PREDICTING K-12 TEACHER SELF-EFFICACY FROM NEUROSCIENCE LITERACY FACTORS

by

Tobey Lewis Nichols

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Philosophy

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ABSTRACT

The purpose of this quantitative correlational study was to explore how K-12 teachers' self-efficacy correlates to their neuroscience literacy factors--a combination of scientific concept of learning and memory and belief in neuromyths. What teachers know about learning, memory, and the brain influences their instructional strategies and achieving academic goals. The better understanding a teacher has of learning, memory and the brain, the higher efficacy teachers' have to execute the necessary actions to achieve desired teaching goals. A sample of 110 K-12 certified teachers were recruited from a large school district in East Tennessee to participate in this present study. Data was collected via a self-paced online survey. In addition to demographic information, the survey included the Conception of Learning and Memory inventory to measure teacher's neuroscientific literacy and the Scale for Teacher Self-Efficacy to measure teacher self-efficacy. Multiple regression was used to measure the correlation between the predictor variables and the criterion variable. There was a statistically significant relationship between the predictor variables and the criterion variable. Therefore, the researcher rejected the null hypothesis. On average results indicated that scientific concept of learning and memory scores were positively associated with teacher self-efficacy scores, while belief in neuromyth scores were negatively associated with teacher self-efficacy scores. Higher neuroscientific knowledge likely increases teacher self-efficacy by helping teachers understand strategies that support learning environments and instructional strategies that support the achievement of learning objectives.

Keywords: neuroeducation, neuroscience literacy, educational neuroscience, teacher self-efficacy, neuromyth, mind brain education

Dedication

This dissertation is dedicated to all those who loved me and supported me through the process. This dissertation is for them and because of them.

To my wife, thank you for partnering with me to make this dissertation possible, financially and logistically. You were generous to allow me to take time to complete this dream. I love you for always supporting my crazy dreams, even when you don’t understand them.

To my daughters, Emma and Callie, thank you for allowing Dad to sneak away to read and write. I hope one day you understand the value of the time I took to work on this dissertation. I love you more than anything.

Acknowledgments

I want to acknowledge all the teachers who taught me along the way and equipped me with the tools I needed to be successful.

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List of Abbreviations

Conceptions of Learning and Memory (CLM)

International Mind, Brain, and Education Society (IMBES)

Teacher Self-Efficacy (TSE)

Teacher Sense of Self-Efficacy Scale (TSES)

Scale for Teacher Self-Efficacy (STSE)

Variance Inflation Factor (VIF)

Visual/Auditory/Kinesthetic Model (VAK)

Visual/Auditory/Read-Write/Kinesthetic Model (VARK)

CHAPTER ONE: INTRODUCTION

Overview

The purpose of this cross-sectional, quantitative correlational study is to determine how accurately teacher self-efficacy can be predicted from a linear combination of neuroscience literacy factors (i.e. scientific concept of learning and memory and belief in neuromyths) for K-12 teachers. Chapter one provides background on the field of educational neuroscience, the influence of knowledge and misconceptions of the brain, and teacher self-efficacy. The background also includes a theoretical framework for this present study. The problem statement identifies the importance of investigating the effect of teacher's scientific concepts and misconceptions of the brain on teacher self-efficacy. The chapter concludes with the present study's research question and definitions of key terms.

Background

Misconceptions of learning and memory are prevalent in education and need to be addressed because they impact teachers' instructional practices (Kim & Sankey, 2017). To address this concern, neuroscience can be employed to promote growth of pedagogical content knowledge by reinforcing what teachers know about their subject matter and their students' learning (Coch, 2018). Educational neuroscience utilizes interdisciplinary collaboration to develop research based best practices founded on what neuroscience, cognitive science, and biology are discovering about the mechanism that supports human thinking and learning (Dubinsky et al., 2019). While the fields of neuroscience, cognitive science, and education are correlated in regard to what they aim to accomplish, it is only in the past few decades that an interdisciplinary approach has been applied to incorporate the traditionally explanatory field of neuroscience with the practical approach of education. Educational neuroscience is a discipline designed to create dialogue between research and practice to improve the practical application of research and better understand the legitimacy of education practices (Dubinsky et al., 2019; Kim and Sankey, 2017).

Historical Background

During the early 1990's the field of educational neuroscience, also commonly referred to as neuroeducation or mind, brain, and education, began to emerge as part of the brain-based education movement. Brain-based education proponents advocated that informing teachers about how the brain processed information would enrich instructional practices (Cain & Cain, 1990). This emerging field was initially met with resistance by Bruer (1997) who questioned the validity of how fields like neuroscience could have meaningful implications on the field of education. Despite resistance from many in the different disciplines that comprise the interdisciplinary field of educational neuroscience, the new discipline pushed forward. The legitimacy of the field further developed with the formation of the International Mind, Brain, and Education Society (IMBES) in 2004 (International Mind, Brain, and Education Society, 2004). In 2007 IMBES created the Mind, Brain, and Education Journal at Harvard University "to promote the integration of the diverse disciplines that investigate human learning and development—to bring together education, biology, and cognitive science to form the new field of mind, brain, and education," (Fischer et al., 2007, p. 1). As of 2021 prestigious universities such as Harvard, Columbia, Vanderbilt, and Johns Hopkins offer graduate degrees specifically in Mind, Brain, and Education.

Educational neuroscience cannot offer all the solutions to problems in education, but it does provide practical applications for educators to improve curriculum and instruction. However, for these benefits to be realized, there are several quandaries that need to be overcome.

For example, neuroscience and education professionals often develop contrasting expectations of each other that challenge the long-term collaboration of the two fields (Edelenbosch et al., 2015). At the root of these mismatching expectations are philosophical differences. Palghat and associates (2017) suggested that educational neuroscience encounters the same problems of many interdisciplinary fields and experiences philosophical differences that impede collaboration due to convoluted communication. To overcome these philosophical differences, defining clear expectations and a common vocabulary is necessary to establish communication standards respective to both fields. Equally important, both researcher and practitioner need to be versed in the common vocabulary. Finding a common vernacular is important to helping educators access the information from other disciplines, but it is also important to research educators' current knowledge of neuroscience and how this affects their practice.

Educational neuroscience continues to develop but needs to define its place in research to progress and influence the field of education; however, researchers from both disciplines need to work together to define this field of research to improve teacher practice and support students' learning (Hruby, 2012). It is important to investigate the barriers that impedes these two disciplines from collaborating. Just because material is available does not mean the benefiting parties are prepared to access the knowledge. Examining how current knowledge influences teacher practice can provide findings that might change educators' perception of the applicability of educational neuroscience.

