about the topic, and to discuss its potential impact on their teaching practices (Hinchey, 2008; Rossman & Rallis, 2003). Individual teacher interviews were conducted among the project’s teacher participants and any other workshop series attendees who volunteered to be interviewed (Appendix D). The teachers were provided with a copy of the interview questions beforehand to facilitate connecting their responses to the information they obtained through the five workshop sessions. The interviews were semi-structured as the questions were a guide which allowed for conversation and spin-off questions between the interviewees and me (Bogdan & Knopp Biklen, 2007; Corbin & Strauss, 2008; Hinchey, 2008). I felt that individual interviews were an appropriate follow-up to the workshop series sessions and the focus group because the information that the teachers were assimilating into their knowledge base was new and unique. I wanted to determine if the teachers felt secure about selecting and implementing brain research strategies with their students at that time which signaled readiness for the planning and action phases of the next research cycle (Kemmis & McTaggart,, 2005). This completed the triangulation of data collected during this phase of Cycle I.

For reasons of practicality and manageability, the teacher participants each selected no fewer than three and no more than five students in their classes for whom teaching strategies were selected based on the empirical brain research. While we discussed the possible strategies together and generated a list of potential activities, each teacher was encouraged to select his/her own strategies to implement with their students. The data analysis from Cycle I informed me as to the overall efficacy of this action research project and confirmed the viability of using some and rejecting other research based strategies to inform teaching practice. Whether successful or unsuccessful, I grew in the knowledge that I had chosen a unique topic to address the problem of student achievement among middle school students, developed a series of logically progressive actions to address the problem, analyzed the data obtained from those actions, and formulated conclusions that may inform general and special education teaching strategies alike.

Cycle II. This cycle lasted from February through May, 2010. Figure 5 is a diagram depicting the process to select subjects. Of the 19 workshop attendees, nine teachers initially volunteered to become members of the PLC and participants in this study. Of the nine participants, seven were special education teachers and two were general education teachers; six teachers taught sixth grade, one taught seventh grade, and two taught eighth grade.

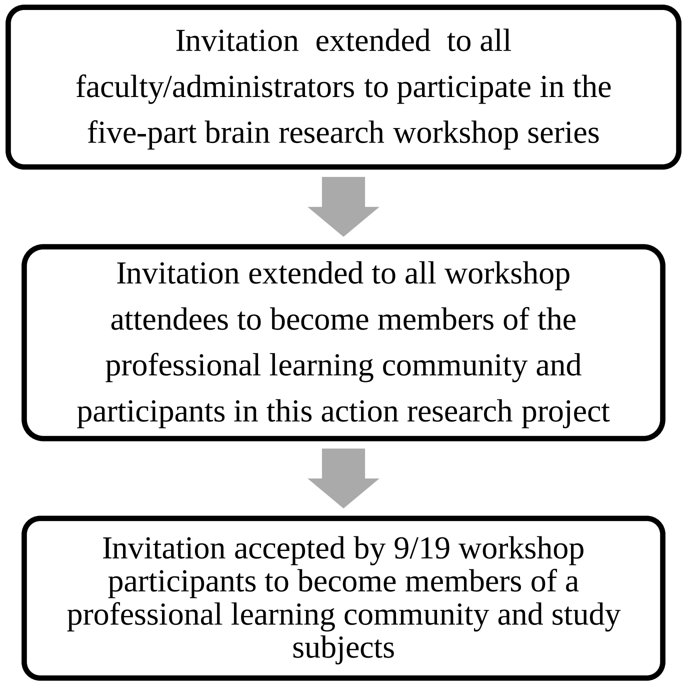

Figure 1. Teacher-Participant Selection

The anticipated plan included the following actions. I conducted weekly observations of several teacher-participants and wrote regular reflective journal entries to supplement the field notes associated with each observation. Semi-structured individual interviews were conducted with each teacher-participant in a two-week cycle to discuss and assess progress, the strengths and weaknesses of the brain-based strategies, student reaction to the strategies, and their progress. A semi-structured interview approach was used to obtain comparable data from the participants while allowing me to ask for clarification or the expansion of ideas from the respondents when necessary (Bogdan & Biklen, 2007). The PLC met every two to three weeks to continue the professional development begun with the brain research workshop series, to discuss teaching strategies, and to provide each other with feedback and findings. Each meeting included those three components and data collection was in the form of field notes and participant observations.

An unanticipated event occurred on March 23rd about which there was little prior notice to include in my original planning for cycle II. Dr. John Jonides, a neuroscientist who had recently published groundbreaking research on working memory capacity at the University of Michigan, was to be the featured researcher on an on-line web chat for members of the Learning and the Brain Society. As a member, I was excited to add this web chat to my action plan in light of the significance of Dr. Jonides' work and our recent references to it during the brain-research workshop series.

In the planning phase of this cycle, I anticipated that the PLC meeting at the end of May, 2010, would be used to re-assess the entire cycle and the participants would determine collaboratively what overall adjustments would be necessary to implement prior to the start of cycle III in September, 2010. However, the teachers provided reflective feedback during cycle II requiring a shift in the timetable and a re-thinking of the "act" phase of the cycle.

Cycle III. In the beginning of April, 2010, the teachers collectively expressed unease and concern about their interpretations of how to implement the strategies that they had chosen from the list we had generated at our first few PLC sessions. They stated fears about not being sure that they were "carrying out the strategies correctly," and that they "might be messing up the study," and that they were "no longer confident when left alone without the support of the group" to implement the activities with their students (PLC members, April, 13, 2010). The group consensus was that I would select the strategies that I wanted them to use. I reluctantly agreed due to the group's expressed level of anxiety and stress. My reluctance stemmed from my belief that the participants would become invested in strategies in which they had become interested from both theoretical and practical perspectives. John Dewey proffered support for this idea when he wrote of how important the concept of interest was in educational endeavors because "one who recognizes the importance of interest will not assume that all minds work in the same way" (2005/1916, p. 142) because they were exposed to the same presentation of the same material. Ideas resonate differently with individuals who are not pulled to newly learned ideas in the same way or with equal intensity and interest. In looking to the literature on constructivism and democratic leadership, I felt that teacher success would come, in part, from their own selection of those strategies that they acknowledged to make sense to each of them, making those strategies potentially the most meaningful given the fact that they each taught classes with unique personalities, characteristics, and needs. Defined as "the theory of learners (in this study, the learners were the teacher participants) constructing meaning based upon their previous knowledge, beliefs, and experiences" (Lambert et al., 2002, p. 1), my goal was to have the teachers augment their existing body of knowledge and experience with empirical brain research and teaching strategies gleaned from that new knowledge base.

As teachers care for their students, action researchers must care for their participants, in this case, teachers. As a direct result of the teachers' reflective reactions to the project at that time, I selected three strategies that we had discussed and developed in prior PLC meetings. They included deep breathing exercises, teaching brain facts and their connection to student learning, and modified *n*-back tasks which included activities such as forward and backward digit spans, spelling backwards, mental math, and occasional student reflections.

Cycle IV. Cycle IV began in September, 2010 with the start of the 2010-11 school year and with it developed four separate situations that merged and created the conditions of a perfect storm. The primary situation was the failure of Sandersville Middle School to achieve its annual yearly performance (AYP) goals as a result of the students' outcomes on the mandated state testing administered the previous spring. The school failed to achieve the required 72% passing percentage in four subgroups, including African American, Hispanic, economically disadvantages, and special education.

The second element of the perfect storm was the launch of a comprehensive new district wide math program, which brought with it the usual accompaniment of stress, uncertainty, and sleepless nights for some. One of those who gave up sleeping for worrying was a participant in the project who felt he was unable to keep up with everything expected of him and do it all well. He made the only choice available to him and opted out of the study.

Thirdly, the principal of Sandersville Middle School made a leadership decision to eliminate all self-contained social studies classes for incoming sixth grade students and program them in inclusion classes, creating the third element of the perfect storm. That decision necessitated another teacher-participant to withdraw from the study because she no longer taught sixth graders in the smaller pull-out setting as she was assigned as the special education inclusion teacher in inclusion classes. In November, 2010, the principal reconsidered the advisability of his original decision and created two smaller pull-out social studies classes in sixth grade, but assigned a new teacher to teach them, leaving the teacher-participant in her inclusion position without, in her opinion, the opportunity to implement brain-based strategies.

Finally, the number of classified sixth grade students, in both general and special education, increased class sizes in all classes to numbers not previously seen in recent years. In addition, the number of classified sixth graders with autistic spectrum disorder (ASD) was the largest we had ever had enter the school at one time. This was the fourth component of the perfect storm scenario in which the entire staff, including the study participants, found itself enmeshed as the school year began. The number of classified students resulted in classes in all subject areas that were out of compliance with the New Jersey Special Education Code (New Jersey Administrative Code, 6A: 14-4. 7(e), 2006, p. 83)**.** The imbalance between general and special education students in some classes resulted in classes that were slower to learn class routines, slower to engage in academic activities, and slower to transition to a middle school mindset. The teachers expressed surprise that it was more difficult to resume the project in September with new students than they had anticipated. I shared their surprise. It was my expectation that at the beginning of a new school year, the brain-based strategies would become part of class routines that were established on the first day of school, making them easier to include in daily class schedules. One sixth grade teacher-participant explained that "you forget at the end of one year how far the students came from September to June and you begin the next year in a June frame-of-mind instead of with September expectations."

The PLC meetings from September, 2010 until November 2, 2010 were characterized by general complaints about these situations, genuine concern for the project, sincere interest in continuing, and guilt about feeling unable to implement the strategies due to the perfect storm, which created circumstances beyond everyone's control. This was one advantage that action research held over more traditional quantitative studies. The PLC had the opportunity through collective reflection to analyze why the beginning of this school year was different than the end of the previous school year and to re-plan and execute actions that met our current circumstances so that the project could go forward. The result of that reflection was that the PLC chose to continue the project through the end of second marking period with a renewed determination to align brain-based strategies with their teaching practices.

The Sandersville School District offered its professional staff a professional development choice known as the Flex Option. Staff members could submit a proposal for a six hour workshop on a topic of their choosing for approval by the central administration. The workshops were scheduled for three, two-hour sessions. The incentive was that all participants who exercised the flex option were excused from the last day of school, which is an in-service day on the calendar and required for anyone who did not participate in one of these workshops. I submitted a proposal to repeat the empirical brain research workshop series that I had presented in February, 2010 during Cycle I. With 17 respondents, I presented the second five-part workshop series in October, 2010, including the same pre- and post-workshop survey that I had used previously. This was an additional opportunity to plan and execute an action that was not previously anticipated, but that enabled me to respond to some of my research questions with increased accuracy from an expanded respondent base. A pre-workshop survey (Appendix A) was administered after having obtained written informed consent from the workshop attendees prior to the first workshop session to assess participants' prior knowledge of educational neuroscience. Informed consent was given for the pre-workshop survey and the post-workshop survey with the participants made fully aware that the surveys were part of the data collection procedures employed in this dissertation research (Patten, 2001).

Cycle V. It was the PLC's intention that cycle V would mirror the actions of Cycles III and IV and extend it from November 15, 2010 through January 28, 2011. The teachers comfortably implemented strategies of their own choosing at this juncture in the project. I planned and led two PLC meetings, interviewed individual teachers, and administered the post-study survey throughout this cycle. I did not conduct field observations as the teachers implemented the strategies due to the restrictions imposed by my schedule.

Data Analysis

Data analysis included the interpretation of the data and the validation of the quantitative and qualitative information obtained from the participants and the researcher. The analysis occurred cycle by cycle and concluded by analyzing and answering the research questions posed at the outset.

The following procedures were applied to Cycles I, IV, and V as they contained both quantitative and qualitative datasets. First, I conducted separate initial data analyses for each of the data bases: qualitative analysis included the identification of categories, codes, themes, and the interrelationship of those themes; quantitative analysis included the derivation of percentages from the survey data due to the small sample number included in the study. Second, according to concurrent embedded design theory, I integrated the data and compared the qualitative sources to the quantitative sources. The purpose of integrating the datasets was "to enrich the descriptions of the sample participants" (Creswell, 2009, p. 215) so that a complete picture of the teachers' responses to the study would emerge. I compared the data through discussion and creating matrices which enabled me to make visual comparisons using the quantitative survey data and qualitative themes (Creswell & Plano Clark, 2007; Johnson & Onwuegbuzie, 2004). Third, the findings were used to answer the corresponding research questions. This procedure is graphically displayed in Figure 1.

Cycles II and III produced qualitative data only. Categories, codes, themes, and their interrelationships were derived from these data sets which included individual interviews and focus groups. They were analyzed through discussion and the creation of matrices to visually C(Bogdan & Knopp Biklen, 2008; Corbin & Strauss, 2008; Creswell, 2007, 2009; Creswell &

Plano Clark, 2007; Hinchey, 2008; Miles & Huberman, 1994). This procedure is displayed graphically in Figure 2.

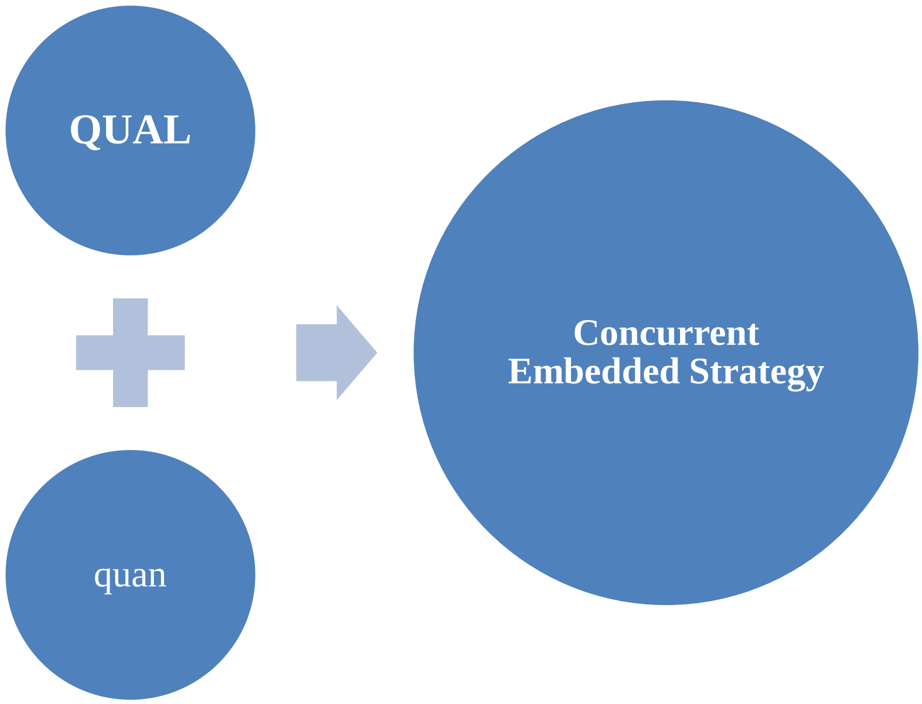

Figure 2. Concurrent Embedded Data Collection/Analysis for Cycles I, II, and V

The most important component of a research study is its validity. Creswell and Plano Clark (2007) define validity "as the ability of the researcher to draw meaningful and accurate conclusions from all of the data in the study" (p. 146). The extent to which a study is valid is the extent to which its findings and their interpretation are trustworthy. Even though the triangulation design merges two disparate databases and makes validation challenging, its philosophical grounding in pragmatism guides the researcher to understand/find/know the consequences of the actions implemented during the research study (Creswell & Plano Clark, 2007; Hinchey, 2008). Did the inclusion of strategies gleaned from empirical brain research change teaching practices among middle school teachers? Evidence from both quantitative and qualitative databases has the potential to provide better results than either dataset could provide if examined singularly. Examining this change phenomenon from multiple perspectives made the identification of additional future actions possible in light of the results of the current study from a practical, pragmatic perspective (Creswell, 2009; Creswell & Plano Clark, 2007; Johnson & Onwuegbuzie, 2004; Miles & Huberman, 1994).

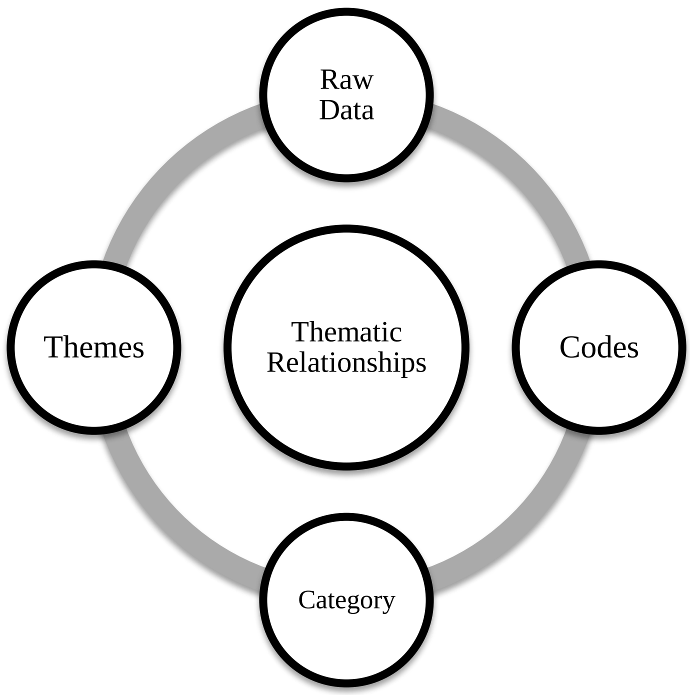

Figure 3. Qualitative Data Collection for Cycles II and III

Ascertaining validity establishes that the qualitative database was accurate. I employed the following strategies to validate the trustworthiness of the qualitative data that I collected throughout the project. Summaries of the findings were presented to the teachers at the final PLC meeting and their feedback confirmed the results in light of their individual and collective experience throughout the study. Called member checking, the teachers verified the accuracy of the findings relative to their involvement (Creswell & Plano Clark, 2007; Hinchey, 2008). A second strategy confirmed the results through a process known as data triangulation. Data was obtained from multiple sources, such as PLC meetings, individual interviews, and personal reflections, to discover and confirm the codes and themes that emerged (Bogdan & Knopp Biklen, 2007; Creswell & Plano Clark, 2007; Hinchey, 2008). The third strategy that I utilized was peer review of the data, its results, and its interpretation. I invited a member of the faculty who has attained the Ph.D. degree and has been through this process, an administrator who is currently pursuing her Ed.D. degree and is just beginning the dissertation phase of her program, and a colleague who I consider to be the quintessential master teacher to review the data, the results, and their interpretation and provide feedback as to the study's overall efficacy (Hinchey, 2008).