Society-at-Large

Although some challenge educational neuroscience as misguided and unable to achieve its ultimate goals, educational neuroscience needs to be further investigated because its potential to further teacher knowledge and change teacher practice. Bowers (2016) argued that while educational neuroscience provides insight into the mechanistic nature of learning, behavior is the measure of learning, presenting psychology as better suited to help educational professionals improve their instructional practice. This, however, seems myopic, only focusing on the product and not the process of creating meaningful instruction. Psychology offers important concepts for outcome measurement but does not offer the same mechanistic explanations for how learning occurs. Allowing teachers to comprehend how learning is occurring provides educators an important understanding that allows them to make informed pedagogical choices. Only measuring behavior does not offer insight into reasons for that behavior occurring and neglects valuable information that teachers can leverage to improve their instructional practices and student outcomes.

Oversimplifications of research and misinterpretations of research leads teachers to misunderstandings about how students learn and brain functionality (Gardner, 2020). Because understanding about the brain influences instructional practice, researching misconceptions of the brain is an important entry point into providing teachers with practical knowledge that could inform their practice. While neuromyths, misconceptions about how the brain functions, are prominent among pre- and in-service teachers, instruction in neuroscience has shown to decrease the promulgation of neuromyths (McMahon et al., 2019). However, neuroscience instruction does not completely eradicate brain misconceptions, making it increasingly important to create systematic and longitudinal approaches that dispel neuromyths (Macdonald et al., 2017). Deeply ingrained misinformation takes time to eliminate, especially the practical application of such misinformation. Therefore, single session professional development is an inadequate avenue for dispelling neuromyths or building scientific concepts of learning and memory.

Teachers and student teachers surveyed about neuromyths reported learning those myths during their teacher preparation programs (Tardif et al., 2015). Such beliefs are propagated through teacher preparation programs infecting the educational system. Such myths need to be corrected at the university level but those already practicing need to be informed of these misconceptions. Teachers are more likely than student teachers to believe in neuromyths (Tardif et al., 2015), making professional development all the more important.

Teachers lack skills in reading, interrupting, and applying research, resulting in neuroscience-specific professional development particularly challenging. Dekker and colleagues (2012) found that teachers who demonstrate significant general knowledge about the brain also believed in more neuromyths, especially those associated with commercial products. “These findings suggest that teachers who are enthusiastic about the possible application of neuroscience findings in the classroom find it difficult to distinguish pseudoscience from scientific facts” (Dekker et al., 2012). Providing information to teachers without context of how to apply it performs a disservice to both teachers and researchers. Teachers need to not simply be informed of the misconceptions but also the implications of such misinformation. Furthermore, teachers need to develop skills and design resources to read and interpret research for themselves so that they can initiate their own foundational knowledge about subjects they find important. Professional development that occurs over time are an opportunity for developing skills for reading and interpreting research.

Theoretical Background

While educational neuroscience might show promise for equipping teachers with tools to make informed instructional decisions, teachers need to apprehend the information as useful and ultimately be willing to learn the content. In-service teachers seeking professional development need to be considered as adult learners, and their goals pragmatic by nature. Adult learners seek learning opportunities that are practical (Knowles, 1972) and that will help them achieve goal-facilitated tasks (Knowles, 1977). Knox (1980) proposed that adult learning opportunities needed to help to develop proficiencies that will improve the learner's ability to complete target tasks. For teachers, then, they seek out professional development opportunities that they perceive as useful and supportive of their instructional practices. Therefore, educational neuroscience needs to be seen as a pragmatic tool for teachers and something that is going to help them achieve instructional goals. Teacher self-efficacy is a teacher's self-perceived ability to achieve teaching and instructional goals within the classroom (Tschannen-Moran & Hoy, 2001). A teachers' knowledge and experience are contributing factors to the development of the teacher self-efficacy (Pfitzner-Eden, 2016). Because educational neuroscience can catalyze teachers' prior knowledge and connect information to their current practices, it is important to better understand how teachers' current scientific concept of learning and memory and belief in neuromyths correlate to their self-efficacy.

Problem Statement

Teachers need to be provided knowledge and professional development opportunities about how individuals learn so they can implement informed instructional decisions. Misconceptions need to be addressed because a higher rate of belief in neuromyths is negatively associate to student centered instructional practices (Ruhaak & Cook, 2018). It is important to address misunderstandings about the learning process and provide teachers current research about how students learn. Teachers' participation in neuroscience-based professional development appears to dispel belief in neuromyths (McMahon et al., 2019) and alter teachers' perceptions of their instructional practices (Howard-Jones et al., 2020). Furthermore, teachers demonstrate an interest in educational neuroscience, recognizing the potential for improving instructional practices (Serpati & Loughan, 2012). Despite prevalent teacher interest, little research has been conducted to examine how teacher knowledge of learning processes contributes to their self-efficacy. Self-efficacy develops from individual's knowledge of how to effectively interact with their environment (Bandura, 1977). Because neuroeducation helps to improve teacher's knowledge of scientific concepts about learning and memory and dispel neuromyths (Macdonald et al., 2017), understanding of basic neuroscientific principles could help to bolster teacher efficacy by improving their understanding of how to better interact with their environment as teachers. The problem is that the empirical research literature has not fully addressed how teachers' neuroscience literacy, including teachers' scientific concept and misconception about the brain influences the important teacher characteristics of self-efficacy (Dekker et al., 2012; Howard-Jones et al., 2020).

Purpose Statement

The purpose of this quantitative correlational study is to explore how K-12 teachers' self-efficacy correlates to their neuroscience literacy factors. Teachers' neuroscience literacy needs to be considered as a holistic measure of how teachers perceive the brain's functioning during learning. Not only does a teachers' understanding of empirical findings of how the brain works influence their instructional choices (Schwartz et al., 2019), but misconceptions about learning also have a significant impact on teachers' instructional practices (Ruhaak & Cook, 2018). Therefore, teachers' neuroscience literacy is comprised of a combination of two separate predictor variables, their scientific concept about the brain's role in learning and memory and their belief in neuromyths. The predictor variable of belief in neuromyths represents common misconceptions about the form and function of the brain, leading to misunderstandings of how the brain functions during learning (Gardner, 2020). Misconceptions about the brain will be measured by participants' agreement with 11-question survey, using a 4-point Likert scale (Grospietsch & Mayer, 2019). Scientific concept of learning and memory, the second predictor variable, represents knowledge about the function, structure, and anatomy of the brain, including how the brain influences students' learning and development (Grospietsch & Mayer, 2019). Scientific concept of the brain will be measured by participants' agreement with 11-question survey, using a 4-point Likert scale (Grospietsch & Mayer, 2019). The criterion variable, teacher self-efficacy is an educator's confidence in his or her ability to execute the necessary actions to achieve desired teaching goals and objectives (Tschannen-Moran & Hoy, 2001). Teacher self-efficacy will be measured by self-reported responses to a 12-question survey, using a 9-point Likert scale, asking participants to identify their confidence in their ability to implement instructional practices, manage a classroom, and engage students in learning activities (Pfitzner-Eden et al., 2014). This present study seeks to investigate how scientific concept of learning and memory and belief in neuromyths predict teacher self-efficacy from a sample of K-12 teachers at a large school district in the southeastern United States.

Significance of the Study

Primary and secondary teachers in the United States are expected to understand their respective curricula and to choose instructional best practices for implementation, but it is not clear if teachers recognize the science behind how students learn. Neuroscience literacy can give teachers reasoning for their instructional decisions, improving their teacher practice and likely their teacher self-efficacy. This present study is an important component in beginning to construct a model of influences on teachers' perceptions of neuroeducation and their willingness to participate in neuroscience-based in-service professional development.

While implementation of neuroeducation has demonstrated initial success in reducing neuromyths (McMahon et al., 2019) and improving teacher practices to be more student-centered (Schwartz et al., 2019), little research has been conducted to study how knowledge of learning affects a teacher's self-efficacy. In order to improve teacher perception of neuroeducation, research needs to be conducted to investigate what traits contribute to teacher's perception of neuroeducation. Dekker and colleagues (2012) found that educators with the best working knowledge about the brain were also the same with the greatest rate of belief in neuromyths. Because the relationship between neuromyths and neuroeducation is not clearly understood, it is difficult to determine how to help make teachers aware of the benefits neuroeducation offers for educational practice. While self-efficacy positively affects an educator's practice, it has not been studied in-depth (Pfitzner-Eden, 2016). A noted problem with the construct of teacher self-efficacy is a lack of research on the contributing factors and origin of teacher efficacy (Klassen et al., 2011). This study proposes to examine important teacher characteristics to better understand teacher self-efficacy.

Research Question

RQ1: How accurately can teacher self-efficacy be predicted from a linear combination of neuroscience literacy factors (scientific concept of learning and memory and belief in neuromyths) for K-12 teachers from a large school district in the southeastern United States?

Definitions

1. *Educational Neuroscience*- A growing field that aims to apply findings from neuroscience and cognitive science to the practice of education. Serves as an interchangeable term with mind, brain, and education and neuroeducation (Ansari, et al., 2012)

2. *Neuromyth* – The assumption that a given educational practice is founded on scientific findings; however, the practice lacks empirical support or research shows to be false. (Gardner, 2020)
3. *Neuroscience Literacy* - An individual's knowledge about how the brain works and the ability to correctly identify fallacies about the brain (Grospietsch & Mayer, 2019).
4. *Teacher self-efficacy*- A teacher's belief of their ability to execute the necessary actions to achieve desired teaching goals and objectives (Pfitzner-Eden, 2016; Tschannen-Moran & Hoy, 2001)

CHAPTER TWO: LITERATURE REVIEW

Overview

The purpose of this literature review is to present essential elements of educational neuroscience, its ability to build teachers' neuroscientific literacy, and the influence of neuroeducation on teacher self-efficacy. This chapter opens with the theoretical groundwork of Bandura's (1977) theory of self-efficacy and its contributing factors. The chapter then provides a thorough review of the literature relevant to educational neuroscience, neuromyths, origins of teachers' neuroscientific literacy, and the benefits of neuroeducation. The chapter ends with a summary.

Theoretical Framework

To further the viability of educational neuroscience as a practical field for improving student outcomes, it is vital to examine how to communicate information from neuroscience, psychology, and cognitive science to educators. Additionally, educational neuroscience needs to research how to encourage teachers to participate in professional development opportunities that provide empirical findings that improve neuroscience literacy and instructional practices. The theory of self-efficacy is important in investigating how teachers perceive their abilities as educators and how that influences their teaching practice. Understanding teachers' current neuroscientific literacy can help to better understand how current neuroscience findings are making their way into teachers understanding of memory and learning. Furthermore, understanding the connection between neuroscience literacy and teacher self-efficacy can generate professional development opportunities for teachers that increase their neuroscience literacy and improve teacher self-efficacy.

Self-Efficacy

Self-efficacy is important in understanding individuals' self-perceptions of their abilities and willingness to participate in particular activities. Bandura (1977) defined self-efficacy as an individual's belief in their ability to effectively perform a target behavior necessary for achieving a desired outcome. As individuals observe and interact with their environment they must choose how to act within that environment. Self-efficacy then is an individual perceived ability to effectively interact with their environment. When an individual perceives a target behavior as unattainable or their abilities unsuited for preforming the behavior, they will likely forego the task to avoid failure. Likewise, individuals will attempt and persist during tasks when they believe they have the ability to attain a target behavior (Bandura 1977).

The theory of self-efficacy originated as a key concept of Bandura's social cognitive theory. Social cognitive theory theorizes that learning is the product of interactions between an individual's cognitive factors, behavior, and the environment in a process called reciprocal interaction (Bandura & Walters, 1977). Cognitive factors include mental capabilities, beliefs, and understandings, while behavior are the actions taken by an individual within the environment, and environment refers to the external factors and context an individual interacts with (Schunk, 2019). All three of these constructs interact with each other to shape an individual's experience. An individual's cognitive factors influence their behavior and choices within the environment. Individuals leverage their personal understanding of the environment to identify what behaviors will yield desired outcomes and enact certain behaviors. Once an individual enacts a given behavior it will change and shape the environment. Similarly, an individual's behavior effects the person because individuals internalize the behaviors, they perceive to have produced desired outcomes within the environment (Bandura & Walters, 1977). The complex processes of reciprocal interactions lead to learning by developing a person's understanding of how behaviors interact within a given environment and informing their future choices.