Chapter 4

Findings

From the popular notion of brain-based learning has emerged the new field of Mind, Brain, and Education (MBE) science which unites the individual strengths of psychology, neuroscience, and education. The merger of theory and research from three different philosophical and practical vantage points has the potential to culminate in a teaching practice that is enriched and enlightened in ways that could not develop from a singular approach alone (Tokuhama-Espinosa, 2010). While all three parent fields have strong historical foundations, the nascent field of Mind, Brain, and Education science is writing its history now, in the early 21st century. The current findings resulted from sharing this expanding knowledge base with middle school teachers and attempting to create a paradigm shift away from solely traditional teaching strategies toward a more eclectic, brain research based view of student learning.

Sharing the results of action research has been described as "telling the story of the research" (Hinchey, 2008, p. 107) and is appropriate to this chapter given that this investigation's topic was personal to group of teachers in the context of their own individual classrooms with their own students. Could they improve their students' academic performance by changing their strategic approach to learning? The story, told through these cyclical findings, followed the format for narrative writing that is often taught to middle school students. In short, a group of teachers, predominantly (but not exclusively) sixth grade special education teachers from Sandersville Middle School, learned about and implemented strategies from empirical brain research to increase academic achievement among selected students. The problems the teachers encountered became clear as the study progressed and resolutions were attempted. Figure 3 is a visual representation of this action research study as it developed over time. Cycles I and II were the

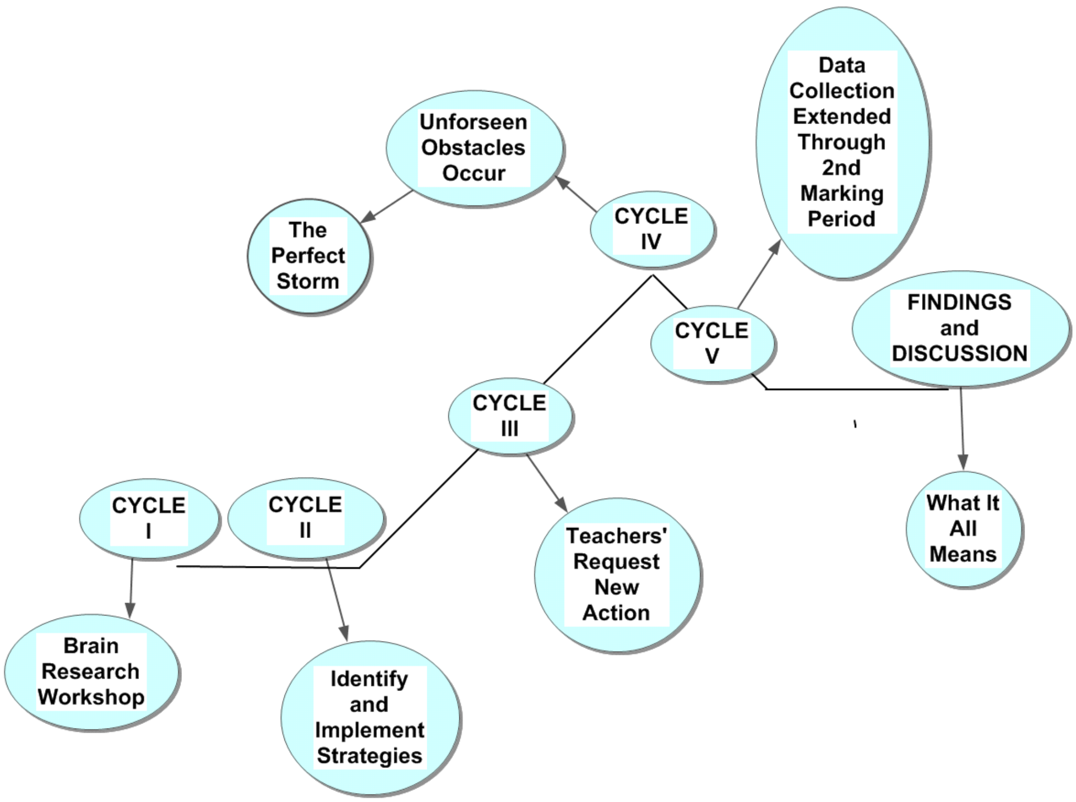

Figure 4. Schematic Illustration of Action Research

introductory phases of the study when the brain research workshop and initial identification and strategy implementation occurred and are depicted at the lower left and of the diagram. The teacher-participants requested a change of action during Cycle II, creating Cycle III, which is shown on the rising slope representing the first problem encountered in this project. Cycle IV is positioned at the peak of the ascending slope as major data collection obstacles were encountered at that point in the study which occurred in September, 2010. Resolutions of these obstacles are shown on the descending slope and were part of Cycle V. Chapter 5 of this report, Conclusions and Implications, includes the final data interpretations and subsequent discussions relevant to this project and are seen as the straight line at the upper right end of the schematic. A strong literary parallel observed between the elements of narrative story development and the evolution of this action research project that resonated with Hinchey's previous statement that sharing the results of action research has been described as "telling the story of the research" (Hinchey, 2008, p. 107). The schematic in Figure 1 highlighted this popular teaching strategy as an approach to sharing the story of this research.

Cycle I (February-March, 2010)

The study began with my professional reflections about middle school teachers with whom I have worked over the years who have focused primarily on teaching strategies related to their content areas and classroom management issues to enhance student achievement to the near exclusion of building generalized learning capacity (Fullan, 2001) among their students. The missing link came from the law, known as No Child Left Behind (NCLB), which mandates the implementation of research-based teaching strategies coupled with my personal, long-standing curiosity about the human brain. The inquiry began, then, by joining research-based teaching strategies with research about the brain and inviting teachers from Sandersville Middle School to participate in this action research approach to increasing academic achievement among their students.

In literature, all good stories have a hook to grab the reader's interest and hold it from start to finish. This action research story had a hook. The first session of the workshop series was conducted by Dr. Russell Buono, a neuroscientist from the Veterans' Hospital in Coatesville, PA. To support his lecture about the brain structure and function, he displayed several preserved human brains, both typical and diseased, a spinal cord, and a dura mater or brain covering. As we stood around the presentation table with Dr. Buono during this interactive presentation, the teachers were invited to ask questions, to make observations, and to handle the brains and examine them, which most did with great enthusiasm, curiosity, and quiet respect. According to one of the participants, "… It was a terrific hook, talk about hooking class. I wanted to touch those brains so badly… a smart hook… it was exciting to me, and made me want to learn more from your program… I was in awe" (M.D., post-workshop individual interview, 4/14/2010). Figure 4 is a photograph depicting two teachers who participated in this unique experience. My journal entries reflected the sense of heightened optimism that I experienced during this session as I felt the palpable excitement and saw some "Aha!" moments in the eyes of my colleagues. I wrote, "It was as if I was holding the essence of a real person in my hands. There was a sense of reverence around the table where the brains were on display. Everyone seemed awestruck" (Sanders, Leadership Journal, February 3, 2010). At this writing, I closed my eyes still felt the inexplicable feeling of holding that brain in my hands.

Data analysis. Data gathering consisted of two phases, a quantitative survey phase and a qualitative phase. The purpose of the pre-and post-workshop surveys were was to measure any change in the workshop attendees' knowledge about empirical brain research that could potentially connect to and change their teaching practice (see Appendices A and B for complete surveys). The quantitative surveys consisted of a Likert scale with open ended question; the qualitative data consisted of responses to a focus group comprised of volunteers who attended the brain research workshop series, individual interviews with workshop attendees, and my journal reflections (Bogdan & Knopp Biklen, 2007; Creswell, 2007; Creswell & Plano Clark, 2007; Osterman & Kottkamp, 2004; Patten, 2001). The timing of Cycle I overlapped the timing of Cycle II. Therefore, for purposes of clarity and cohesiveness, I have reported all overlapping research activities that related to the workshop as part of Cycle I.

Prior to the start of the workshop's first session, all attendees completed a short pre-workshop survey to ascertain their opinions regarding general topics related to brain research and education. Table 1 summarizes the results of that initial survey. The results were skewed sharply to the left indicating that the respondents strongly favored the idea of brain research

Figure 5. Teachers Examine a Human Brain Specimen and Human Spinal Cord Specimen
The specimens in the middle dish are neurotypical or healthy brains, while the other two specimens in the dish on the left are from patients who had been afflicted with Alzheimer's disease during their lifetime. (Permission granted to include photograph.)

impacting their teaching practice. Little, if any, variation was noted among their responses. It appeared that they were familiar with the concepts identified in the question items, which made potential changes in their opinions about brain research affecting their teaching practice unclear at best and unlikely at worst. Their overwhelmingly positive response to the topic, however, was encouraging as we embarked on this change initiative together.

Given the extremely skewed response profile of the pre-workshop survey, I reconsidered the design of the initial survey. The pre-workshop survey had been pretested with a group of ten sixth through eighth grade teachers who were unable to attend the workshop series for a variety of reasons. They reported that the statements were clear, well structured, and comprehensible. Due to the possibility that statements in the first survey were incorrectly phrased, or that they were too content specific, or that I had misjudged the teachers' background knowledge, I designed a different post-workshop survey as a corrective measure to remove any inherent flaws in the pre-workshop survey. Through this action, I hoped to create a survey that would document the effectiveness of the workshop in changing the teachers' knowledge of empirical brain-based research in their practice. The post-workshop Likert survey included statements referring to the specific topics discussed during the workshop series, not unlike the statements included in the initial survey. To determine if the teachers' knowledge base about the topic had changed, it was, "necessary to write a number of items (regarding specific concepts) to get a comprehensive measure of attitudes toward such a comprehensive construct" (Patten, 2001, p. 37). It included two additional statements to accommodate the need to cross- reference specific concepts with multiple statements, which are summarized in Table 2.

A similar response pattern was observed in the post-workshop survey as occurred in the initial survey. The results were skewed sharply to the left indicating agreement with the survey statements with little variation from the respondents. While this did not indicate that a change in the respondents' opinions occurred as a result of brain research workshop, it did indicate that the information was well received.

Table 1. Pre-Brain Research Workshop Survey Responses
N = 19

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Item1: Teaching practice should be guided by research.					
N	11	8	0	0	0
Percentage	58 %	42 %	0 %	0 %	0 %
Item 2: I want to know what parts of the brain control specific learning functions.					
N	8	7	4	0	0
Percentage	42 %	37 %	21 %	0 %	0 %
Item 3: I would rather know how the brain enables us to think and to learn.					
N	10	7	1	1	0
Percentage	53 %	37 %	5 %	5 %	0 %
Item 4: I think the information from this workshop will positively impact my teaching.					
N	8	8	2	0	Missing: 1
Percentage	42.1 %	42.1 %	10.5 %	0 %	5.3 %
Item 5: It is important to know if "brain-based" programs/products come from empirically based research.					
N	9	9	1	0	0
Percentage	47 %	47 %	5 %	0 %	0 %
Item 6: Teachers should know the difference between brain facts and brain myths.					
N	15	4	0	0	0
Percenetage	79 %	21 %	0 %	0 %	0 %
Item 7: The issue of increasing student attention is central to my teaching practice.					
N	15	3	1	0	0
Percentage	79 %	16 %	5 %	0 %	0 %
Item 8: The issue of reducing emotional resistance to learning among my students is important to my teaching practice.					
N	13	5	1	0	0
Percentage	68 %	26 %	5 %	0 %	0 %

Adapted from Patten, 2001, p. 85

Responses to an open-ended question on the post-workshop survey regarding the participants' overall impressions of the five-part workshop series were overwhelmingly positive and included statements such as, "This workshop has opened my mind and has made me eager to learn more about the brain and its function. You have made me hungry to learn. I hope I can do this to my students;" "Although I only had the opportunity to attend two some of the sessions, I feel that it will have a lasting effect on my teaching;" "Excellent! Your presentation was excellent and succeeded where others have failed. You made me think;" “Workshops were fabulous. Informative, clearly presented, lots of references to sources;" "I feel that every teacher and student should be in-serviced on this brain information;" It was so different, different than anything I've ever experienced in any kind of workshop." These responses provided insight into the skewed quantitative data that was presented in Table 2. While the numerical data did not suggest that any changes in the teacher's knowledge base had occurred, their elaborated responses indicated that they gleaned new information, usable ideas, and provocative connections to their teaching as a direct result of the research they heard presented and discussed during the workshop series.

At that juncture, I became uncertain as to whether or not any teachers would be willing to continue the project with me and become the study subjects as their active participation would increase significantly for the duration of the project. I reflected that

> If they aren't interested or I haven't provided them with the right information or motivation, I will lose the subjects for my study. This is a real exercise in my servant leadership because if I can provide the teachers with whatever they need to carry out this task, they will eventually continue to develop the strategies on their own. If I can't provide the right support, however, I will be back to the drawing board and out of time. (Sanders, Leadership Journal, March 1, 2010).

It was through the focus group and individual post-workshop interviews that my fears were allayed, and I knew that I am, indeed, a servant leader with the potential to move the teachers

Table 2. Post-Brain Research Workshop Survey Responses
N = 14

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Item 1: Brain research should inform teaching practice.					
N	8	6	0	0	0
Percentage	57 %	42 %	0 %	0 %	0 %
Item 2: Knowing parts of the brain that control specific learning functions impacts teaching practice.					
N	2	6	4	2	0
Percentage	14 %	43 %	29 %	14 %	0 %
Item 3: Knowledge of neural networks, synaptic connections, working memory capacity, etc. will improve my teaching.					
N	7	6	0	0	Missing: 1
Percentage	50 %	42 %	0 %	0%	7 %
Item 4: This workshop has connected brain research to my teaching practice.					
N	6	8	0	0	0
Percentage	42 %	57 %	0 %	0 %	0 %
Item 5: My previous teaching experience has been influenced by neuromyths.					
N	4	5	5	0	0
Percentage	29 %	36 %	36 %	0 %	0 %
Item 6: My future teaching practice will be influenced by brain research regarding neurofact not neuromyth.					
N	4	9	1	0	0
Percentage	29 %	64 %	7 %	0 %	0 %
Item 7: I learned strategies to increase student attention.					
N	5	8	1	0	0
Percentage	35 %	57 %	7 %	0 %	0 %
Item 8: I learned strategies to decrease emotional resistance to learning among students.					
N	1	9	4	0	0
Percentage	7 %	64 %	29 %	0 %	0 %
Item 9: Pursuing study of brain based strategies will enhance my teaching practice.					
N	8	6	0	0	0
Percentage	57 %	43 %	0 %	0 %	0 %
Item 10: Connecting brain research to teaching strategies should be part of mandatory professional development.					
N	9	5	0	0	0
Percentage	64 %	36 %	0 %	0 %	0 %

(Adapted from Patten, 2001, p. 85)

forward and affect some degree of change. One focus group member confidently expressed that the knowledge we gained as a result of implementing research-based strategies would become "part of our best practice in this building because of what we know." Another colleague commented that "this would be great workshop for one of our in-service days." During the course of the workshop series, from February 3 – March 3, 2010, teachers who were unable to attend approached me at various times with not only polite inquiries about our progress, but added comments such as, "I've heard it's really great and everyone is talking about it," and, "We've been discussing your workshop in our team meetings and have even put you in our monthly report to the principal." On another occasion, I happened upon two teacher-participants in the hallway as they discussed the topic of working memory and how they wanted to utilize the research-based training exercises to try to build working memory capacity and learning capacity in their students. A newer member of the faculty who attended the first workshop series in February, 2010 told me that if she had seen this workshop listed in our district's flex option program for professional development, a program in which any member of the professional staff may conduct a six hour workshop on an approved, appropriate topic which is offered to the entire district, she may not have chosen it. "However," she added, "it was here in the building, *it was you*, and it was so very interesting…It made me want to look more into it myself which is something I wouldn't have done before." Renewed and re-energized, these reactions shut down my second guessing and pushed me forward.