Learning how behaviors interact with the environment takes place through both enactive and vicarious learning. Enactive learning takes place through an individual's direct behavior within the environment and the internalization of the results, while vicarious learning takes place by an individual observing others' behaviors within the environment and internalizing the results (Schunk, 2019). Both enactive and vicarious learning allow the individual to recognize patterns of how behaviors interact with the environment and develop symbolic representations that inform how the individual will take action in the future (Bandura, 1986). Vicarious learning allows individuals to begin to understand novel behaviors that they don't have experiences with themselves and to build more complex understandings of behaviors they are familiar with. Enactive learning provides individuals with powerful experiences with behaviors by collecting firsthand understandings of how behaviors interact with the environment. Much of learning happens through a combination of these two constructs (Schunk, 2019).

Enactive and vicarious learning through reciprocal interaction is reinforced by the idea of consequences. Within an environment individual observe the consequences of behaviors and how they interact with the environment. These observations can happen through direct experience or vicariously. When interacting through direct experience, individuals create hypotheses of what behavior, or combination of behaviors will yield a desired outcome within the environment (Bandura, 1971). Conversely, modeling offers individuals vicarious opportunities to see how certain behaviors interact with the environment (Bandura, 1971). The consequences associated with the behavior(s) witnessed, whether favorable or negative, shape an individual's future behaviors. When behaviors yield a favorable outcome, they reinforce the effectiveness of a given behavior. When they have unfavorable outcomes, it deters an individual from replicating the behavior in similar future situations. When trying to face a new situation an individual will consider possible consequences to potential behaviors and select the most favorable outcome (Bandura, 1971). Consequences work as a motivator when potential consequences are highly desired and discourage individuals from taking actions when the potential consequences are too risky for the individual (Bandura, 1971). Self-efficacy evolves from an individual's understanding of behavioral interactions with the environment. Individuals develop mental models of what behaviors are effective in a given situation and develop a self-perception of their ability to participate in these behaviors. Consequences associated with these behaviors help to develop and reinforce an individual's efficacy (Bandura, 1977).

Social cognitive theory examines learners as active participants within their environment, constructing knowledge from their interactions and observations. A key component of a person's interaction with the environment is their personal agency, the ability to exercise control over events and environments that affect their lives (Bandura, 1992). An individual's sense of self is in part defined by their understanding of themselves in relationship to environmental variables, including others (Garrett & Hough, 2018). An individual's agency then is based on their perception of how events, others, and the environment will affect their daily lives and their ability to successfully exercise control in situations they will encounter. Personal agency is central to social cognitive theory concept of reciprocal interaction because how a person exerts control over their circumstances will shape their experience. The behavior individuals choose to engage in will ultimately shape their outcome within the environment (Bandura & Walters, 1977). The outcome will in turn be internalized, shaping the individuals learning in that circumstance (Bandura, 1992). In the same way that the environment shapes an individual's behavior, an individual's behavior, once acted out, shapes the environment through their contribution. For teachers, their neuroscientific knowledge likely shapes their perceived agency to control the classroom because their understanding of learning and memory shapes how they perceive how learning takes place in the classroom. Teachers will then choose behaviors (i.e., instructional practices) that fit their sense of agency within the classroom, therefore shaping the environment.

A key factor of personal agency is a person's self-efficacy because their belief in their ability will drive their behavior (Bandura, 2001). Self-efficacy is not the person's actual ability to achieve the target behavior but their perception of their ability. This is an important demarcation because a person's belief in their ability influences what activities they choose to participate but not their ability at the activity (Bandura, 1977; Bandura 1997). Furthermore, when an individual has a high personal efficacy in the target behavior, they are more likely to persist during difficulties because they believe they can achieve the behavior (Bandura, 1997). Having a personal efficacy that exceeds ability helps an individual persist and develop new capabilities in the face of adversity (Bandura, 1986) and even perform better than others with similar ability levels (Bandura, 1992). Teachers' self-efficacy is important because it influences teacher's ability to persist when faced with adversity in their teacher practice (Gibson & Dembo, 1984; Tschannen-Moran, Anita, & Hoy, 1998). For example, teachers with higher self-efficacy are more likely to persist when students struggle (Gibson & Dembo, 1984). Gaining a better understanding of the constructs that shape a teacher's self-efficacy could help to improve teachers' ability to persist when faced with setbacks and adversity.

Bandura (1977) theorized that a personal efficacy is derived from four sources: (1) past accomplishments of the target behavior, (2) observations of others' experiences with the target behavior, (3) verbal persuasion, and (4) biological and psychological states. Previous encounters with the target behavior establish a bases of an individual's efficacy to successfully complete the task in the future (Bandura, 1986). For example, when an individual repeatedly fails at a task, they begin to believe that they are unable to a complete the task, therefore lowering their personal efficacy of that behavior. A sense of personal efficacy develops in relation to an understanding of other individuals (Garrett & Hough, 2018). When an individual has little, or no previous experience with the target behavior, they base their efficacy on others' experiences with the target behavior and their personal knowledge (Bandura, 1977). Additionally, verbal cues of one's ability to complete a task, positive or negative, can influence an individual's perception of their personal efficacy. These verbal cues can be internal, such as self-instruction, or external, such as exhortation (Bandura, 1977). Finally, biological and psychological states can influence a person's capacity to judge their ability to complete a target behavior. For example, extreme anxiety can inhibit an otherwise capable person from completing or participating in the target behavior (Bandura, 1986).

Of the four sources of self-efficacy discussed above, personal experience with the behavior stands as the strongest factor in developing an individual's self-efficacy (Bandura, 1997). When an individual is able to participate in a subjectively difficulty situation and successfully master the behavior their self-efficacy increases (Bandura, 1977). Conversely, failure to successfully enact the target behavior lowers the individual's self-efficacy. However, compared to low personal efficacy, a high self-efficacy seems to be less affected by failures and negative experiences because the individual is determined to preserver (Bandura, 1997). For teachers, their understanding about how the brain works to support memory and learning (i.e. neuroscientific literacy), gives them cognitive resources to choose effective teaching strategies.

An increased neuroscientific literacy allows teachers to better understand the learning process and create student centered learning experiences and achieve academic goals (Schwartz et al., 2019). Knowledge of memory and learning allows teachers to successfully engage in mastery experiences that increase their teacher self-efficacy by making choices that are supported by current research.