While comments such as these inflated the ego and implied that the workshop was a life-changing experience, other colleagues expressed their positive reaction with more reserve. When the focus group members were asked if they thought their teaching practice had been impacted by the workshop, an experienced special education teacher who had attended all the sessions replied, “I think not yet, but I think I want it to.” Another shared the same sentiment with her response, “I think it will.” A concern raised by a well respected math teacher who has a Ph.D. in communications and a teaching tenure equal to mine, cut right to the issue of validation and identifying observable behavior. He stated, “I don’t know how you’re going to validate it unless we come up with a way, something observable that you can report on…How do we know we’re actually releasing neurotransmitters?...Do we have a baseline?” Fortunately for me, this experienced teacher did not accept my weak explanation of using backward logic, using observation student behavior to infer that neural connections were being made in a coordinated, optimal fashion, as a replacement practice for obtaining real baseline data from which to continue the study.

Focus group and individual interview results. After organizing the raw data obtained from those teachers who voluntarily participated in a post-workshop focus group and individual semi-structured interviews, I began to mine the data for its patterns and its meaning (Appendices C and D). Bogdan and Biklan (2007) describe a qualitative research interview as a purposeful conversation, the dialogue of this action research story. My interviews were designed using a semi-structured, open-ended format that allowed me and my interviewees’ latitude and plenty of conversation “space” in which to respond to each other. I listened to and looked for patterns among all the responses, such as the use of similar terminology, the description of similar experiences, or the connections some teachers made between their current practice and the new information they were processing, and identified those emerging categories as they were repeated among the teachers. I approached the information obtained from the focus group in the same way and looked for its patterns among the threads of conversation, opinion, and insights offered by my colleagues.

In order to make a voluminous amount of raw data manageable and readable, Anfara, Brown, and Mangione (2002) suggest the construction of a code matrix or map. Read from the bottom up, the map guides the reader from the initial codes imposed on the raw data, to the more refined categories, to the themes which tie directly back into the project's heart, the research questions. Therefore, the matrix that is included is partially constructed as it is a data map that relates to the first research question only. It is Anfara, Brown, and Mangione's contention that this process adds a necessary layer of rigor and transparency to the analysis of qualitative data that must be present in all serious research (2002). Table 3 is a partial code map that presents data from multiple sources in an inductive format, from general information to a brief analytical, interpretive summary at the top of the matrix.

The emergent concepts identified in the data's first iteration listed in Table 3 represent topics, statements, or concepts stated at least twice by the teacher participants during the post-workshop focus group or individually conducted interviews. For example, the following emergent concepts appeared repeatedly in the teachers' comments: "provided topical focus," "need to delve deeper," "discovered new information," "stimulating/provocative," "want more information" (Focus group comments, 3/16/10; Individual interviews, 4/10). Those ideas were synthesized and merged into the categories identified in the second iteration and labeled as new information and deeper topic development categories. These categories enabled me to identify the stated professional development needs of the participants during our professional learning community/focus group meetings that began during Cycle II. The teachers' expressed need for not only more information but deeper topic development guided my planning for these sessions. The synthesized data iterations resulted in the following interpretative theme for Cycle I.

Table 3. Partial Code Map for Research Question #1.

RQ #1	
Did the middle school teachers at Sandersville Middle School gain usable knowledge connecting empirical brain research to teaching practice? If so, what was the extent of their change in knowledge?	
3rd Iteration: Thematic Interpretation	
Teachers are receptive to new, "out of their comfort zone" information, especially when it can be connected to their classroom experiences. Surface discussions are not acceptable to satisfy their intellectual curiosity; they want to go deeper into topic development and rarely have the chance to do so. Baseline information is readily available to assist in the assessment of their success building both working memory capacity and learning capacity in general using strategies such as the *n*-back task and relaxation techniques.	
2nd Iteration: Categories	
1A. Measurable baselines	1D. Working memory capacity expansion
1B. New information	1E. Relaxation/Meditation
1C. Deeper topic development	
1st Iteration: Emergent Concepts	
1A. Not a leap of faith	1G. Want more info (emotion/stress)
1B. Provided topical focus	1H. Can expand working memory capacity
1C. Need to delve deeper	1I. *n*-back tasks
1D. Discovered new information	1J. Increasing attention
1E. Self-motivated	1K. Relaxation/meditation
1F. Stimulating/provocative	1L. Want measurable baselines

Adapted from Anfara, Brown, & Mangione, 2002

> Teachers are receptive to new, "out of their comfort zone" information, especially when It can be connected to their classroom experiences. Surface discussions are not acceptable to satisfy their intellectual curiosity; they want to go deeper into topic development and rarely have the chance to do so (Partial Code Map for Brain-Based Teaching Data, 4/10).

As a cognitive tool, the code map enabled me to systematically organize the raw data, with each iteration bringing me closer to a cohesive grasp of its meaning. Including not only new brain research topics but delving deeper into topics already included in the workshop became a clear mandate from the respondents.

Cycle II (March – mid-May, 2010)

Cycle II included additional introductory research and initial actions in the story of this project as can be seen in Figure 3. The teachers who participated in the workshop series were invited to become members of a select professional learning community (PLC) which met four times during this cycle, approximately bi-weekly, to extend the professional development phase of the study and to continuously assess the brain-based strategy implementation phase.

The PLC functioned as a data source, as their interactions with each other, with me, and with their students determined the ebb and flow of all research actions. The observation protocol involved writing field notes as the teachers were engaged in PLC activities, such as discussing empirical brain research or appropriate brain-based teaching strategies or brainstorming barriers to strategy implementation that they encountered with their students (Creswell, 2009). In this way, a research dimension was added to the professional learning community's mission of creating a culture of collaboration with a focus on results to ensure that students learn (DuFour, 2004).

Data analysis. Data gathering began with the teachers obtaining quantitative baseline data on working memory from their selected students, which was an area of particular interest and in-depth discussion during the workshop session devoted to the topic of attention. I engaged in an unplanned on-line chat with a noted neuroscientist whose research specialty was working memory and attention as part of my membership in the Learning and the Brain Society and also conducted bi-weekly professional learning community meetings in which the teachers participated. Field observations were conducted during and after the implementation of teacher selected strategies in several classes.

Baseline data. The teacher participants administered the number memory forward and number memory reversed subtests of the *Test of Auditory Processing Skills – 3* to selected students to obtain baseline measures of each student's working memory. The students listened to increasingly longer strings of randomized numbers from zero to nine and repeated them back to the examiner exactly. They repeated the first number set in the forward order and the second set was repeated in reverse order. Performance on these tasks is an accepted measure of working memory ability in both the scientific and education communities and is supported by the research presented during the brain research workshop (Jaeggie, Buschkuehl, Jonides, & Perrig, 2008; Jonides, 2010; Klingberg, 2009; Sternberg, 2008). Standard scores were derived from the raw scores and one mean standard score was derived to represent the entire group of students. The results are depicted in Table 4.

Table 4. Baseline Working Memory Mean Scores
N=11. The number memory forward and number memory reversed mean scaled scores were used to derive the overall group working memory mean score.

Subtests	Mean Scaled Scores
Number Memory Forward, Pre-Strategies	6
Number Memory Reversed, Pre-Strategies	6
Group Working Memory Score	6

These results may be interpreted to mean that as a group, the students' mean working memory scaled score was in the low range of ability. On this measure, a scaled score of ten plus or minus three indicated performance in the average range.

The teachers were instructed to select three to five students in any of their classes about whom they would collect data related to brain-based teaching strategy implementation, although the strategies were carried out with the teachers' entire class. It was made clear that these students did not have to be classified for special education in order to be the focus of the strategy implementation, that the teachers could select students who were achieving at or above academic expectations. It was not surprising, however, that the special education teachers selected classified students to observe and the general education teachers selected non-classified students about whom to make observations and collect data. The teachers also selected challenging students, both academically and behaviorally; students who could not or would not respond to the teachers' efforts to enhance their learning and/or behavior outcomes. The teachers provided a bulleted list of the reasons why they selected each student based on their own observations, the students' learning profiles, their attention issues, and similar characteristics. Figure 6 is a word cloud depicting the words and phrases used the most often by the teachers to describe their selected students. A word cloud is a graphic representation of text in which the most frequently appearing words are given greater prominence in the arrangement than the other words (McNaught & Lam, 2010). The words displayed most prominently in the word cloud added a layer of meaning to the numerical baseline data that was also gathered from the same students. They portrayed low achieving students (from the baseline data) who struggled with comprehension and attention, who were distracted and unmotivated, who daydreamed and could not follow directions, and who became angry, explosive, and shut down (from the teachers' observations and behavioral descriptions). Combining both quantitative and qualitative datasets resulted in more complete student profiles than could have been interpreted from either dataset alone.

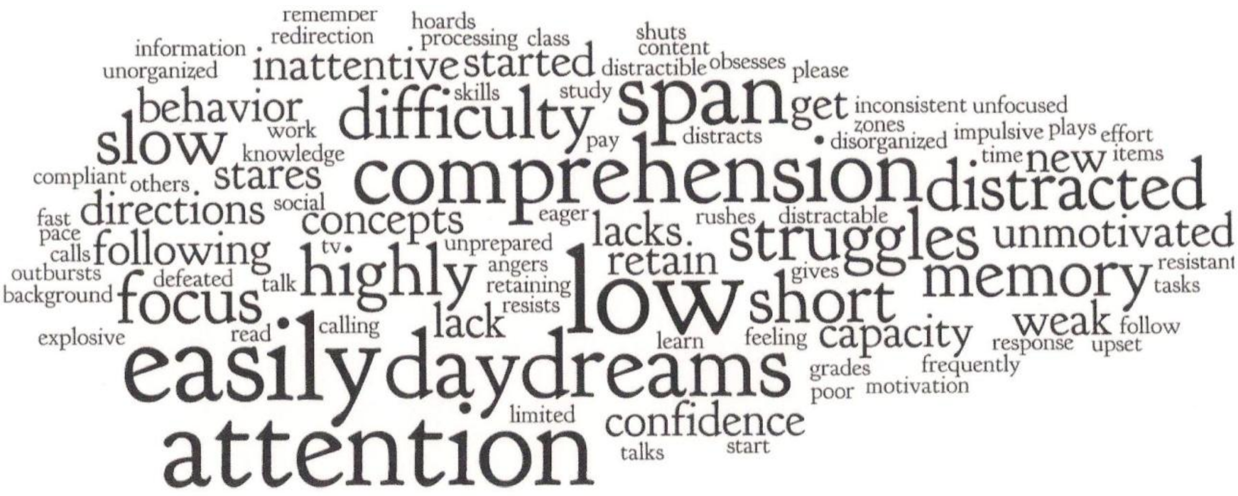

Figure 6. Pre-Strategy Implementation Word Cloud
This word cloud graphically depicts the teachers' descriptions of students who they selected to observed as they began implementing research based brain strategies during Cycle II.

On-line web chat. As a member of the Learning and the Brain Society, I participated in a monthly on-line web chat on March 23, 2010, which coincidentally featured Dr. John Jonides, a neuroscientist whose seminal work in the area of working memory and attention had been discussed during the workshop. Having received a transcript of the chat from the society, I coded it as raw data (see Appendix E for the abridged transcript), however, the richness of Dr. Jonides' dialogue resonated deeply with the tenets of qualitative research, causing me to choose his words over my sterile, decontextualized codes. Not only was this the first professional on-line chat in which I had ever participated, I, along with the moderator, was the only other person talking with Dr. Jonides, so our conversation was tailored to the discussion I had recently had with my teacher participants. I directed our specific questions and concerns to him and was rewarded with invaluable information around which we designed several learning/training strategies for our students.

Dr. Jonides and his research group at the University of Michigan have determined that working memory capacity, the functional behavior of the brain that enables us to hold information in mind while we manipulate it, to solve problems and to think, can be expanded through training (2008). Prior to this seminal research, some neuroscientists believed that the working memory capacity an individual was born with was unchangeable over the life span. The implications of this research for educators are highly significant because it means that when the right strategies are developed, teachers will be able to literally teach their students how to think and potentially increase their intelligence.

In response to my direct question about whether middle school classroom teachers could expand working memory capacity in their students using their course content as stimuli, Dr. Jonides responded,

> Yes, indeed, I think it is. We now know that there are training techniques that allow people to improve their working memory in a way that transfers from one working memory task to another…Right now, we are concentrating only on the *n*-back task because we know that it works…One nice feature of the *n*-back is that it is available online so that the trainers don't have to re-invent the wheel with the task…Our research has shown so far that the content of the *n*-back is largely irrelevant to the training effect. So, most any material should work; or at least that's what I think right now. (Jonides, On-line Web Chat, March 23, 2010).

As our conversation continued, I inquired whether appropriate baseline data could be obtained using a specific testing technique known as number memory forward and reversed, an assessment I use routinely during speech/language evaluations and school psychologists use to measure working memory as a function of learning. Dr. Jonides was supportive of my idea.

> Digits forward and backward are a very standard way of assessing baseline performance. Good idea…Well, there is certainly no harm in using digit span as a measure of capacity to establish a baseline and to see whether that baseline performance can be changed via training (Jonides, On-line Web Chat, March 23, 3010).

The importance of this discussion about working memory capacity relates to a researcher's or a teacher's ability to strengthen students' attention. Dr. Jonides' expressed this interpretation of his research findings.

> Indeed, I think that one of the things that working memory training accomplishes is focusing attention on a single task for a length of time, thereby decreasing distractibility. As you get better at it, you are able to focus for longer periods of time…we can now demonstrate what happens in the brain as a function of working memory training. We haven't published this result yet, but our data suggest that what happens is that the circuitry that is responsible for working memory decreases in activity with more training. So, this then frees up this circuitry to work on other aspects of problem solving. Essentially, you get better at the memory part of thinking, freeing up those parts of the brain to devote to other parts of the thinking process (Jonides, On-line Web Chat, March 23, 2010).

Dr. Jonides described working memory as a significant component of fluid intelligence, which is the ability to think and solve novel problems beyond the mere retrieval of stored information. "According to various studies, the correlation between working memory capacity and fluid intelligence is about .50, which is very sizable (Jonides, On-line Web Chat, March 23, 2010). This relationship is tremendously important to education for two reasons. The first reason is that through training, working memory can be expanded. The second reason is a logical extension of the first and poses this critical question: If working memory capacity can be expanded, can intelligence be increased as well? According to Dr. Jonides, "…many think that intelligence is native to us and that it is unteachable. This, as it turns out, is simply dead wrong. We are learning more and more that the ability to think productively and act intelligently is eminently teachable" (Jonides, On-line Web Chat, March 23, 2010).

The effects of this serendipitous on-line chat had an immediate impact on the project. Our baseline measure selection and design of tasks similar to the *n*-back task were supported by one of the pre-eminent researchers of working memory in the field. The timing of this web chat subsequent to the brain research workshop series, yet prior to the teachers' immersion in implementing the brain-based strategies was fortuitous. It provided all the study participants with a sense of validation of our previous workshop discussions that could only come from having a renowned expert in the field of working memory corroborate our interpretation of the research. Dr. Jonides offered proof that working memory capacity can be expanded in the laboratory and the possibility that it could be taught in the classroom as well. He provided a depth of discussion about working memory, working memory capacity, expanding that capacity and its relationship to intelligence that the teachers sought as a result of our workshop interactions. It also brought an external energy to the group effort that elevated our thoughts of the possible to that of the probable, under the right conditions. The remainder of the action research project would determine if we had created the conditions in our classrooms to increase working memory capacity and directly impact student attention. This was an essential finding of this study. In this experience, teachers comprehended empirical brain research and interpreted it through their design of research based teaching strategies.

Field observations. I conducted two field observations toward the end of Cycle II that occurred in a sixth grade special education resource room and self-contained class. At the PLC meeting on April 20th, I asked for volunteers to participate in field observations that would allow me to observe the teachers implementing the selected brain strategies with their students. While all the teachers volunteered, only two were able to be scheduled at that time due to scheduling conflicts. I was present for the full 54 minute class periods but collected data for 25 minutes which was the amount of time it took the teachers to conduct the strategy implementation and to note student reactions and behavior extending beyond the implementation period. At the times of the observations, each of the classes was arranged in traditional rows of five to seven desks deep and five rows across the front of the room, although this was not always the desk configuration. The teachers circulated around their rooms frequently, especially as the lessons moved to student centered assignments. As I was assigned to deliver speech/language services to these classes, my presence for observation and data collection purposes was neither noteworthy nor intrusive.

Having discussed which strategies might be the most effective with their students with each other from the start of Cycle II, both teachers used the same adaptation of the *n*-back task and were comfortable doing so based on Dr. Jonides' discussion with me. They each selected target vocabulary from their content areas, one chose vocabulary from the novel the class was reading and the other chose vocabulary from the social studies chapter under discussion. Each vocabulary word was represented by a labeled picture and followed the following procedure. Each teacher displayed one picture at a time, named the vocabulary word, and went on to the next picture, displaying each picture for about three seconds, according to Jonides' suggestion (On-line Web Chat, March 23, 2010). The pictures were re-ordered periodically and were shown repeatedly in these sequences. In a randomized order, the teacher would follow that procedure and then ask the students, “What was one picture back from this one?” or “What was two pictures back from this one?” The students wrote down their responses. This continued until the students had written down ten responses. The next part of this working memory task involved both teachers then switching to a number series, starting with two sets of a two number series, then two sets of a three number series, followed by two sets of a four number series until the students made the requisite number of errors. Without asking for any repetitions, which was not allowed, the students wrote the number series down. The teachers quickly discovered that the students could cheat by writing the numbers down in a backward order but using a number forward strategy. Some students wrote them in forward order from right to left on their papers instead of from left to right, starting with the last number they heard spoken and proceeding backward through the number series. Using this strategy, the numbers appeared to be in reverse order, but were written forwards. The teachers subsequently became more vigilant and the students more compliant, although they did not realize that they were cheating in the first place, according to them. In both activities, the students were required to hold either the vocabulary words or numbers in mind, manipulate that information, and formulate a written response. According to the Jaeggi, Buschkul, Jonides, and Perrig (2008) study, a 1-back task trained subjects, but expanding working memory capacity began with 2-back tasks, 3-back tasks, 4-back tasks, and so on. A comparison of these observations is depicted in Figure 7.