According to the theory of self-efficacy, individuals who lack experience in a target behavior base their efficacy on their knowledge about the environment and others' experiences with the target behavior (Bandura, 1977). For teachers who lack mastery experiences and knowledge about memory and learning, they are likely to have a low teacher efficacy because they lack the resources to identify educational best practices for their context. Preservice teachers who lack mastery experiences rely heavily on their understanding of how students learn in the classroom and from other teachers' experiences to inform their instructional practices. For example, preservice STEM teachers showed higher self-efficacy after being exposed to integrated STEM instructional modeling (Johnson et al., 2021). For in-service teachers, as they improve their neuroscience literacy, they are likely to increase the occurrence of mastery experiences because they can identify and implement research based best practices. For instance, following a neuroscience-based teacher professional development, teachers were more aware of their role in supporting student's construction of knowledge through their instructional practices (Dubinsky et al., 2013). Because self-efficacy is informed by not only mastery experience, but knowledge to choose the correct target behavior for a given situation, increased neuroscientific knowledge could help teachers feel more confident to choose appropriate instructional practices.

Teacher Self-Efficacy

Teacher self-efficacy is developed from the conceptual framework expressed by Bandura

(1977). Teacher self-efficacy is a teacher's belief of his or her ability to execute the necessary actions to achieve desired teaching goals and objectives (Pfitzner-Eden, 2016; Tschannen-Moran & Hoy, 2001). For teachers, their self-efficacy gives insight into their self-perceived abilities as a teacher and willingness to engage in key teaching domains. Self-efficacy is a key determinant of a person's agency within a particular context (Bandura, 2001) and a teacher's role in the classroom relies on their ability to practice agency by exerting orchestrating control over classroom events and environment. In a study conducted using multi-level model to investigate school-level influences on teacher self-efficacy, Pas et al. (2012) found that school-level contextual factors (e.g., enrollment and student behavior) did not significantly predict teacher self-efficacy; rather, teacher self-efficacy was predicted by a teacher's sense of preparedness. A teacher's sense of agency within the environment, based on the knowledge and abilities they were equipped (i.e., their preparedness) with gives them the conviction to be successful in the classroom. Additionally, teacher self-efficacy appears to be a key determinant in a teacher's success in instructional practices and student success (Henson, 2001). Hence, understanding a teacher's efficacy in the classroom and its contributing factors is essential in improving teacher practices and student outcomes.

While teacher self-efficacy has been a focus of research for over 40 years, the origins of teacher self-efficacy are still unclear and lack focus (Klassen et al., 2011). However, improving teacher self-efficacy starts with understanding the contributing factors of the construct. In addition to teacher preparedness correlation to teacher self-efficacy (Pas et al., 2012), a teacher's mastery experiences play a significant role in developing a teacher's efficacy. A study of German preservice teachers showed that when accounting for all four sources of self-efficacy put forth by Bandura (1977), advanced preservice teacher's self-efficacy was predominately influenced by their mastery experience (Pfitzner-Eden, 2016). This suggests that as teachers are given tools to prepare them for the classroom and have mastery experiences, they feel more confidence in their sense of agency within their classroom and ability to replicate that success in the future. Furthermore, teacher self-efficacy seems to grow over time (Pas et al., 2012), proposing that as teachers gain experience in the classroom, successful classroom interaction result in an increased efficacy of teacher practice. Therefore, identifying resources and strategies that help support teaches' classroom mastery experience, such a neuroscientific literacy, would likely increase teacher efficacy.

Teacher self-efficacy is an important teacher characteristic because of its correlation to teacher practice and student achievement. A systematic literature by Zee and Koomen (2016) revealed that teacher self-efficacy had been correlated repeatedly to positive classroom quality, such as implementing new instructional strategies and pedagogical choices. Additionally, teachers with higher self-efficacy also have more favorable perceptions of inclusive practices (Savolainen et al., 2020). Teachers that are confident in their abilities are likely not stagnant in their practice because they see the value of trying new instructional strategies that will benefits their desired outcomes. People with higher self-efficacy are willing to preserver when met with a challenge while trying to achieve a desired outcome (Bandura, 1997). Similarly, efficacious teachers are likely willing to try new instructional strategies because they are not dissuaded by the prospect of failure. Rather, the opportunity to try new instructional strategies and inclusive practices are an opportunity to improve further.

In addition to teacher practices, teacher self-efficacy is also linked to student outcomes. A systematic literature review by Zee and Koomen (2016) showed that all but one article reviewed reported that teacher self-efficacy had a direct impact on student overall achievement. Similarly, a meta-analysis of 16 studies found a positive correlation between teacher efficacy and student achievement, but not across all teaching self-efficacy domains (Kim & Seo, 2018). Because teacher self-efficacy can fluctuate across teaching domains (Zee et al., 2017), further investigation via meta-analysis showed that teacher self-efficacy subscales of instructional practices and student engagement were correlated with higher student achievement, but classroom management subscales were not significantly correlated (Kim & Seo, 2018). Techer efficacy derived from teacher practice was likely a more significant contributor to student success because it directly supported teacher and student goals. While classroom environment plays an important role in the learning process, teacher self-perception of their instructional ability would directly support student learning by directing a teacher to select pedagogical choices that best support student achievement of learning goals and objectives. A teacher's understanding of learning and memory underlies teacher self-efficacy by helping teachers understand how to make informed pedagogical choices. Investigating avenues for improving teacher self-efficacy, such as neuroscience literacy, could be a way of improving teaching practices that help support student outcomes.

High teacher self-efficacy also appears to shape student's perception of their teachers and foster student-teacher relationships. In a study of 51 math and science teachers, Miller and associates (2016) found that higher teacher self-efficacy was associated with students having higher perception of their teacher's competency and higher levels of respect for their teachers. The relationships between students and teachers are an important piece of the learning environment and a teacher's confidence in their abilities helps to foster these relationships. Equally, student teacher relationships indirectly shape teacher self-efficacy (Zee et al., 2017). Positive student-teacher relationships increase teacher perception of student engagement, while poor student behavior increases a teacher's perception of conflict and lowers student specific teaching efficacy. There is a reciprocal nature between self-efficacy and interaction with the environment that must be considered in educational research (Schunk & Mullen, 2012). The correlation of teacher self-efficacy and student teacher relationship shows the reciprocal nature of teacher self-efficacy. Higher teacher self-efficacy correlates to positive teacher and student outcomes, but positive teacher and student outcomes foster master experiences that in turn appear to raise teacher self-efficacy. Investigating avenues for improving teacher self-efficacy, such as neuroscience literacy, could be a way of improving teaching practices that help support student outcomes and perpetuate a teacher's efficacy over time.

Future research is needed to help understand how to improve teacher self-efficacy because of its benefits to teachers and students. Targeted teacher professional developments have shown to increase teacher self-efficacy when focusing on improving teacher practice (Yoo, 2016). Yoo (2016) provided teachers with a 5-week online teacher professional development opportunity that looked to improve teacher self-efficacy by providing teachers with instructional best practices, observational assignments, implementation opportunities, and instructional feedback. After 5 weeks teachers reported higher self-efficacy. By providing teachers with information that empowered them to obtain mastery experiences and better understand their teacher practices, teachers' efficacy was improved. Similarly, teachers with a higher perception of preparedness for teaching had higher self-efficacy (Pas et al., 2012). While the predictors of teacher self-efficacy have lacked attention (Henson, 2001), educational neuroscience could be a prime opportunity to better understand the development of teacher self-efficacy and enrich teacher practice through improving teacher self-efficacy. Neuroscientific literacy helps teachers better understand the science of learning and make informed instructional decisions. As a result, teachers are likely to feel more prepared, leading to more master experiences and likely develop a higher efficacy of their teaching practices.

Related Literature

Educational neuroscience is an emerging interdisciplinary field of research with the goal of combining the research-based field of neuroscience and psychology with the practical field of education. However, teachers often lack the foundational resources to access and correctly interpret research from neuroscience and psychology. This leads to educators holding misconceptions about the brain, known as neuromyths, and an inability to correctly identify facts about the brain (van Dijk & Lane, 2020). Neuroscience and psychology offer a way to teach educators how to use empirical findings to better understand how students learn and choose effective pedagogical strategies. For instance, when teachers receive instruction in neuroscience, teachers change their instructional strategies to be more student centered (Dubinsky et al., 2013). For preservice teacher this instruction should come from their teacher preparation coursework and in-service teachers should be receiving this from professional development opportunities.

Educational Neuroscience

Educational neuroscience originates from a desire to utilize the findings from neuroscience and other cognitive sciences to inform educational practice. A history of neuroscience helps to understand the origins that inspired educational neuroscience. The study of the brain can be traced back to the first visual description and mentions of the brain in seventeenth century BCE Egypt; however, at this time the heart was seen as the origin of the mind and thought (Gross, 1998). In the early mentions of the brain, Egyptians had noticed a change in behavior following battlefield injuries, making it the first recognition of the brain's control over an individual's behavior (Kandel et al., 2000). Later, Alcmaeon of Croton wrote during the fifth century BCE as the first to recognize the brain as the source of thought and processing of sensory information following his dissection of the eye (Gross, 1998). Leonardo Di Vinci's dissections and inquiry into the neuroanatomy furthered understanding about the connection of the body to the brain as the perpetuator of thought and reasoning (Gross, 1998). Similarly, the drawings and descriptions of Vesalius in his seminal work, *De Humani Corporis Fabrica Libri Septem*, gave detailed accounts of the anatomy and structure of the brain (Catani & Sandrone, 2015).

During the 18th century through the early 20th century, discoveries of the brain evolved and were driven by connections of behavior to injuries and autopsies of the brain, not just describing the anatomy of the brain (Gross, 1998). A prime example of this is the popular case study from 1848 of Phineas Gage's injury to his prefrontal cortex from a railroad spike, leading to observations of the prefrontal cortex's role in executive function and emotion control (Van Horn et al., 2012). During the turn of the twentieth century, new staining techniques made it possible for scientist to improve brain mapping by using thin slices of the brain to identify differentiated areas of the brain; this improvement to cartography helped to improve localization of behavior through associated symptoms (Catani & Sandrone, 2015). Brain mapping evolved again starting in the 1930's when scientist used electrodes to stimulate various areas of animal subjects' brains in order to identify control centers in the brain (Catani & Sandrone, 2015). Finally, the invention of post-modern imaging techniques, such as magnetic resonance imaging (MRI), allowed scientist to gain a better understanding of brain function in living test subjects (Catani & Sandrone, 2015). During the rapid growth of interest in the brains anatomy and function in determining behavior, neuroscience emerged as an academic discipline in the second half of the 20th century (Shepard, 2009).

Human interest in the brain has moved beyond simple neural anatomy and cartography to localizing functions and processes in the brain. The evolution of neuroscience from the Egyptians to post-modern imaging techniques have allowed neuroscientist to gain a better understanding of the anatomy, structure, and function of the brain. Emerging from the findings of neuroscience, the trend of brain-based education developed in the early 1990's to enrich education practices with the findings of neuroscience (Cain & Cain, 1990). However, it wasn't until the early 2000's that the formal discipline of educational neuroscience began with the formation of the International Mind, Brain, and Education Society (IMBES) in 2004 (International Mind, Brain, and Education Society, 2004).

Byrnes and Vu (2015) defined educational neuroscience as the intersection of psychology, neuroscience, and education, "'memory' for psychology, 'localized function' for neuroscience, and 'instructional approach' for education" (p. 222); in these overlapping boundaries educational neuroscience aims to establish its place as an academic discipline. According to Campbell (2011), educational neuroscience advances beyond researching the physiological and biological foundations of brain function to applying the field of neuroscience to help solve practical problems and catalyze progress in education. Through an attempt to grasp the mechanisms that support the process of learning, educators can begin to develop more meaningful curriculum and choosing the most appropriate instructional practices. However, the emerging field has experienced trouble finding traction because of the difficult nature of connecting the objective findings of the brain and the subjective nature of measuring individuals' behaviors (Campbell, 2011).

Academic disciplines are defined by the boundaries of what information they explore and discuss; in interdisciplinary work, boundaries are crossed between disciplines to generate new knowledge that neither discipline would typically generate on their own. Boundary work is used to understand the academic boundaries of disciplinary work and how disciplines are separated from each other (Friman, 2010). Educational neuroscience needs to identify the differences in each discipline and work to find common ground. Edelenbosch and colleagues (2015) found that neuroscientists and educators projected different expectations, epistemological difference, and differing professional language that made collaboration between researchers and practitioners difficult. The demarcations that each group creates separates them. If educational neuroscience is going to find practical applications, it is going to need to find a common language between the various disciplines. Similarly, it will be essential that the discipline develop appropriate theories that help to find common ground among the discipline.