The students in the self-contained social studies class struggled more with the tasks than did the students in the resource room setting. They required more time to begin class due to the need for constant redirection; there was constant background noise caused by their extraneous movements; they could not remember the directions and requested repetitions which they could not have; they slowed down the teacher's pacing which lengthened the activity, delaying the start of class; and, they did not demonstrate any increased focus of attention or calmness when class began. The resource room students took a shorter amount of time to begin the activities; they were quiet; they did not ask for repetitions; they kept up with the teacher's pace; and, they did not over react to the announcement of the digits reversed task as the other group regularly did.

The resource room teacher asked her students for feedback when the tasks were completed as part of her personal assessment of the strategies' effectiveness. "It was fun." "It was hard, but I liked it." "I couldn't pay attention." One student responded that he "was bored," a typical response from him regarding most all learning activities. When asked why the memory task was difficult, he replied, "I couldn't focus." Another student offered that a faster presentation of the picture stimuli would "be harder to remember." This same teacher commented to me that she had observed several students using their own strategies to remember the sequence of pictures. One student moved his lips as he spontaneously employed mental verbal rehearsal, another was also observed to mouth the words as she counted on her fingers to remember the picture series, and a third student closed her eyes and said that she "saw the words in my mind." Another student volunteered that he closed his eyes and pictured the numbers to "see the image." During another field observation on 5/10/2010, this class was observed to be quiet with no calling out during the minutes after the *n*-back task had been completed. Ten minutes after the strategy completion, some random movement from students was noted and some random calling out began. Thirteen minutes after the strategy was finished, the typical amount of ambient noise and conversation among the usual students was observed. As the teacher participants had agreed that they were looking for a recoup of 10 minutes instructional time after investing up to 10 minutes in implementing a strategy, this teacher stated that she felt "today was a real success and I hope to build on it as we go forward."

	Resource Room	**Self-Contained**
Similarities	• Classroom arrangement: traditional rows • *N*-back task variations • Directions to students	
Differences	• Students were quiet and focused with no extraneous movement or side conversations	• Students were talkative, required constant redirection, delaying the start of class • Steady, low level background movement noise as students shuffle papers and squirm
	• Students did not ask for repetition of target vocabulary words during *n*-back task	• Students immediately asked for repetition of target vocabulary words for *n*-back task
	• Students progress with teacher's pacing	• Students slow teacher's pacing and lengthen time required for this activity
	• Students did not react to teacher's introduction to digits reversed task	• Students reacted loudly to teacher's introduction to digits reversed task as if they had never heard it before, which they had
	• Students maintained quiet attention for 13 minutes after *n*-back and digits forward and reversed strategies were completed	• Students resumed loud talking, standing, and moving around classroom when brain strategies were completed
	• Strategy took 10 minutes	• Strategy took 15 minutes

Figure 7. Field Observation Comparisons

Professional learning community. The initial PLC meetings were planned to accomplish two distinct purposes: first, to delve more deeply into the brain research workshop topics already discussed and present new topics, such as mirror neurons; and, second, to move the study forward by engaging the teachers in strategy selection and implementation. The teachers participated in a brainstorming session during the first meeting to collectively decide what baseline data and teaching strategies were appropriate for our purposes. Among their consideration for baseline data were an attitude survey, backward digit spans, and bulleted lists describing their selected students. Of the possibilities, forward and reversed digit spans as measures of working memory and bulleted descriptive lists were selected by the group as has been previously presented in this chapter. Subsequent meetings were organized around the topics of research, strategies, and findings, and are summarized in Table 5.

As the teachers' strategy implementation progressed, their concerns about their strategy choices, the logistics involved in implementation, and the lack of imposed structure inherent in the project emerged with each PLC meeting, as can be seen in Table 5. The teachers' comments cluster around two areas of concern: too much freedom to make strategy choices, and the amount of time required to execute the strategies and tally observations of student learning behavior. Despite the knowledge they had gained during the workshop and PLC meetings, this group of teachers expressed a lack of confidence in their ability to implement that knowledge as represented by their struggle to choose strategies. "We teach in a structured way, we need to use a structured approach to using these strategies." "Tell us what to do" was echoed by each individual participant at the May 14, 2010 PLC meeting. "Ten minutes to do the *n*-back task makes a huge difference – it takes too much class time," "taking tallies is useful but not feasible; have someone else tally while you implement the strategy." The concerns did not stem from the

Table 5. PLC Meetings Summary for Cycle II

3/18/2010	4/07/2010	4/20/2010	5/14/2010
Brainstorming Baselines: Attitude survey; Backward digit span; Student descriptions			
Research: None discussed due to brainstorming	Research: Connecting emotions with other body systems; Freeze-Frame process for controlling anger; Article: brain based products	Research: Reviewed Jonides web chat; Mirror neurons	Research: Reviewed materials and information from the Learning and the Brain Conference I attended on 5/4-6 in Washington, D.C.
Strategies: Analogies: *n*-back tasks; Memory tasks; "If…then: statements; Relaxation/meditation; Teach students how their brain works	Strategies: www.sharpbrains.com; www.cognitivefun.com; Design tally sheet to track behavior for 10 min. after strategy implementation	Strategies: *n*-back materials; 4 step directions from Jonides web chat; Relaxation/meditation; 10 min. observation of student behavior after strategies	Strategies: No strategy discussion due to the teachers concern re: the project and time investment
Feedback/Findings: None at this time	Feedback/Findings: Time required to tally observed student behavior is excessive and will hopefully become more streamlined and faster to implement	Feedback/Findings: 15 min. *n*-back training time is too long during class; Research saying "don't make learning a competition" isn't always a problem; Some students are resistant to strategies but majority are enthusiastic and cooperative	Feedback/Findings: Having teachers pick their own strategies was "totally unstructured," "tell me what to do," "we teach in a structured way," "I wasn't comfortable doing it that way," "10 min. to do *n*-back task takes too much class time"

research that demonstrated that working memory/attention could be expanded, but from the teachers' implementation of the *n*-back strategy design as they implemented it with younger, learning disabled students who were not similar to the college student group on whom the seminal research was performed. The PLC concerns turned into discussions of the possibility of changing the strategy designs for the *n*-back they were using to ones that were more suited to their time constraints and population. One teacher said, “I would love to re-work this design and tailor it to my specific class of students, start at the beginning of the year, and do an *n*-back type task everyday for the entire year and see what changes in learning behavior I observe.” Another responded, “If expanding working memory really does increase intelligence and problem solving ability, I want to apply that theory to teach my students how to learn. If they can do that, then they can learn anything.” “I love the idea of expanding working memory, but I’m afraid I’m not implementing the strategy correctly and I can’t afford to waste valuable class time.” The second outcome of this PLC meeting was to end Cycle II in which the teachers were encouraged to select their own strategies and materials and to begin Cycle III in which I responded to their requests to provide them with structure and gave them a daily schedule of strategies to implement.

Cycle II illuminated an interesting, albeit surprising insight. Every teacher in this tenured, experienced group was reluctant to select and implement strategies independent of the other group members and to create their own structure in their classes. They floundered without structure, without being told what to do, for how long, and with what materials. It was partly an issue of time invested in an unknown outcome and partly an issue of fear, the fear of failure or making poor choices or implementing the strategies incorrectly, by the teachers own admission.

Cycle III (mid-May – mid-June, 2010)

The schedule of strategies that I organized for the teachers rotated through a typical five day school week with increasingly difficult strategies highlighted each day to provide the students with different challenges to develop their working memories. A sample strategy schedule is found in Appendix F. The activities repeated in the same Monday to Friday sequence throughout this brief cycle. Percentages were derived from the raw scores obtained by the teachers from their selected students and represented a range of correct responses as the students attempted to engage in each of the five different working memory activities over the course of a week. Table 6 represents the average percentage achieved by all the selected students for whom data was submitted. These results indicated that although the activities increased in difficulty as the week progressed, the students' demonstrated the most difficulty with the auditory word span repetition strategy on Wednesdays which was the only activity that used word stimuli instead of numbers. During the focus group at the end of Cycle III, the teachers' collectively expressed the reaction that the auditory serial addition span was the most difficult. When asked if they observed any improvement with that task over time, the group consensus was that there was not any noticeable increase in student scores because there was not enough time before the school year ended or that due to other academic and social requirements, they "didn't do it enough" to know if the students would become more successful given more time

Table 6. Results of Strategy Implementation for Cycle III.
The number of correct student responses to teacher directed strategy implementation are represented in percentages.

Monday	Tuesday	Wednesday	Thursday	Friday
Auditory Digit Span Forward	Auditory Digit Span Backward	Auditory Word Span Repetition	Auditory Serial Addition Span	Single *n*-Back Task: Numbers
69.3%	75.2%	36.1%	52.9%	80%

On June 16, 2010, I conducted a focus group with the teachers to review the project and to strategize together for the 2010-2011 school year when they would implement strategies with a new group of students. The questions posed to the group are found in Appendix G. I coded the teachers' responses to search for patterns of duplicated words and phrases from which a thematic interpretation of Cycles II and III would emerge. The results are shown in Table 7.

The teachers were definite in describing themselves as teachers first and teachers of a content area second. The connection to this study was that the teachers' primary focus was to teach students how to learn and then how to apply those skills to learning a variety content. It was interesting to note that a general education teacher observed that in her opinion, all teachers should have a more general knowledge of children and how they learn instead of the state mandated curriculum specialization to enhance student achievement. Despite their claim not to be tied to their individual curricula, they were very critical of the amount of time it took to implement the relaxation and brain-based strategies with their students. This criticism also stemmed from the short period of time in which the strategies were implemented making the occurrence of positive student behavior and achievement outcomes unrealistic.

Given enough weeks or months in which to invest the time, changes in student learning behavior may have been more possible. It should be recalled from several field observations that I conducted in May, 2010, that the students were quiet and engaged during the *n*-back task. It took ten to 13 minutes before this normally noisy, talkative, distractible group began to move around and randomly call out from their seats. This met the teachers' expectations of recouping a minimum of ten minutes instructional time after investing ten minutes in strategy implementation, suggesting that this gain in instructional time could be met or exceeded if the students had more time to practice the brain-based strategies over a more extended time period. At the end of this Cycle III, the participants obtained baseline data using the same number memory forward and reversed tasks that were administered during Cycle II. Scaled scores were derived from the raw scores and one mean scaled score was derived to represent the entire group

Table 7. Code Map for Cycles II and III Focus Group

Research Questions			
RQ #1: Did the middle school teachers at SMS gain usable knowledge connecting empirical brain research to teaching practice?	**RQ #2:** Did brain-based "usable knowledge" change middle school teachers' teaching practice?	**RQ #3:** What was the teachers' perception of changes in student achievement at the conclusion of this study?	**RQ #4:** Did teachers observe changes in students' attention related to brain-based teaching strategies?

3rd Iteration: Thematic Interpretation

The teachers, both general and special education, were unanimous in their view that individual student achievement is more important than being tied to the curriculum. While the state requires that teachers have content specialization, teachers state that they need knowledge of the whole child if students are to achieve maximally in any content area. The participants were definite in their view that the strategy implementation took too much class time with no observable changes in behavior, focus, or attention to date. They also felt that they had not utilized the strategies for a long enough time period to expect to see any changes in student attention or achievement. Several admitted that their strategy implementation was sporadic and not as consistently carried out as was discussed. The relaxation strategy was identified as the most classroom friendly strategy. It was suggested that the student advisory period or an exploratory cycle might be a better time to execute the strategies and track student outcomes.

2nd Iteration: Categories

1A. Teachers need general knowledge of students
2A. Student achievement is most important
2B. Strategies took too much class time
2C. Relaxation strategy
2D. Advisory/Exploratory periods
2E. Sporadic strategy implementation
3A. No observable change in behavior yet
3B. Students requested feedback re: performance with strategies
4A. No observable change in attention

1st Iteration: Emerging Concepts

1. Teacher first, content specialist secondarily
2. Cross curricula when necessary
3. Have flexibility to adjust curriculum when necessary
4. Teaching curriculum exactly leads to superficial teaching
5. High stakes testing ties teachers to curricula
6. Flexibility comes from pacing
7. Pacing suffers if tied to curriculum
8. Can address student weaknesses if not tied to curriculum
9. Can be tied to both curricula and student achievement
10. Student achievement more important than curriculum
11. Teachers need general knowledge of whole child; state requires content specialization
12. Teachers must step beyond content area to help students form connections with other areas
13. Program took too much time
14. Relaxation strategy is great
15. Didn't do strategies long enough to see changes; sporadic delivery
16. Strategies are good for advisory period
17. Part of daily routine next year
18. Some new strategies difficult
19. Student reminders to do activities; want feedback
20. No changes in behavior; better focus

Adapted from Anfara, Brown, and Mangione, 200

Table 8. Baseline Working Memory Mean Scores
The number memory forward and number memory reversed mean scaled scores were used to derive the overall working memory mean score which represented the student group where N=7.

Subtests	Mean Scaled Scores
Number Memory Forward, Pre-Strategies	9.5
Number Memory Reversed, Pre-Strategies	8
Working Memory Mean Score	8.7

of students. The results depicted in Table 8 are interpreted to mean that as a group, the students' mean working memory scaled score improved to the average range of ability. Although this improved scaled score suggested that the teacher selected student group experienced a notable improvement in working memory resulting from the brain-based strategy implementation, it is critical to note that this result may not be valid for three reasons. The first reason is the short time frame the teachers had to implement the revised strategy schedule; the second is the unequal number of strategy sessions executed among the teachers; and, third, fewer students were re-tested at the end of Cycle III than were re-tested at the end of Cycle II. While inconclusive due to the small and variable Ns from pre-baseline to post-baseline testing, these results implied a positive trend in improved working memory among the teacher's students.

During Cycle III, the teachers included descriptions of student behavior as part of their post-strategy implementation baseline data collection. A second word cloud was generated from these descriptions to get a sense of the teachers' subjective reactions to changes in student learning behavior at the end of this cycle based on the visual frequency word count displayed in Figure 8. These post-strategy descriptors suggested that behavioral changes were observed by the teachers given their use of words such as "calm," focused," "paying attention," along with words such as "off-task," "frustrated," and "squirmy."

Figure 8. Post-Strategy Implementation Word Cloud
This word cloud is an imaged word frequency count of the descriptors used by teacher participants to describe student behavior at the end of Cycle III.

Cycle IV (September, 2010 – November, 2010)

Cycle IV was to begin the first day of school with the teachers, now knowledgeable about brain-based strategies, incorporating the strategies into their daily teaching agenda with a new group of students. Excitement about our anticipated outcomes ran high until a dose of reality dissipated our enthusiasm. Four seemingly isolated yet related situations occurred that were beyond our immediate control, yet impacted our efforts directly and were viewed as a perfect storm as depicted in Figure 9. First, Sandersville Middle School did not meet its annual yearly progress for the 2009-2010 school year, designating it as a failing school. Second, the sixth grade self-contained humanities (social studies) classes were eliminated and those students were enrolled in inclusion classes of 28-30 students with two teachers. Third, a general increase in classified sixth graders with a specific increase in the number of students on the autistic spectrum overtaxed our limited resources, especially the manpower necessary to create classes that were compliant with the New Jersey Special Education Code in terms of adult to student ratios. Fourth, the district instituted a comprehensive new math program that challenged the most seasoned veteran teachers and demanded a significant investment of time, practice, and in-servicing to learn. The overall impact of these four situations on the project was twofold: it reduced the number of teacher participants who began the study from nine teachers to six teachers, and two of those participants were unable to participate fully. It must also be noted that one of the teachers who no longer participated in the study was on a maternity leave beginning in September, 2010.

Professional learning community. The format of these PLC meetings was the same as those initiated during Cycle II. New research was introduced for discussion purposes, strategies were reviewed and analyzed, and the participants shared feedback, findings, and concerns with the group. The teachers continued to seek new and more in-depth discussion about the research topics that had been introduced during the workshop. They began to relate the research to their new students and were able to discuss their observations and pose questions about their learning in terms of working memory, attention types, fixed and growth mindsets, intelligence theories, and the emotional factors that inhibit or enhance students' learning. As a group, the teachers continued to develop their interest in working memory and the recent research that has appeared in the literature regarding its impact on learning, thinking, and problem solving. I continued to take field notes and add reflections to my research journal. Carol Dweck's (2006) motivation research, which was undertaken with a middle school population, was also a focus of our discussions throughout Cycles IV and V as the teachers attempted to adapt it to their students.

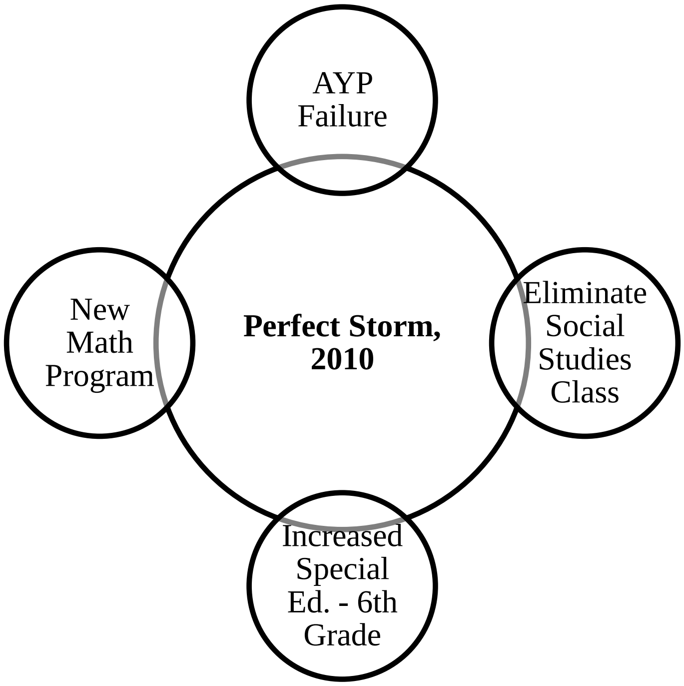

Figure 9. Sandersville Middle Schools' Perfect Storm

Implied in the research question related to decreasing emotional resistance to learning was the notion of increasing student motivation. Therefore, another research area that stimulated discussion, connections to students, and the development of a potential classroom strategy was the Brainology computer program, developed not only to teach students how their brains function, but also to teach them how to use their brains to increase their motivation for learning and to change their thinking from fixed mindsets to growth mindsets (Dweck, 2006). While the cost of purchasing student licenses was prohibitive and prevented the students from experiencing the computer program, the teacher lessons that accompanied the computer program were available on-line. A teacher's guide was provided for each of the four lessons included in the computer program from which we developed the four main topics in a series of student friendly sentences designed to elaborate the concepts being taught. Each topic was divided into five single explanatory statements mounted individually to be displayed in the classrooms and presented one day at a time across a full week for four weeks. The explanatory statements built on each other, but individually provided daily class discussions led by those teachers who were interested in including this strategy in their daily routine.

While all four teachers who incorporated these topics and related statements reported high student interest and productive discussions, the eighth grade special education math teacher who taught a small group of students with extremely low math skills was the most enthusiastic. She noticed that her students asked many questions during the class discussions of each brain topic, talked about their own learning experiences, and became more self-aware. One topic dealt with stress and anxiety. She was shocked when one student asked her to define anxiety as she assumed that "everyone knows what stress is." She explained that she described to the class how the body feels when experiencing stress or anxiety and helped her students make connections to their own previous fight, flight, or freeze experiences. "I watched these low level, self-contained students self-reflect. They were using high level analytical skills to evaluate themselves and were completely engaged in this discussion." The students themselves were able to identify characteristics of their learning strengths and weaknesses that they articulated to each other. Due to their difficulty with written expression, the teacher wrote down the students' comments during this discussion and included them as part of the group reflection. "The brain quotes taught me that I need a quiet place to learn. It helped me to know about myself," stated one student. "The quotes made me think about myself. I have a hard time staying focused. I am trying to figure out how I learn. I know that I work best at the library," thought another student. "I really like the quotes…They help me understand why I have trouble in school. School is hard and I'm not really good at math. The quotes really teach me a lot of stuff," shared another. "The quotes taught me stuff I never knew like how my brain works and why I can't remember stuff. I learn differently," expressed a student who generally gave up when the work became challenging. The teacher also reported a "marked increase in student focus" when the discussions ended, and although time consuming, "the benefits are worth it."

The feedback portion of each PLC meeting became increasingly focused on teacher concerns related to their difficulty establishing baselines, implementing strategies, and tracking student responses. Every one of the teacher participants experienced some degree of lessened involvement in the project for reasons directly related to the four situations that defined Sandersville Middle School in September, 2010. Priorities had shifted as a result of our failing school status which increased the pressure on all teachers to analyze our failure, student by student, and to provide appropriate interventions across grade levels to increase student achievement by whatever means. More classified students with significant learning needs now sat in sixth grade inclusion classes than ever before in the history of the school, changing the complexion of general education and special education classes alike. The new math program was a drain on teachers' time and energy and increased the anxiety of a staff already stressed by our failing status. The various issues encountered during Cycle IV are depicted in Table 9.

Individual teacher interviews. In October, 2010, I scheduled individual interviews with four special education teachers and one general education teacher. This series of interviews was designed to take the pulse of the project and determine if any changes were necessary or possible at that juncture. The interview questions were structured to keep the notion of changing teaching practices uppermost in the teachers' minds as we discussed and analyzed the impact of our work on ourselves and our students. The interview questions are found in Appendix H. The results of

Table 9. PLC Meetings Summary for Cycle IV

September 17, 2010	November 9, 2010	November 23, 2010
Research: Importance of strengthening working memory (Gathercole, S.E. & Alloway, T.P., 2008)	Research: Gathercole, S.E. & Alloway, T.P. (2008) book and handout; Top-down, bottom-up leadership	Research:
Strategies: Teach how the brain works (Dweck); 10 minute rule (Medina); Intentional analogies; *n*-back task; Spelling content area vocabulary words backwards; Relaxation exercises; Students design their own graphic organizers	Strategies: What strategies, if any, are realistic to pursue? Brain facts (Dweck)	Strategies: More brain facts; What strategies are you using?
Feedback, Findings, Concerns: Strategies take too much time; Very low 6th graders in general and special education; Strategies causing oppositional behavior among some autistic students	Feedback, Findings, Concerns: Strategies take too much time; Low functioning students in all classes, all grade levels; Students need practice writing reflections; Top-down leadership not necessary for this project to succeed	Feedback, Findings, Concerns: Teachers expressed sense of lack of progress and concern for the project; Teachers agreed to continue project through second marking period; Students remind teachers to "do the brain stuff;" Students enjoy brain facts talks; "I learn differently," "The quotes teach me how my brain works," "Now I know that I need quiet to do my work."

these interviews echoed the feedback/findings/concerns portion of our PLC meetings.

While the teachers embraced the new ideas highlighted by the empirical brain research and actively reflected on them as they developed weekly lesson plans, they clung to the status quo's curricular demands and were reluctant to trade a time investment for potential student achievement gains even when they sensed that gains were possible if the strategies were implemented rigorously and routinely. This, however, was not a time for adventurous undertakings with uncertain outcomes for teachers buffeted by the winds of annual yearly progress failure, an increase of students with extremely special needs in the inclusion classes, and a new district math curriculum. The results of these interviews suggested that the teachers' thinking had been stimulated, new strategies had been attempted, and perhaps the time had not yet come for a complete revamping of teaching practices given Sandersville's climate. However, the seeds of teaching practice change had been planted and some had begun to take root, but they will require much more nourishment and nurturing to firmly take hold and yield an outcome of increased student achievement. The teachers' responses were coded, mapped, related to corresponding research questions, and presented in Table 10.

In responding to the interview questions, the teachers made an equivalent number of comments highlighting problem areas they encountered as they did observations of how they benefited from the experience. As I conducted the interviews, I heard more negatively skewed comments and did not expect to find the balanced expression of positive and negative views that I saw when I analyzed the interviews. The comments reflected the stress they felt resulting from the perfect storm that began in September, 2010; they questioned the trade-off between time and strategy implementation; they thought that these strategies did not belong in content area classes, but perhaps in advisory or exploratory settings; some couldn't be convinced to change their teaching practices, while others could.

The teachers were also asked to write a brief assessment of the study. In addition to their overall opinions, they were asked to comment on the project's impact on their teaching practices

Table 10. Code Map for Cycle IV Teacher Interviews

3rd Interation: Thematic Interpretation

The perfect storm that began the 2010-11 school year was characterized by failure to achieve annual yearly progress goals, a larger group of classified 6th graders with more students on the autistic spectrum than ever before, and a new math curriculum. In addition, the teachers identified other stressors impacting the study such as the time required to implement the strategies during class, the state test, larger inclusion classes with needier classifier students, more students in inclusion, and teaching multiple grade levels with the new math program. The exploratory cycle,, advisory, or intervention cycles were seen as better academic venues to implement the brain strategies than core classes. Despite these issues, the teachers were stimulated and changed their thinking about student learning. They added new strategies to their "toolbox of tricks" while eliminating strategies that they now viewed as being problematic and unsupportive of student learning, such as strategies that required students to multitask or put too much information into their working memories. They included these new strategies in their lesson plans and think differently about their students when teaching. Inclusion settings present specific difficulties in which teachers not involved in this study have been unwilling to cooperate and invest the time in the strategies. Related outcomes included providing a parent component in the future as well as obtaining support from the administration.

2nd Iteration: Categories

1A. Perfect storm, September, 2010	2A. Changed thinking	3A. Teaching practice remains unchanged	4A. Educate parents
1B. Pressures/stressors	2B. Including new strategies currently	3B. Can't be convinced to change teaching practice	4B. Administrators must see value and support use of strategies
1C. Different challenges at different times of the year	2C. Will consider additional strategies, i.e., analogies, open-ended ques./thinking	3C. Inclusion settings	
1D. Not core classes for strategies			

1st Iteration: Emerging Concepts

1A. Cuts lessons short	2A. Want my Master's	3A. Haven't changed my practice	4A. Educate parents
1B. Don't know if it is worth investment of time	2B. Changed my thinking	3B. Can't be convinced to change	4B. Must be seen as meaningful by admin. to get support
1C. Impossible in Inclusion	2C. Will change some current practices	3C. Inclusion teachers unwilling to invest time and participate	
1D. Time constraints	2D. Incorporate strategies in my lessons, i.e.,		
1E. AYP failure	2E. Include strategies in my lessons		
1F. Large classes, i.e., 32 with 17+ classified	2F. Will try new strategies		
1G. School events interfere	2G. Provide syn-naps		
1H. Perfect storm	2H. Will add new strategies daily		
1I. Stressors: time invested, state test, new math curriculum AYP failure, more students with ASD			
1J. Exploratory cycle, advisory, intervention classes better venues, not core classes			

Adapted from Anfara, Brown, and Mangione, 2002 and if they felt that it would change as a result of this experience. The three teachers who wrote statements expressed varying summative opinions which were both encouraging and thought provoking. This project attempted to influence teachers' teaching practices, which meant changing their teaching identity, a task to be taken neither lightly nor without regard for the students in their care who are directly affected by that practice. One teacher expressed her thought that, "I am trying to make the learning experiences more authentic for the students. Learning about working memory has taught me to think about my philosophy of education in a different way." She wrote about reducing the amount of information she gave her students so that they could hold it in their working memories in order to retain it. "I also spent time teaching the students how to study instead of simply telling them that they needed to go home and study." She had begun to rethink the outcomes she wanted from her learning disabled students in the classroom. Another teacher was supportive of the study but assigned it a lesser priority in September due primarily to the school's annual yearly progress failure. While he claimed to be applying the brain research information in his teaching practice, he also wrote that "unfortunately the structure of the school schedule and the demands placed on meeting NCLB benchmarks have made this project take a 'back burner' in the classroom." Although September 2010's perfect storm impacted the teachers' ability to carry out strategies proffered by brain research, its challenges did not eradicate the positive reactions and experiences of Cycles I, II, and III.

The brain workshop/PLC topics and discussions provided new and different insights into teaching and learning strategies that were not content area dependent but facilitated general learning skills applicable to any content area. Concepts not previously introduced through teacher preparation experiences fueled these insights and expanded the teachers' knowledge of brain based learning as demonstrated by reading and discussing empirical research studies directly instead of through third party interpretations of the research as it is found in some texts. "I think that my thinking has been 'awakened' as to the brain/memory idea and how it relates to the students," responded one teacher. "I approached this project with some understanding of how the brain functioned. I now know more, and I am applying that information into my teaching practices," wrote another participant. Reflecting on student outcomes, retention and maintenance of learning skills, information load consideration, and personal philosophies of education were findings that bolstered the overall effectiveness of this action research project.

In addition to the stress of not meeting the school's annual yearly progress goals, one teacher who had begun the project with her own pull-out classes the previous year had been reassigned as an in-class support teacher in inclusion classes when the sixth grade self-contained humanities classes were eliminated in favor of inclusion settings for all students. She was unable to influence her general education teaching partners to engage in the project on her behalf and implement any strategies with their students. "I found it difficult – especially when working with other teachers who weren't necessarily on board with the ideas." This project was also directly affected by September's perfect storm.

Teacher Survey. The study was developed in two phases. The first phase extended from February, 2010 until June, 2010. The teachers began to implement new strategies with students who were known to them that academic year. In the second phase, from September, 2010 to January, 2011, the same teachers implemented known strategies with a new group of students. A Likert survey was developed to gauge the teachers' reflective assessment of the project at its mid-point and again at its conclusion in January, 2011. In September, 2010, the teachers expressed optimism about the upcoming year based on their experiences the previous school year. They included brain strategies in their lesson plans, from timed lesson presentations to breaks between lesson segments to specific tasks for increasing working memory capacity. The teachers acknowledged the importance of facilitating learning using brain strategies and specifically teaching their students how to learn, all from our discussions during the PLC meetings. The unanimous drawback to the successful implementation of the strategies was the time involved in carrying them out, which represented time taken away from teaching their curricular content. One teacher commented about how her new knowledge of the brain had impacted her own life. "I have also reflected on myself. I have found that multitasking isn't really beneficial for me as a whole person," she expressed. A heightened awareness of emotionality in learning resulted in another teacher mentioning how she is now cognizant of "the tremendous impact stress has on learning" and how she is both mindful and watchful as she actively teaches all her students. The midpoint and post-study Likert scale results will be presented together with Cycle V findings.

Flex option brain research workshop. An opportunity to present the brain research information to another group of teachers from throughout the Sandersville School District occurred in September, 2010. The five-part empirical brain research workshop series that was offered to the faculty and staff at Sandersville Middle School was also offered to any interested teachers and specialists throughout the district through the professional development flex option program. I conducted the same five-part brain research workshop series that I had presented in February, 2010 for 17 district colleagues in three, two hour sessions over the course of two weeks in October, 2010. The same pre- and post-workshop surveys that had been administered to the middle school attendees were administered to the teachers and specialists who attended the flex option sessions. They came for the same reasons that the middle school teachers had come, to learn more about brain functioning and its connection to learning and to satisfy their own personal curiosity about specific topics such as autism, attention, memory, and the emotional basis of learning, according to their anonymous pre-workshop surveys. Percentages were extrapolated from their Likert scale results and are presented in Table 11. Dr. Buono was unable to participate in this workshop presentation, which changed the experience for these teachers in that they did not have a firsthand opportunity to view, hold, examine, and stand in awe of real human brains, spinal cord and brain covering as the middle school teachers had.

As with the middle school teachers, the district teachers' predominantly agreed and strongly agreed with the survey statements with very few in the neutral and disagree categories and none who strongly disagreed with any of the statements. Most responses were skewed to the left as occurred with the first survey results. The post-workshop survey results are indicated in Table 12. A similar pattern was observed for the post-workshop survey results.

The district teachers thought that a large amount of well documented information about the brain and learning was presented; some thought too much information was included and would have preferred fewer topics presented in greater depth. Most comments were offered regarding the teachers' appreciation of the concept of working memory in learning environments as had the Sandersville teachers. The strategies were well received and accompanied by enthusiastic promises of inclusion in the teachers' various learning environments. The teachers unanimously stated in their concluding written remarks that their teaching practice had been changed by the workshop information, ranging from increased awareness to those who had already begun including some strategies in their teaching. Two of the district teachers requested that I offer monthly follow-up meetings regarding brain research and learning/teaching. This was an unexpected outcome which highlighted the interest these teachers shared in wanting to learn more about the brain and to learn in greater depth instead of merely skimming the surface.

Table 11. Flex Option Pre-Brain Research Workshop Survey
N = 17

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Item 1: Teaching practice should be guided by research.					
N	9	8	0	0	0
Percentage	53 %	47 %	0 %	0 %	0 %
Item 2: I want to know what parts of the brain control specific learning functions.					
N	3	11	3	0	0
Percentage	18 %	64 %	18 %	0 %	0 %
Item 3: I would rather know how the brain enables us to think and to learn.					
N	11	5	1	0	0
Percentage	64 %	29 %	5 %	0 %	0 %
Item 4: I think the information from this workshop will positively impact my teaching.					
N	4	13	0	0	0
Percentage	24 %	76 %	0 %	0 %	0 %
Item 5: It is important to know if "brain-based" programs/products come from empirically based research.					
N	8	8	1	0	0
Percentage	47 %	47 %	6 %	0 %	0 %
Item 6: Teachers should know the difference between brain facts and brain myths.					
N	12	5	0	0	0
Percentage	71 %	29 %	0 %	0 %	0 %
Item 7: The issue of increasing student attention is central to my teaching practice.					
N	10	6	0	1	0
Percentage	59 %	35 %	0 %	6 %	0 %
Item 8: The issue of reducing emotional resistance to learning among my students is important to my teaching practice.					
N	14	2	1	0	0
Percentage	82 %	12 %	6 %	0 %	0 %

Adapted from Patten, 2001, p.85

Table 12. Flex Option Post-Brain Research Workshop Survey
N = 17

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Item 1: Brain research should inform teaching practice.					
N	13	4	0	0	0
Percentage	76 %	24 %	0 %	0 %	0 %
Item 2: Knowing the parts of the brain that control learning functions impacts teaching practice.					
N	2	10	5	0	0
Percentage	12 %	59 %	29 %	0 %	0 %
Item 3: Knowledge of neural networks, synaptic connections, working memory capacity, etc. will improve my teaching.					
N	11	5	1	0	0
Percentage	65 %	29 %	6 %	0 %	0 %
Item 4: This workshop has connected brain research to my teaching practice.					
N	9	7	1	0	0
Percentage	53 %	41 %	6 %	0 %	0 %
Item 5: My previous teaching experience has been influenced by neuromyths.					
N	1	9	4	2	1
	6 %	53 %	23 %	12 %	6 %
Item 6: My future teaching practice will be influenced by brain research regarding neurofact not neuromyth.					
N	11	5	1	0	0
Percentage	65 %	29 %	6 %	0 %	0 %
Item 7: I learned strategies to increase student attention.					
N	6	11	0	0	0
Percentage	35 %	65 %	0 %	0 %	0 %
Item 8: I learned strategies to decrease emotional resistance to learning among students.					
N	6	10	1	0	0
Percentage	35 %	59 %	6 %	0 %	0 %
Item 9: Pursuing study of brain-based strategies will enhance my teaching practice.					
N	12	5	0	0	0
Percentage	71 %	29 %	0 %	0 %	0 %
Item 10: Connecting brain research to teaching strategies should be mandatory professional development.					
N	10	7	0	0	0
Percentage	59 %	41 %	0 %	0 %	0 %

Adapted from Patten, 2001, p.85

shared in wanting to learn more about the brain and to learn in greater depth instead of merely skimming the surface.