Traditionally, education has relied heavily on psychology to explain how individuals learn and to develop best pedagogical practices to support learning. Psychological theories focus on explaining human behavior and the process of changing human behavior but lack the ability to define the underlying mechanisms that define human behavior. While the instructional expertise found in educational psychology provides valuable behavioral data on human change that could support the discovery of underlying mechanisms of learning, conversely, neuroscience can be applied to illuminate how the brain functions under certain conditions and what instructional practice actually facilitates changes occurring (Berninger & Corina, 1998). Educational neuroscience aims to find commonality between behavioral based research and the biophysiological foundations of behavior, which is an important step in supporting the development of individuals. Although the disciplines of neuroscience and education seem to have established philosophically different approaches, Samuels (2009) suggested that the two fields collaborate by focusing on shared problems that the disciplines try to solve and holding purposeful discourse on the different assumptions and approaches to solving the problems. Furthermore, Samuels suggested that, although the disciplines are foundationally different, their goals are similar, meaning that, through discourse on differences, new solutions can be developed for the purpose of helping individuals.

Neuromyths

An important trajectory of research within educational neuroscience is that of neuromyths. Neuromyths are misconceptions and misrepresentations of how the brain or mind functions (Gardner, 2020). At the center of educational neuroscience is the goal of investigating topics in neuroscience and establishing their applicability in education; likewise, using educational practices to inspire neuroscientific findings. However, education practitioners often misunderstand and misrepresent information of the functionality of the brain and its application to educational practices. The origin of these neuromyths in education are still being understood by researchers.

Neuromyths in education appear to be developed from two key factors. First, the oversimplification of complex findings in neuroscience, interpreted by educational professionals untrained in neuroscience, seems to lead to confusion about their applicability (Gardner, 2020). With best intentions, educators find information that is pertinent and, in an attempt to make it accessible to educators, obscure the true nature of the findings. This misinformation leads to teachers making misinformed pedagogical choices. Another origin of neuromyths are teacher preparation programs. When interviewed, preservice teachers identified their evidence-based teacher preparation programs as the source of their beliefs in neuroscience (Rogers & Cheung, 2020). Educators, even teacher preparation faculty, lack training in educational neuroscience and therefore perpetuate misunderstandings of the science of learning. However, as Samuels (2009) articulated that it is easy for educators to experience a lack knowledge about the current literature in neuroscience when they have not developed the resources to explore that collection of literature. The perpetuation of neuromyths in preservice teacher education is another artifact of the chasm between neuroscience and education. It is important that educators gain training in neuroscience and other cognitive science relevant to education.

A survey conducted by Dekker et al. (2012) found that approximately half (49%) of teachers incorrectly agreed with myths presented to them. Similarly, a study by Macdonald et al. (2017) found that educators endorsed an average of 56% of neuromyths. While the myths teachers endorsed varied, more than 80% of teachers agreed with myths about the effectiveness of preferential learning styles and hemispherical dominance playing a role in learning (Dekker et al., 2012). Macdonald et al. (2017) found that 71% of all educators, and 68% of participants with high exposure to neuroscience, affirmed neuromyths about learning styles driving students' senses. Conversely, participants were able to correctly answer statements about childhood language acquisition and how extended rehearsal of information affects the structure of the brain (Dekker et al., 2012). And only 33% of participants endorsed myths about individuals only using 10% of their brain (Macdonald et al., 2017). Those who held a more philosophical view of neuroscience, compared to scientific view, and those with a more intuitive thinking style endorse more neuromyths than peers; conversely, educators that endorse a growth mindset and a higher scientific literacy endorsed less neuromyths than other participants (van Elk, 2019).

Learning Styles

Learning styles refer to individual preferences to process information in particular modalities and that learning is more effective when individual learning preferences are utilized (Pashler et al., 2009). Since the development of the learning styles hypothesis, it has been widely embraced by educators and seen as an important tool for informing instructional practices. This wide embrace is likely due to the prevalence of learning styles in teacher resources (e.g., websites, blogs, teacher preparation material, state teacher certification exams, and teacher educators), the intuitive nature of learning styles, and the self-perpetuation of the theory's popularity (Himmele & Himmele, 2021; Willingham, 2015). A review of 20 textbooks used in educator preparation programs revealed that 80% of the textbook's presented information on learning styles, with 25% of the textbooks recommending it as an instructional strategy (Wininger et al., 2019). Furthermore, Macdonald et al. (2017) found that 71% of all educators, and 68% of participants with high exposure to neuroscience, affirmed neuromyths about learning styles driving students' senses. The most commonly adopted model of learning styles is the visual, auditory, kinesthetic model (VAK), or the visual, auditory, read-write, kinesthetic (VARK) models due to their concrete and practical application based on the senses (Cuevas, 2015).

Teachers perceive differences in students and learning style theory offers a tangible way to differentiate to these differences, however it isn't effective (Himmele & Himmele, 2021). Ironically, learning styles looks to address the uniqueness of each student by categorizing them, therefore stripping them of their uniqueness. Ultimately, the attempt to categorize learners using learning styles fails to meet their unique needs (Willingham, 2015). A review of the research by Pashler and collogues (2009) found that despite the vast body of work done on learning styles, empirical research has not used rigorous methodology to support the learning style hypothesis; in fact, they found that most rigorous research was contradictory to the hypothesis. For example, Coffield et al. (2004) found that students do not perform better than their peers when receiving information in their preferred modality.

The learning style myth seems to be problematic because it categorizes learners and potentially limit their comprehensible input. Brown (2014) argues that learning styles directs learners to focus on their strengths and neglect their weaknesses. Additionally, identification of a particular learning style may limit a learner's willingness to engage in other learning styles and lower their efficacy in other modalities (Willingham, 2015). The use of learning styles are also time intensive to utilize and without empirical support the theory does not justify the use of instructional time to determine and implement learning style based instructional practices (Rohrer & Pashler, 2012). Rather than tailoring learning experiences to students learning style preferences, learning experiences should use all of a student's aptitudes. Some researchers reference the need for educators to utilize various modalities in their instructional practice to reach various learner's styles (Paolini, 2015); rather teachers should be using multimodal learning experiences so that student can encounter information in a verity of ways (Himmele & Himmele, 2021).

Pashler and collogues (2009) argue, to support the learning style hypothesis research must demonstrate that an instructional method in a student's preferred modality would increase the student's learning, which has not yet been demonstrated by empirical research. Research shows that students should be receiving various opportunities to interact with learning materials, recall key ideas, and put the new concepts into their own words, a process called elaboration, to increase retention of information (Brown, 2014). The limited evidence of the learning style neuromyth could simply be an artifact of unintentionally practicing repetition of information recall and elaboration through an attempt to present information in various modalities while trying to reach different learning styles. Until further research utilizes rigorous methodological practices to demonstrate the validity of the learning style hypothesis, learning styles should not be utilized to inform instructional practices.