Baseline data. The teacher-participants from Sandervsille Middle School were again requested in September, 2010 to select three to five new students and administer the number memory forward and number memory reversed subtests of the *Test of Auditory Processing Skills – 3* to obtain baseline measures of each student's working memory as they had done in March, 2010 with their previous year's students. The teachers were reminded to gather this data at PLC meetings and by e-mail several times with no objections raised by the participants.

Scaled scores were derived from the raw scores and one mean scaled score was derived to represent the entire group of students. The results are depicted in Table 13. These results may be interpreted to mean that as a group, the students' mean working memory scaled score was in the low range of ability.

Only two of the six active participants collected baseline data at the beginning of Cycle IV. This was a ripple effect of the perfect storm's maelstrom in which Sanderville Middle

Table 13. Baseline Working Memory Mean Scaled Scores
The number memory forward and number memory reversed mean scaled scores were used to derive the overall working memory mean score which represented the student group, N=8.

Subtests	Mean Scaled Scores
Number Memory Forward, Pre-Strategies	4.3
Number Memory Reversed, Pre-Strategies	6.9
Working Memory Mean Score	5.6

School was ensnared in September, 2010. Whether touched by a collective paralysis or overwhelmed by guilt, this topic became the white elephant in the room during our PLC meetings from September through January, 2011. When asked individually, the teachers' responses included, “I just couldn’t fit it in,” “I’m feeling the pressure of failing AYP and have to focus on that,” “There are too many kids and they are too low functioning,” “I’ll get to it,” “The beginning of the year is so busy,” “I can’t get anything accomplished. I don’t know what’s wrong.”

At the November 9, 2010 PLC meeting, I raised the question of how effective my bottom-up leadership was in light of the teachers’ inability to respond to the study protocols that had been previously established. Some expressed feelings of guilt and not wanting to face me at PLC meetings. Another teacher denied that my bottom-up approach was ineffective by stating that, “We knew what you needed and what we were getting ourselves into when we volunteered to be part of your study.” Everyone present unanimously agreed.

These findings suggest that without top-down leadership from the administration, especially in the conditions of the perfect storm, bottom-up leadership is ineffective and powerless to mediate the prevailing conditions. Administrative support is not the same as leadership; this project had administrative lip-service without a visible presence to which the participants were accountable. The brain research workshop provided cognitive empowerment for the teachers to explore new concepts and new strategies together to enhance their teaching practice while the PLC meetings enabled them to interact in a spirit of collegiality and collaboration, two qualities Evans (1996, p. 232) identified as necessary for creating lasting change. However, as DuFour, DuFour, Eaker, and Many (2006) explain, bottom-up leadership and reform is laudable but has never been known to happen in a school setting without the principal’s direct involvement. As this project’s leader, I led from the bottom-up because I am in the trenches daily with my colleagues, not in a top-down position of validated leadership. As such, I could only invite teachers and staff to become involved in the project and attempt to influence their teaching practice without mandating their involvement. “Piloting a project with interested staff can be a valuable way to build shared knowledge regarding its effectiveness, but substantive change that transforms a culture will ultimately require more than an invitation” (DuFour, DuFour, Eaker, & Many, 2006, p. 191). Some accepted my invitation to learn and to change, but alone, I was incapable of breaking up the perfect storm and could only ride it out with my fellow teachers.

Cycle V (November, 2010 – January, 2011)

The teachers had unanimously agreed to extend the project until the end of the second marking period in the hopes that they would rekindle the fire of their enthusiasm that had been damped but not extinguished by the perfect storm scenario which continued to overshadow Sandersville Middle School. The issue of time was never resolved to the teachers’ satisfaction and continued to plague their efforts to implement strategies that ate up time they felt they could not afford to spend in endeavors that took them away from their varied curricula, although they continued to try. The strategies had inadvertently become another stressor with which the teachers had to contend, given their expressed feelings of guilt and unease whenever a PLC meeting approached.

Professional learning community. The content of the PLC meetings continued in the same vein as they had from the beginning with an added emphasis on bringing the project to a conclusion. The teachers remained both enamored of their new information, continually seeking more brain research each time we met, yet unsure of the strategies’ place in their classrooms at a time of heightened academic need. Table 14 summarized the agendas of these last PLC meetings as the group brought closure to the study. They responded positively to the PLC format in conjunction with the initial brain research workshop and expressed its effectiveness in transmitting this body of knowledge as a bridge connecting the fields of education and neuroscience to enhance their teaching practices.

Table 14. PLC Meetings Summary for Cycle V

December 21, 2010	January 11, 2011
Research: Tokuhama-Espinosa, *Mind, Brain, and Education Science*, 2011	Research: Discussed excerpts from Packiam Alloway's *Improving working Memory*,2011, w/ handout
Strategies: Any progress? Any more barriers?	Strategies: 1. Give students several seconds to reply instead of the normal single second and the quality of their response will increase; 2. Principles that great teachers follow, Tokuhama-Espinosa, 2011, handout
Feedback, Findings, Concerns: K.C. doesn't see any progress with digits; checked students confidential files to see their working memory scores from evaluations and found them to be extremely low; Benefits to discussing brain facts included raising students' self-awareness about how they learn and why they don't learn	Feedback, Findings, Concerns: 1. The teachers engaged in a lengthy discussion about both handouts as they related to their teaching practice and to this project. They are intrigued by the concept of working memory and the research is causing them to understand their students differently than they have previously. They expressed a strong interest in continuing to implement related strategies after the project has concluded. 2. Several teachers want to continue PLC meetings after the project has ended.

Teacher survey. When the study concluded on January 28, 2011, the teachers completed the same survey they had taken when the school year began in September. The survey attempted to discover what the teachers had gleaned over the course of the past year in terms of both brain research and practical teaching strategies. The combination of the empirical brain research workshop coupled with the PLC meetings expanded the teachers knowledge base to a great degree. They also felt that other teachers at Sandersville Middle School would benefit from the brain workshop information. A majority of teachers expressed a better understanding of their students from that information. While most teachers indicated that their teaching practice was positively impacted by the project, they were unanimously impressed by the knowledge they gained in the process. This change in practice was reflected in their lesson plans, in investing some amount of time in strategy implementation with the potential for additional change when the perfect storm subsides. No teacher claimed that his/her teaching practice remained unchanged after participating in the project. In response to statements about increasing attention and decreasing emotional resistance to learning among students, most of the teachers responded that this had occurred, but to a lesser degree. Some teachers felt that teaching their students about their brains had a positive, motivating impact on the students, but most had no opinion.

Baseline data. At the end of Cycle V, baseline data was obtained from the two participants who had collected data using the same number memory forward and reversed tasks that were administered during Cycle IV. The results, found in Table 15, revealed some surprising findings. Overall, the student group mean scaled score increased from the low range in the pre-strategy condition to the below average range in the post-strategy condition. The five students in the eighth grade group had the most interesting changes of all the students. Their pre-strategy number forward scaled score was in the very low range while their post-strategy number forward score increased to the below average range. Their pre-strategy number reversed scaled score was below average while their post-strategy number reversed scaled score improved to the average range with four out of the five students scoring in the average range.

Table 15. Baseline Working Memory Mean Scaled Scores
N = 8. The number memory forward and number memory reversed mean scaled scores were used to derive the overall working memory mean score which represented the student group.

Subtests	Mean Scaled Scores
Number Memory Forward, Post-Strategies	6.7
Number Memory Reversed, Post-Strategies	8.5
Working Memory Mean Score	7.6

Teacher Survey. The teachers were asked to complete one final survey that was derived primarily from the research questions that the study attempted to answer. The teachers provided me with a plethora of information from which I created a code map that was dense with their insights and observations. The duplication of questions and responses indicated that the study's saturation point had been reached by the teacher participants as no new insights or conclusions were forthcoming. I have included the third iteration of the code map, the themes, as a final summation since these results represent a microcosm of the entire project.

> As a group, the teachers gained usable knowledge connecting brain research to teaching practice and most incorporated new learning strategies in their teaching practice. This knowledge is reflected in their lesson plans and teaching. The concept of working memory capacity and its connection to intelligence was especially thought provoking and the center of many discussions. Due primarily to the time constraints involved in implementing the strategies, not all participants changed their teaching practice nor plan to do so. Several thought that core subject areas were not the places for these strategies, that perhaps the daily advisory period or exploratory cycle would be more effective times. Student achievement remained unchanged although increased self-awareness among the students, emotional resiliency, and use of terms such as fight, flight, or freeze became common. The participants chose students whose learning disabilities were perhaps too severe to follow through the project and would choose less involved students in the future. They felt that the strategies would have been more effective given more time or a higher achieving student with whom to implement them. The relaxation strategy appeared to yield the strongest results. The workshop/PLC format was felt to be a strength in terms of topics/strategies/handouts. The research was flexible and

responded to the teachers' needs as best as possible with the prevailing perfect storm conditions that characterized the 2010-11 school year.

As the perfect storm continued to rage, we continued to hold the line and teach like our hair was on fire (Esquith, 2007).

Chapter 5

Conclusions and Implications

This study sought to answer questions about infusing selected principles and practices of mind, brain, and education science into the teaching strategies of middle school teachers at the Sandersville Middle School to affect their teaching practice. If teachers gained usable knowledge from interpreting empirical brain research, could they increase student attention and decrease resistance to learning? Could their knowledge of brain-based teaching strategies be stimulated through the creation of an initial workshop series and then sustained by a professional learning community to enhance their professional development? My leadership of the project from its thoughtful inception through its evolution and development to its eventual conclusion was also a considered piece of this action research puzzle.

A concurrent embedded mixed methods approach to this action research study combined quantitative data within the larger framework of qualitative datasets to answer the study's research questions. The cyclical design of action research (Kemmis & McTaggart, 2005) afforded the participants the opportunity to adjust the process in response to the ebb and flow of life in a middle school, to the impact of empirical brain research in a public school learning environment, and to the unanticipated effects of a "perfect storm" of circumstances beyond our control putting this study in the eye of the storm. The quantitative data was gathered through establishing pre- and post-strategy baseline data and several sets of pre- and post-survey questionnaires, while the qualitative data consisted of PLC/focus groups, individual interviews, field observations, word clouds, and personal reflections.

Research Goals

The primary goal of this research was to change the teaching practices of a group of middle school teachers to include the principles and selected practices of mind, brain, and education science to ultimately increase student achievement. A comparable goal was to determine if my leadership in the project enabled the participants to gain usable knowledge in mind, brain, and education science. The impetus for these changes was a series of related objectives designed to empower middle school teachers to interpret pertinent empirical brain research, devise strategies to support their students' learning, and implement those strategies to enhance student achievement as part of their teaching practices.

My research partially achieved its aims. It took me from the unknown with little or no previous research on which to rely to a position of clarified thinking tempered by the realities of contemporary public schooling. This study set the stage for future brain research implementation at Sandersville Middle School, establishing a foundation from which to continue informing teachers and enabling them to develop their students' brain functioning so as to ideally achieve optimal learning outcomes, and thereby changing their teaching practices as well.

Both of the brain workshop series, the PLC format, and the brain strategy implementation components of this project created a framework for first order change among the teacher participants. With my direction and support, the teachers engaged in learning endeavors and strategy utilization to seek answers to the research questions I had posed at the study's outset. By following the protocol for executing the project and adding new strategies to their daily lesson planning, the teachers were actively engaged in first order change. While second order change, a change in personal values and belief systems (Argyris, 1990; Senge, 1990; Osterman & Kottkamp, 2004), is highly desirable in a study such as this one, I could not impose my values and beliefs about learning and teaching on others, no matter how open they were to new and different ways of thinking about their teaching practice. That could be viewed as a type of "power over" thinking that Mary Parker Follett wrote about in the 1920's (as cited in Kreisberg, 1992) which continues to be a threat to the relationship building with moral purpose that undergirds contemporary change initiatives, especially in education (Fullan, 2001).

Second order change, while spoken of easily and sought after by many, requires a slow, evolutionary, thoughtful process before it merges with and begins to change the core beliefs of your personal and professional self. It is my contention that the intent to change the belief systems of others, the essence of transformational leadership, is a very serious, ethically bound, and morally responsible endeavor that should not be attempted frivolously or thoughtlessly (Burns, 1978; Couto, 1993; Evans, 1996; Fullan, 2001; Leithwood, 2007; Senge, 1990, 1999; Shapiro & Stefkovich, 2005; Strike & Soltis, 2004). And yet, it is possible that through the framework of a first order change initiative, the seeds of second order change are sown, nurtured, and begin to stretch to conscious awareness and action. While my desire to foster second order change among the participants was pure, this project was really a recipe for first order change with the potential to become second order change over time. That potential could become a reality for three reasons. Attendees at both brain workshop series expressed a desire to continue to come together and advance the professional development aspect of the PLC; the study participants at Sandersville Middle School plan to continue implementing brain-based teaching/learning strategies on their own; and, one tenured teacher with an advanced reading specialist degree realized that she changed her philosophy of education from the beginning of the project to its conclusion.

Laying a foundation that fosters an evolution of learning, action, and reflection is leadership that enhances individual and organizational growth and encourages change that is lasting (Argyris, 1990; Evans, 1996; Osterman & Kottkamp, 2005; Senge, 1990, 1999), or second order. As I look at Sandersville Middle School through Bolman and Deal's (2003) human resources lens, I believe that that view of organizational leadership resonates with my self-identification as a servant leader. I have attempted to empower the participants by exposing them to a field of knowledge that is on the cutting edge of brain-based teaching and learning science. I formed a PLC as a vehicle for the dissemination of that knowledge to the teachers, the implementation of related brain-based strategies with their students, and their ability to reflect together about the impact of mind, brain, and education science on their teaching practices (DuFour, DuFour, Eaker, & Many, 2006; Senge, 1990, 1999). Organizational change stems from the success of those first and second order change initiatives.

Teachers and staff from Sandersville Middle School as well as from the district at large demonstrated a keen interest in the brain and its impact on teaching practice throughout the two five-part workshop series and 10 PLC meetings that took place from February, 2010 through January, 2011. With the first empirical brain research workshop as the springboard during Cycle I, the PLC meetings allowed the participants to process the information, ask questions, have discussions with their peers, clarify topics, and grasp the concepts at a deeper level than that provided during the workshop series. Teachers from throughout the district who participated in the second workshop series offered during Cycle IV requested that the workshop meetings continue after the mandatory six hours due to their heightened interest in brain research and their expressed desire to connect it functionally with their teaching practice. As a result of their discussions and our individual interviews, the teachers suggested that the scope of the brain research workshop series should be expanded, differentiated, and offered to parents and to students. These groups were not included in the original plan for this research and, although some students at Sandersville Middle School were taught brain facts as part of their teachers' selected strategies, a parent group was not formed because this recommendation did not emerge until Cycle IV when the project was nearing its conclusion. However, this three-pronged approach to expanding the brain research knowledge base for the entire Sandersville learning community holds promise for the future.

In research, as in life, events occur over which we have little or no control that can significantly influence our varied endeavors. Unbeknownst to the Sandersville Middle School staff, four unrelated storm clouds gathered over the summer vacation period and merged on the first day of the 2010-11 school year to form a "perfect storm" situation. These four factors included the following conditions: Sandersville Middle School did not meet its annual yearly progress markers designating it as a failing school; the self-contained social studies classes for incoming classified sixth grade students was eliminated with those students placed in inclusion settings; there was a significant increased in classified sixth grade students, particularly students with autistic spectrum disorder; and, a new, district-wide math program was initiated. The 2010-11 perfect storm proved to be too much of a barrier for some teacher participants to overcome as it nearly quashed their active involvement in the project, challenging their willingness to change their teaching practices. Several teachers, however, reported including brain strategies in their weekly lesson plans and executed their lessons with a newly informed awareness of their students, causing them to provide short breaks when they noticed signs of fatigue, breaking class periods into several shorter learning segments, and chunking material to aid retention, organization, and connections to other concepts or experiences. The teachers reported thinking about working memory and how they could expand it in their varied classes. Without the pressures created by the perfect storm, a greater level of active teacher participation would have been more sustainable throughout the entire study.

Most teachers did not perceive any changes in student achievement that could be attributed to the brain-based strategies at the conclusion of the project. There may have been several reasons why the teachers did not perceive positive changes. For example, the teachers reported that a longer implementation phase could have yielded different results based on their observations of student interest in the strategies and their increasingly successful outcomes remembering the digits forward and reversed strategies. The teacher who taught the lowest eighth grade math students at Sandersville Middle School pre- and post-tested five of her six students using the number memory forward and backward protocols. All five pre-tested in the very low range of ability. She implemented the digits forward and reversed repetition strategy to develop the students' working memories and abandoned it in favor of the teaching them brain facts because she did not see them being successful. Three out of the five students scored in the average range of ability when they were post-tested. A sixth grade special education teacher taught her students the fight-flight-freeze anxiety vocabulary. The students used those words to describe their feelings and their impulses when faced with problem situations during class. Their teacher reported this to be a highly successful strategy outcome in her class despite the lack of improved student achievement in language arts. While these subtle changes in student skill development and self-awareness were positive occurrences, they were not connected to subject specific academic achievement.

The teachers did not report increased student attention related to their strategy implementation, except for one teacher who implemented relaxation and deep breathing before her class began several times a week. After several weeks, she noticed that the whole class retained good focus throughout the class period. Other teachers reported that student attention increased during the strategy implementation but did not carry over into class. In response to this research question, two teachers commented that they may have selected students whose academic ability was too low to be affected by the strategies and that they would include students with higher ability levels if they were to repeat the study. Despite these observations expressed during PLC meetings, the second word cloud generated by the teachers' written descriptions of student attention and behavior at the end of Cycle III included words such as "focused," "paying attention," "sit still," "improved," "understood", and "calm," suggesting behavior changes had been noted and documented.

Overall, the teacher participants did not report generalized decreased emotional resistance to learning stemming from the strategy implementation. Several felt their students were more resilient and less emotionally reactive when dealing with stressful situations. Their knowledge of brain facts related to anxiety was attributed to their willingness to think first, and then act as well as to their increased ability to know if they were in a state of fight, flight, or freeze.

The workshop/PLC format did help to create a bridge between empirical brain research and teaching practice among the teacher participants at Sandersville Middle School. Teachers stated that the format exceeded their expectations for gaining new and deeper knowledge about brain research. Viewing and handling human brains continued to be the highlight of the workshop series and all subsequent PLC meetings because it made the topic tangible and very real. The frequent, interactive PLC meetings enabled the teachers to express their concerns about the looseness of the study structure during Cycle II which enabled me to reflect and respond to their concerns. In formulating a new strategy schedule for everyone to follow, Cycle II was ended and Cycle III was initiated.

My leadership role in this project partially enabled the teacher participants to gain usable knowledge in the principles and selected practices of educational neuroscience. My role in presenting the workshop series and conducting PLC meetings was instrumental in connecting brain research to teaching practice for the participating teachers. I chose the topics, the handouts, all supporting materials, and developed the strategies that the teachers implemented. Creating Cycle III in response to the teachers' concerns about the project required me to be flexible and responsive to them while remaining faithful to the project. However, my bottom-up leadership did not exert a strong enough influence to keep their level of involvement elevated and active during the perfect storm conditions that existed during Cycles IV and V. Only two of the six teachers who continued the project in September, 2010 in Cycle IV collected baseline data despite my encouragement to do so at every PLC meeting. Three of the six teachers implemented strategies, halving the potential for changing the group's teaching practice and affecting student learning. The perfect storm was too powerful, too threatening, and too pervasive for me to fight from the trenches alone, rendering my leadership role only partially effective.

Research Implications

Most teacher preparation programs do not require students to study the brain and its functions as they relate to learning at the present time. Cutting edge research is currently being designed and executed on topics such as working memory capacity and motivation to assist teachers in understanding why students learn well and why they struggle to learn. Connecting this research to learning strengthens the foundation on which teachers build their practice and gives it the research base required by current legislation such as No Child Left Behind. With the number of classified students rising each year as evidenced by the increasing number of those students enrolled at Sandersville Middle School, it is reasonable to surmise that current teaching practices have not met the challenges presented by students with special needs well enough to declassify them and return them to general education. With the number of general education students who are proficient on high stakes standardized testing and not advanced proficient as evidenced by the population at SMS, it would seem that current teaching practices are holding the line and not advancing student learning. While new curricula abound every year, it is the teacher's responsibility to develop each student's learning ability no matter how naturally gifted or challenged they may be, regardless of the content being taught. As students progress to middle school and high school, learning how to learn is traded for learning curricular content, especially in our high stakes testing climate. While inconclusive, the results of this study imply that working memory can be trained and strengthened by investing class time in strategies to expand working memory capacity. Research has demonstrated that working memory is intimately related to fluid intelligence, the intelligence we use to solve novel problems and to think. If teachers invest some time in expanding working memory capacity, they help their students develop higher order critical thinking skills, the essence of true learning.

The impetus behind a project such as this one must come, at least in part, from the top-down. Without the superintendent's or principal's mandate, a volunteer project is quickly replaced by those that are mandated and becomes unsustainable. The new district wide mandated math curriculum forced one participant to reconsider his ability to participate in this project due to the demands of the new program and he reluctantly withdrew in September, 2010. With an administrative mandate comes accountability as well which imposes sustainability.

Accountability is a way to ensure that data collection leads to measurable outcomes, which was a shortcoming of the present study. The conditions of the perfect storm became the mandate and replaced my bottom-up attempts to have the teachers gather baseline data and implement strategies that would have led to measurable outcomes.

The research reviewed by the workshop attendees was primarily conducted in university research facilities with college students. That does not always translate well to the secondary or primary level classroom as we experienced with the n-back tasks that were attempted in our middle school setting. The dissimilarities between the two situations were significant enough to cause me to wonder if they could be equivalently redesigned. This study showed that there is not always a straight line between interpreting research and applying it directly to various teaching environments, especially for participants with such varied experience. Can research tailored to a public middle school use the same design as that conducted in a university research laboratory? Would it be more equivalent if the subjects, regardless of age, experience, and academic ability, performed the n-back tasks individually and not as a group as occurred in this project? Can the timing be lengthened or shortened and extended over a longer time period depending on the setting? Questions such as these were highlighted by the current study and should be considered when future research is planned in a setting such as Sandersville Middle School.

Time is one of the most precious resources a teacher has. Without top-down authorization, teachers run the gamut from being politely reluctant to flatly refusing to invest precious time in volunteer activities, especially over an extended time period. Every teacher in this study was critical of the time investment they were asked to make and it became the reason that three teachers only attended PLC meetings without obtaining baselines or implementing strategies and charting results. As a result of the research discussed at the workshop/PLC meetings, the teachers became very interested in the topic of working memory and were intrigued by the possibility that they could expand working memory capacity through the implementation of certain strategies. Strategies such as the digits forward, digits backward, and n-back tasks were identified by an expert in the field as the best ones to use, but they are time consuming. The question then becomes, should this group of strategies be removed from the classroom and be implemented in the speech/language treatment room with no more than two students at a time using computers? This work also falls under the umbrella of goals addressed by speech/language pathologists in school settings. Relaxation and deep breathing can be carried out in the classroom which can be timed by the minute, requiring a minimal investment of time. This procedural change shifts the study's focus away from the classroom and into a smaller, more controlled environment that is better suited for a specialist such as a speech/language pathologist to conduct than a teacher.

Professional Research Implications

An essential question around which my work as a speech/language pathologist revolves has always been, "How do children learn?" This is because our thinking and our learning strengths and weaknesses are revealed through our understanding and use of language. As brain research expands our knowledge base connecting brain function to learning, my questions multiply. Topics such as brain plasticity, synaptic growth, working memory, mirror neurons, attention, and motivation, bring to mind faces of my students who are successful learners and those who are challenged by the learning process. Understanding learning processes is fundamental to effective teaching. Recognizing those who learn well and knowing why they learn is as important as recognizing those who do not learn easily and why they struggle. The multiple content areas that children study share a basic, common learning system despite the variations that make us unique learners. Teaching specific content integrates basic learning processes with concepts and experiences germane to each curricular area taught. My professional responsibility to my students and to their teachers is to know what research is current and to share those insights with my colleagues at Sandersville Middle School, regardless of their curricular discipline.

Follow Up Actions

This action research study was designed to accomplish two specific goals. What I did not anticipate were off-shoots of the project creating research interests of their own among the teacher participants and me. My approach would be to create individual studies from the larger one and attempt to use the strengths and revise the weaknesses inherent in each. Analyzing the current study resulted in four separate but related topics around which action research projects could be designed. They include continuing professional development through the existing PLC, securing a top-down mandate from Sandersville Middle School's principal to implement a version of the current project, integrating the Brainology computer program into the curriculum, and refining the implementation of working memory strategies with identified students.

To address the teachers' desire to acquire more information and to facilitate discussion of empirical brain research connected to teaching practice, the professional learning community format that has already been established would continue to exist as a stand-alone project. The entire staff of Sandersville Middle School would be re-invited as well as the district teachers who attended the second, flex option workshop. The purpose of the action research design would be to measure changes in the teachers' knowledge base and in their teaching practice as a result of the new information. An ancillary PLC for interested parents of Sandersville Middle School students would be created to include the community in brain research discussions as it relates to their children's learning. The topics would complement the information presented at the teachers' PLC but would also address specific interests and needs as well, such as sleep, nutrition, and the teenage brain and their effects on brain development and learning. Both PLC groups would be encouraged to define concepts related to brain development and brain facts relevant for sixth through eighth grade students. They would be similar to the facts presented through the Brainology computer program designed by Dr. Dweck to facilitate growth mindsets vs. fixed mindsets in students (2006).

Securing a top-down mandate from Sandersville Middle School's principal would be challenging, but not impossible if he can be persuaded of the current project's importance and if it is framed within the current scheduling structure. Assuming that he can be convinced of its value, there are two possible places in the existing schedule where a variation of the current project would be appropriate, during an advisory cycle or an exploratory cycle. Advisory is half the students' lunch period and is reserved for character education, interventions, and related activities. Sandersville Middle School has five exploratory cycles that occur every other day for an approximate six week period and currently include art, music, computers, communication skills, and 21st century skills. In either advisory or exploratory cycles, one existing program would have to be replaced by the re-named and redesigned brain research project. Every student at SMS would be involved in the project regardless of which class period the principal designated.

The Brainology computer program includes a teacher led component to encourage discussion and to facilitate creating growth mindsets and diminishing fixed mindsets among students. It could also be an advisory, exploratory, or after school program. Building in working memory activities would be a beneficial part of the total growth mindset approach given the time frame in which it would be scheduled. The significant drawback to implementing this program is that student licenses must be purchased at a cost that would be prohibitive for the entire student population or even a grade level. Identifying students at-risk for passing the state test might be a reasonable compromise if alternatives had to be considered and funding was available.

Implementing working memory activities, regardless of the type, proved to be a difficult endeavor with an entire class and yet, productive for one teacher with a very small class. The environment contained distractions such as ambient noise, visual distractions, and variations in signal-to-noise ratios for directions from the front of the room to the back of the room. The biggest complicating factor was the amount of time required to implement the strategy; 15 minutes out of a 54 minute class period is 1/3 of the total class time, a significant investment of that valuable resource. As a separate action research study, I would identify students with weak working memory scores from either psychological or speech/language Child Study Team evaluations. Using existing computer programs, the students would work in a small treatment room, not in their classrooms, two to three times a week for 25 minutes at a time on the working memory tasks. The sessions would last for one marking period at a time. At the end of each marking period, the students would be re-assessed to determine if they would continue through the next marking period or if their scores had increased into the average range and they would be dismissed from the study.

Connecting empirical brain research to teaching practice among middle school teachers has been an invigorating, thought provoking, sometimes frustrating, often rewarding endeavor. It opened a door of inquiry through which several of my colleagues and I walked together. Those who actively participated, experienced positive benefits to one degree or another and expressed new found ways to understand their students and increase their learning success. For one experienced teacher, this action research project changed her philosophy of education.

It has also changed me. It was with a profound sense of awe, respect and curiosity that I held a human brain in my hands during the first session of the brain research workshop that marked the initial action of this action research study and reflected on the essence of life, thought, emotion, and learning. Quiet now, no electrical charges pulsing, no neurotransmitters flowing, no synapses connecting; this brain no longer lived, or thought, or felt, or learned. Had the person whose life was defined by this brain that I held been a happy, productive, fulfilled individual who had attained his or her maximal potential over his life span or had he not known that he could push his brain to expand its capacity to learn and solve problems and think, and therefore, did not? Twenty first century brain research has proven that brain functions can be expanded to enhance learning capability over a person's lifespan. That is why this research matters.

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Appendix A

Pre-Educational Neuroscience Workshop Survey

I would like to invite you to participate in a short survey. This is an anonymous survey and all information will be kept strictly confidential. By participating in the survey, you are giving me permission to use your information as data for a dissertation project that is in partial fulfillment of the requirements for the Ed.D. degree, for publication or education purposes. Thank you for your help!

Directions: Please read each item carefully. Then **x** your response.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disgree
1. Teaching practice should be guided by research.	_____	_____	_____	_____	_____
2. I want to know what *parts* of the brain control specific learning functions.	_____	_____	_____	_____	_____
3. I would rather know *how* the brain enables us to think and to learn.	_____	_____	_____	_____	_____
4. I think the information from this workshop will positively impact my teaching.	_____	_____	_____	_____	_____
5. It is important to know if "brain-based" programs/ products come from empirically based research.	_____	_____	_____	_____	_____
6. Teachers should know the difference between brain facts and brain myths.	_____	_____	_____	_____	_____
7. The issue of increasing student attention is central to my teaching practice.	_____	_____	_____	_____	_____
8. The issue of reducing emotional resistance to learning among my students is important to my teaching practice.	_____	_____	_____	_____	_____

9. I have an understanding of neuroscience/brain-based research from the following sources (Check all that apply):

____ Personal Curiosity ____ College Course(s) ____ Books, Journals, Magazines

____ Inservice Programs ____Other: (Please specify)____

10. I want to learn more about the brain's connection to the following (Check all that apply):

____All types of memory ____ Creativity ____ Comprehesion

____ Information storage/retrieval ____ Visualization ____Numeracy (math)

____ Literacy (reading/writing) ____ Other: ____

11. What other comments or questions do you have? ____

____

Appendix B
Post-Educational Neuroscience Workshop Survey

I would like to invite you to participate in a short survey. This is an anonymous survey and all information will be kept strictly confidential. By participating in the survey, you are giving me permission to use your information as data for a dissertation project that is in partial fulfillment of the requirements for the Ed.D. degree, for publication or education purposes. Thank you for your help!

Directions: Please read each item carefully. Then **x** your response.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Brain research should inform teaching practice.	____	____	____	____	____
2. Knowing the parts of the brain that control specific learning functions impacts teaching practice.	____	____	____	____	____
3. Knowledge of neural networks, synaptic connections, WM capacity, etc. will improve my teaching.	____	____	____	____	____
4. This workshop has connected brain research to my teaching practice.	____	____	____	____	____
5. My previous teaching practice has been influenced by neuromyths.	____	____	____	____	____
6. My future teaching practice will be influenced by brain research regarding neurofact not neuromyth.	____	____	____	____	____
7. I learned strategies to increase student attention.	____	____	____	____	____
8. I learned strategies to decrease emotional resistance to learning among students.	____	____	____	____	____
9. Pursuing study of brain based strategies will enhance my teaching practice.	____	____	____	____	____
10. Connecting brain research to teaching strategies should be part of mandatory professional development.	____	____	____	____	____

11. Please respond to the following quotes as they relate to this workshop (on the back).

"Although a good deal of money is spent on staff development in the U.S., most is spent on sessions and workshops that are often intellectually superficial, disconnected from deep issues of curriculum and learning, fragmented and noncumulative…Teacher learning is usually seen as either something that just happens as a matter of course from experience or as the product of training in particular methods or curricula."

12. Please write your overall impression of this workshop series (on the back).

Appendix C
Focus Group Questions

1. Are there learning activities that we can do in the classroom that might release neurotransmitters and electrical impulses that we're not going to see that will increase attention and reduce emotional resistance to learning? Is the project worth pursuing?

2. Do you think that we should work to reduce the opportunity for irrelevant information to occupy working memory space and give students some other activity to focus on?

3. Can we design something that is a syn-nap (a mental or physical break) that can be viewed as fun by the kids but is still relevant to the topic for that day? Change the presentation of the material?

4. Can you pair activities or strategies to accomplish the goal of expanding working memory capacity and opening up that thinking space for learning?

5. Would you use those strategies before class starts so the students can empty out their working memory and be prepared to receive instruction? Would you do it at the beginning and the end so they can then reflect back on the lesson?

6. Do you think you can spot kids in your class who are so distractible that you're going to make the leap and guess that their working memory is filled with extraneous information that is irrelevant to the class?

7. Do you think we can train working memory in our specific disciplines? Could you somehow apply the *n*-back task that we read about and discussed?

8. If an educational neuroscientist was sitting next to you this morning, what would you want to ask that person?

9. Do you think your teaching has been impacted by the workshop?

Appendix D
Post-Educational Neuroscience Workshop Individual Interview Protocol

1. Prior to this workshop, have you ever explored the concept of educational neuroscience or brain-based teaching? Could you explain what that involved?

2. Does it have a place in your teaching practice? Why or why not?

3. Now, after the workshop, what might you try doing differently in any aspect of your teaching? Did you hear anything during the workshop that might be worth trying?

4. What additional information would you like to have to supplement the ideas you heard about in the workshop? Are there any other specific topics that would be of interest to you in this field?

5. In your opinion, is it important for teachers to know about the places in the brain where neural activity occurs *and* to know about how learning takes place? Is it an either/or proposition?

6. In reflecting on your teaching practice and experiences in the classroom, what area would you like to supplement with background knowledge and practical, hands on suggestions?

7. What is your impression of "neuromyths?" Have they ever been a part of your own learning or your teaching practice? Have they been debunked, or not?

8. Could you describe to me how you identify when a student is attending to you and your lesson? How about when they are not attending? What behavior do you observe? How do you sustain their attention and/or regain it when they lose their focus?

9. What does it look like when a student is affectively or emotionally resisting learning environments, situations, or activities? How do you try to turn that student around?

10. Could you explain how important the factors of attention and emotion are to the students to whom you teach language arts, science, social studies, or math? What other factors must be present for your students to learn from you?

11. Among all the district requirements for curriculum and record keeping and other forms of accountability which seem to increase every year, what makes new strategies or new teaching practices worth serious consideration on your part?

12. What did you hear in the workshop that surprised you?

13. Is brain research different than other kinds of strategies that we use in education?

14. How did it feel to see and hold a real human brain?

Appendix E

Abridged Transcript of On-Line Web Chat with Dr. John Jonides

[courtney] 8:01 pm: Good evening! Welcome to this month's online live chat of the Learning and Brain Society!

[courtney] 8:01 pm: My name is Courtney Phillipps, I will be moderating tonight's chat.

[courtney] 8:01 pm: Tonight we are honored to welcome Dr. John Jonides as our guest host of the chat.

[courtney] 8:02 pm: Dr. Jonides is the Daniel J. Weintraub Professor of Psychology and Neuroscience at the University of Michigan, as well as Co-Director of the functional MRI Center there.

[courtney] 8:03 pm: Dr. Jonides, perhaps you can tell us a little about why the concepts of "fluid intelligence" and "working memory" are important for education.

[Dr. Jonides] 8:04 pm: Thank you, Courtney. I'd be happy to

[Dr. Jonides] 8:04 pm: Fluid intelligence is the ability to think and solve novel problems that involve more than just the retrieval of some piece of information from memory. At its core, it is the reason that humans are as smart as they are.

[courtney] 8:05 pm: It also sounds like something that is difficult to teach.

[Dr. Jonides] 8:06 pm: Working memory, as it turns out, is a huge component of fluid intelligence. According to various studies, the correlation between working memory capacity and fluid intelligence is about .50, which is very sizable. So, assuming that this correlation is not just spurious, there is very tight relationship between working memory and IQ

[Dr. Jonides] 8:07 pm: To respond to your observation, many think that intelligence is native to us and that it is unteachable. This, as it turns out, is simply dead wrong. We are learning more and more that the ability to think productively and act intelligently is eminently teachable.

[isanders] 8:08 pm: Dr. Jonides, I am a middle school speech/language pathologist. In your opinion, is it possible for classroom teachers to expand working memory capacity in their students?

[Dr. Jonides] 8:09 pm: Yes, indeed, I think it is. We now know that there are training techniques that allow people to improve

their workiing memory in a way that transfers from one working memory task to another. So, it is definitely possible to improve working memory by training.

[caseyandriley] 8:10 pm: Your findings would seem to have application for those with AD/HD who often display deficits in working memory, and thus, possibly, receive diminished scores on an intelligence test.

[Dr. Jonides] 8:10 pm: Indeed, we have a program of reseach now ongoing to find out if our training techniques work with

ADHD children. Unfortunately, I don't know the results of this work quite yet, but I think you're right that this is a pregnant area for further research.

[isanders] 8:11 pm: Is it possible for teachers to design their own n-back tasks using their course content as the stimuli?

[Dr. Jonides] 8:11 pm: I hadn't thought of this, but I don't see why not. Our research has shown so far that the content of the n-back task is largely irrelevant to the training effect. So, most any material should work; or at least that's what I think right now.

[isanders] 8:12 pm: What training methods would be realistic for classroom teachers to use to try to expand working memory capacity in your opinion?

[Dr. Jonides] 8:14 pm: About training methods: Right now, we are concentrating only on the n-back task, in large part because we know that it works. But I suspect that other working memory tasks may be as effective. What is critical is that when people get better at these tasks, they are not just learning a task-specific strategy. If they are, then there won't be any transfer to any other skills, which, after all, is the point of the training

[isanders] 8:15 pm: how critical is the timing of stimulus presentation in the n-back task? What would you suggest as an appropriate timing interval?

[Dr. Jonides] 8:17 pm: One nice feature of the n-back task is that it is availabe online so that the trainers don't have to re-invent the wheel with the task. I don't know what is critical about the timing in the task, but our work suggests that an interval of 3 sec or so between successive stimuli is a good pace for the task. This may not be critical, but we know that this pacing works pretty well.

[courtney] 8:19 pm: What was the test of fluid intelligence like?

[Dr. Jonides] 8:20 pm: I just took a minute to dig up some websites that have the n-back task available. Of course, they are not tailored to the test-taker, but they give you a sense of the task:

[Dr. Jonides] 8:20 pm: http://iddl.vt.edu/~rfentres/dualnback/index.php

...http://soakyourhead.com/Default.aspx

...http://brainworkshop.sourceforge.net/

...http://dual-n-back.com/

...http://cognitivefun.net/test/5

...http://shawnpresser.blogspot.com/2008/04/brain-rage.html

...http://www.cse.ucsd.edu/~ckanan/FluidIntelligence.html

[isanders] 8:20 pm: Thank you for that information. The concept of working memory has been a topic of discussion among the classroom teachers in my building, especially the special education teachers. They are very interested in pursuing expanding working memory capacity and they have asked for my help in designing learning activities that will do that. I think that we should establish baselines for the students using digits forward and backward assessments. Would you agree?

[Dr. Jonides] 8:21 pm: The fluid intelligence tasks we have used are standard psychometric ones. The most common is the Raven's Advanced Progressive Matrices test. It is a non-verbal test that is supposed to be culture-free although it's likely not that. But it correlates well with such things as school performance.

[Dr. Jonides] 8:22 pm: Digits forward and backward are a very standard way of assessing baseline performance. Good idea.

[Dr. Jonides] 8:24 pm: I should add, though, that there are other standard measures of working memory capacity. Such things as listening span and reading span. One that is available online is called Operation Span. I don't have the website for it at hand, but you may be able to Google it (its originating author is Randy Engle at Geogia Tech).

[courtney] 8:26 pm: Are there differences in people's capacities in the different kinds of working memory?

[isanders] 8:26 pm: I think that teachers can be reluctant to delve more deeply into some areas of assessment than others and wonder if they would feel more competent using the digits spans tests to start identifying students whom they suspect of having weak working memory.

[Dr. Jonides] 8:27 pm: Well, there is certainly no harm in using digit span as a measure of capacity to establish a baseline and to see whether that baseline performance can be changed via training.

[Dr. Jonides] 8:28 pm: Working memory may be somewhat material specific, but there is a very large correlation among different measures of it, so I think when you've measured it one way, you will have a pretty good idea of overall capacity even though there may be small differences as a function of the type of material used.

[courtney] 8:30 pm: @isanders: How can a teacher identify a student who might have weak working memory? What things have you noticed?

[isanders] 8:33 pm: The distractibility similar to that of a student diagnosed with ADHD, emotional stress when they are faced with certain learning tasks such as math or writing. These are some of the things teachers have inquired about as identifying factors. I think they are on target, especially when these behaviors occur over time. Are we on target here?

[Dr. Jonides] 8:33 pm: Well, there are standard neuropsychological tests of working memory (such things as the Token Test, or Following Instructions, that will certainly identify weak workiing memory capacity. But even more casually, I do think it's possible to detect a weakness in working memory capacity by a sort of "bedside" test. Consider for example, giving a student an instruction to do 4 things: put the pencil in a drawer, fold the paper in half, place a coin under the desk, and place the eraser to the right

[Dr. Jonides] 8:34 pm: Sorry, that was cut off: "to the right of the desk." Then see how many of these things the students can do in the correct order compared to other students.

[Dr. Jonides] 8:34 pm: I missed the point about distractibility. What is the issue here?

[courtney] 8:37 pm: I'll just repeat what we said:

[courtney] 8:37 pm: @isanders: How can a teacher identify a student who might have weak working memory? What things ...have you noticed?

...[isanders] 8:33 pm: The distractibility similar to that of a student diagnosed with ADHD, emotional stress when they are ...faced with certain learning tasks such as math or writing.

These are some of the things teachers have inquired about as ...identifying factors. I think they are on target, especially when these behaviors occur over time. Are we on target here?

[isanders] 8:37 pm: Those students who are not diagnosed with ADHD but who demonstrate distractibility during class because their WM are filled with irrelevant information and are unable to maintain their focus on the task at hand.

[Dr. Jonides] 8:38 pm: Yes, I am sure that weakness in working memory is influenced by distractibility. So even a sub-clinical student who does not show outward symptoms of ADHD might nevertheless be distractible, and that will certainly lower working memory capacity with consequences for other cognitive tasks.

[Dr. Jonides] 8:39 pm: Indeed, I think that one of the things that working memory training accomplishes is focusing attention on a single task for a length of time, thereby decreasing distractibility. As you get better at it, you are able to focus for longer periods of time.

[isanders] 8:41 pm: There are some researchers, such as Gathercole and Alloway, who seem to subscribe to an intervention program that seems to advocate compensatory strategies instead of attempting to expand WM. I would think that a combination of the two approaches would be more beneficial to students. Could you comment on their work perhaps?

[Dr. Jonides] 8:42 pm: It's possible that compensatory strategies would be an additional benefit, but I don't think the jury is in on this just yet.

[isanders] 8:46 pm: Your work has been so important in demonstrating that through expanding WM, students' intelligence is directly impacted. I think a demonstrable change far surpasses the short-term effects of compensation. A true expansion of WM capacity translates into more, better, more long lasting learning. That is truly connecting brain research with teaching practice!

[Dr. Jonides] 8:47 pm: Well, let's not get too far ahead of ourselves. I want to be conservative about one point in particular: We don't yet know how long-lasting the effect of working memory training is. We are working on that this very minute, but we don't yet know the answer.

[Dr. Jonides] 8:49 pm: One thing we do know, though, is that we can now demonstrate what happens in the brain as a function of working memory training. We haven't published this result yet, but our data suggest that what happens is that the circuitry that is responsible for working memory DECREASES in activity with more training. So, this then frees up this circuitry to work on other aspects of problem solving. Essentially, you get better at the memory part of thinking, freeing up those parts of the brain to devote

[Dr. Jonides] 8:49 pm: to other parts of the thinking process

[courtney] 8:50 pm: That is really interesting: the brain gets more efficient, so it can devote resources to other things?

[Dr. Jonides] 8:51 pm: Exactly. The process makes a whole lot of sense, really. If you have a limited brain capacity to devote to a task, you're better off using less of it on the memory processes that you need.

[courtney] 8:54 pm: That is really exciting, especially if you consider that if the brain then gets more practice at those "upper level" processes, it might then also become more efficient at those as well.

[Dr. Jonides] 8:54 pm: Indeed, that's a good inference. Unfortunately, no one has found a way yet to train those upper level processes. That would certainly be an important development.

[courtney] 8:57 pm: I am always struck by the similarities between the brain and muscles, for example: training working memory almost sounds like building up your general strength, which you need if you want to train to be a great athlete or dancer.

[Dr. Jonides] 8:58 pm: Others have commented on just the same thing. But the analogy is not perfect. When you train muscles, you actually grow new striated muscle fiber, but you don't grow new neurons, at least in the brain as a whole. But the analogy might carry to the synapses between neurons, which certainly do grow with training.

[isanders] 8:58 pm: Practically speaking, teachers could easily devote the time they spend to their "Do Now" activities at the beginning of class to training WM with perhaps better quality results.

[Dr. Jonides] 8:59 pm: Not a bad thought. We have found that as little as 15 minutes of training per day is effective.

[isanders] 8:59 pm: Thank you for all your insights on this important topic. I've enjoyed it immensely!

[courtney] 9:00 pm: Dr. Jonides, thank you so much for your time and for sharing your knowledge with us!

[Dr. Jonides] 9:00 pm: I have also. Thank you for participating.

Appendix F
Sample Weekly Strategy Schedule

<u>Monday:</u> 2 activities

- <u>30 second relaxation:</u> Students close eyes, sit at desk with hands together, listening to their breathing, teacher quietly and soothingly talks about listening to their breathing
- <u>Auditory Digit Span Forward</u>
    -
    - 3 digit spans, i.e., (7, 1, 9) – 5 different combinations
    - 4 digit spans, i.e., (3, 8, 0, 2) – 5 different combinations
        - Make up your own number series between 0-9 for each digit span. You can repeat numbers in a span if you choose to do so.
        -
        - Students write number series down and hand in for you to tally.
        - When target students reach 80% accuracy for 3 <u>and</u> 4 digit span series, we will increase the series to 4 and 5 digits, etc.

<u>Tuesday:</u> 2 activities

- <u>30 second relaxation:</u> Same as above
- <u>Auditory Digit Span Backward</u>
    - Same as above only students write the number series down in reverse order

<u>Wednesday:</u> 2 activities

- <u>30 second relaxation:</u> Same as above
- <u>Auditory Word Span Repetition</u>
    - 10 presentations of series of words in a monotone delivery
        - 1 syllable words, i.e., (car, boat, hair, pen, bird) – 5 different words
        - 2 syllable words, i.e., (upstairs, outside, pencil) - 5 different words
            - You may use the same words in a series if you choose to do so
            - Students write down word series after hearing all the words
            - Keep using 1 and 2 syllable words. If the students reach 100% accuracy, we may consider increasing to 3 syllable words

<u>Thursday:</u> 2 activities

- <u>45 second relaxation:</u> Same as above
- <u>Auditory Serial Addition Span</u>
    - You will prepare a series of numbers from 0 – 0
    - In a monotone deliver, you will say the first 2 numbers with a pause in between them. The students are to add together the last 2 numbers they hear. <u>They will listen to and figure out a series of simple, 1 digit addition problems.</u>
        - If you say 1 (pause) 7, they will write down 8. Then you will say only one number, 3, and they must add that to the number they heard you say before the 3 which was 7. They should write down 10. (They will be thinking about the answer to the previous addition problem and probably become confused at first until get some practice at remembering the numbers you *say* and remember that those are the numbers they must add together. They are not adding each number to the answer they just calculated. They have to learn to

hold the numbers you say in their mind, manipulate them, and write down the answer.

Friday: 2 activities

- 60 second relaxation: Same as above
- Single *n*-Back Task with numbers (auditory only, not auditory *and* visual)
    - Prepare a number span with enough numbers to include 10 *n*-backs presented in a random order.
        - Say a few numbers, then say, "What's 1 back from the last number I said?" Write it down." (Eventually, you will just have to say, "What's 1 back?") Vary the amount of numbers you say before you ask them to write down 1 back.
        - When your target students get 80% correct, increase the *n* to 2 back. Say a few numbers (varying the amount) and then say, "What's 2 back? Write it down."
        - When your targets students get 80% correct, increase the *n* to 3 back and continue increasing the *n* as far as you can, using 80% accuracy as your standard.

Appendix G
Focus Group Questions

1. Do you consider yourself a teacher or a teacher of mathematics, a teacher of science, a teacher of language arts, a teacher of humanities?

2. Is there a difference?

3. Are you tied to your curriculum? What does that mean?

4. Are you tied to student achievement/learning? What does that mean?

5. Can you be tied to both?

6. Is one more important than the other?

7. Will you consider continuing relaxation during class? How many minutes per class?

8. What differences did you observe among the students with the working memory exercises?

9. Are they worth continuing next year?

9a. Should they continue to be varied everyday or should they always be the same?

9b. how much time will you be willing to spend on them?

10. Are you interested in teaching your students about how their brains work?

11. Should we develop analogies/metaphors as a way to connect new information to old?

Appendix H
Interview Questions

1. How is the project going? (Positives? Negatives?)

2. Is anything different about this year from last year? (Pro? Con?)

3. Are the professional articles and discussions helpful to your teaching practice? Do they influence your teaching practice at all?

4. Have you changed any aspect of your teaching practice as a result of this project?

5. Through this project, can I convince you to change your teaching practice to any degree?

6. Are the selected strategies appropriate for your students or should they be adjusted?

7. Are the selected strategies appropriate for your teaching situation or should they be adjusted?

8. Will you discuss your opinion about dedicating class time daily to implementing "stand-alone" strategies that are outside your curriculum?

9. Can we reconsider some strategies that might be attempted daily as you deliver the curriculum (use of analogies; adding a unit on the brain and learning a la Carol Dweck, spelling core vocabulary words backwards; etc)?

10. If necessary, would you consider extending the project through the second marking period or should it conclude at the end of the first marking period?

11. Please write a brief statement of your assessment of the project to date. Include observations and opinions about the impact of the project (the professional articles and the strategies) on your teaching practice. Will your teaching practice change as a result of this experience by the time we are finished?