Memory, Learning, and the Brain

There are several neuromyths that abound about learning, memory, and the brain, including, individuals only use 10 % of their brain, the number of brain cells people have are predetermine and limit their intellectual potential, and early learning experience shape future ability and can’t be fixed (Dekker et al. 2012; Gaeke, 2008; Howard Jones et al., 2009; Organization for Economic Co-operation, and Development, 2002). Contrary to these ideas, the brain works as an interconnected network of neural pathways that use various senses to allow our primitive brains to interact with an increasingly more complex world (Gaeke, 2008). Additionally, the brain is constantly reorganizing by creating new neurons and neural pathways to accommodate new information and skills, a process known as neuroplasticity (Kolb et al., 2003). Empirical research shows that the brain is not limited by what percentage can be used or limited by early experiences. For students to effectively interact with their environments and learn new material the brain must be stimulated through repetition, retrieval, and elaboration (Brown, 2014).

Learning is a complex biological process that many misunderstand. At the core of this misunderstanding is an inability to differentiate between real learning and phenomenon that are mischaracterized as learning. Brown (2014) defines learning as memory traces that are formed into mental models and strengthened through a process called retrieval, the process of recalling information from memory traces. Mental models are mental representations of how information relates with each other and their practical applications. An example of a misconception of learning is the comparison of the strategies of mass practice and interleaving (Brown, 2014).

Mass practice is a traditional education practice of introducing information or skills and then practicing them in isolation until the learner has mastered the material (i.e., practice makes perfect). Conversely, interleaving is the practice of mixing different skills and information, practicing multiple sources at a time with space between practices, allowing for recall of information to be spaced out between practices. Brown (2014) argues that many people adopt a mass practice approach because it appears to yield better results because learners show progress quickly but this type of learning lacks durability. Mass practice helps in the immediacy but does not support transfer, a learner's ability to apply learned information to novel situations. However, interleaving does not show immediate gains or proficiency but does show long-term durability and a student's ability to transfer the information.

Simply revisiting the information is not enough, but recalling information needs to be paired with application through elaboration of the information. Elaboration while learning allows individuals to integrate new information with existing understanding to develop a deeper understanding of the new information and explain the connections (Dunlosky et al., 2013). People are drawn to mass practice because it is often easier than interspersing the information over various periods of recall. However, the higher cognitive demand associated with interleaving information increases the difficulty of recall and actually strengthens memory (Brown, 2014). Repeated retrieval of information, or the testing effect, increases long-term recall compared to mass practice, and enhances the ability to transfer that information to new ideas (Roediger & Butler, 2011). When information is recalled and utilized, the neural pathways associated with the information are strengthened (Carpenter, 2009). After applying information, like in the process of elaboration, the brain creates memory traces that are congruent with the new information (Brown, 2014). Mast practices gives the illusion of learning because it loops information through short term memory but does not transfer to new and novel situations as effectively as repeated recall (Brown, 2014).

Mistakes can often be powerful teachers; however, individuals are susceptible to storing mistaken information if errors are left unchecked. People use narrative as a way to make sense of the world around them, but these narratives do not always match reality. This is why it is important to have objective measures (e.g., teachers and tests) to identify how our internal narratives match reality (Brown, 2014). Teachers need to be equipped with the skills to seek and digest empirically based scientific findings to improve their understanding of memory, learning, and the brain (Gaeke, 2008). Neuromyths about memory, learning, and the brain are dangerous because they waste teacher resources and misinform instructional practices (Dekker et al., 2012). Educational neuroscience is a means to help preservice and in-service teachers identify how their narratives of learning and memory match empirical findings on the subject.

Hemispheric Dominance

Hemispheric dominance is a neuromyth that postulates that individuals favor either the right, creative hemisphere of their brain, or the left, logical hemisphere of their brain (Organization for Economic Co-operation, and Development, 2002). The myth of hemispheric dominance likely originates from early research on split brain patients and hemispheric specialization originating from the work of Sperry Noble (Tardif et al., 2015). While there are various products and curriculums available that claim a scientifically based approach to addressing hemispheric differences, there is no scientific evidence for hemispheric dominance or specialization in individuals; rather, empirical findings support an integrated theory of the brain (i.e., the brain uses various regions when processing input) (Geake, 2008; Lindell & Kidd, 2011). Similar to the learning style hypothesis, hemispheric dominance influences some educators to attribute differences between learners to hemispheric dominance and their corresponding learning preference, creative or logical (e.g., a student is creative because they are right brained, or the student is more logical because they are left brained).

Educators that embrace hemispheric dominance look to balance student's hemisphere by either matching learning experiences to the student's hemispheric specialization, or by embracing learning experiences that challenge a student's typical preferences to balance their hemispheres (Lindell & Kidd, 2011). Many of the authors and curriculums that perpetuate the hemispheric dominance myth use brain-based research to justify hemispheric balancing, but their use of the empirical research is misunderstood and misguided (Tardif et al., 2015). Educational neuroscience looks to improve the communication between cognitive disciplines and education to help improve such misunderstandings because when teachers misunderstand or are presented with conclusions not properly supported by empirical research, the instructional decisions they make are misguided as well. It is important for teachers to have a firm understanding on learning and memory so that they can make informed instructional decisions that best support student outcomes. This is why neuroscientific literacy is an important indicator of a teachers understanding about the brain. Teachers need to be equipped with the skills to seek and digest empirically based scientific findings to improve their understanding of learning, memory and the brain (Gaeke, 2008).

Controversy in Educational Neuroscience

While educational neuroscience aims to improve education practices by identifying neuromyths and strengthening instructional practices with neuroscientific findings, not all researchers and practitioners agree that educational neuroscience is the correct approach moving forward. Bowers (2016) argued that educational neuroscience is an unnecessary field because findings from the field are typically already obvious conclusions, already established by behavioral research, or not actually derived from or are misrepresentations of actual neuroscience findings. Because of this, Bowers argued that psychology is a better fit to continue to augment the study of education. But, Bowers' argument minimalizes the multidimensional nature of many of the problems in education. Education composes complex problems that could benefit from an examination of the problems from multiple philosophical perspectives. To reiterate the argument of Samuel (2009), researchers from different disciplines such as psychology, neuroscience, cognitive science, and education need to conduct difficult conversations to better differentiate how each discipline can contribute to practical solutions for educators' complex problems. Often these conversations do not occur, leaving educational neuroscience disadvantaged, unable to progress because of miscommunication (Palghat et al. 2017). Difficult problems are rarely solved by simple solutions. While some see the epistemological difference as the fatal flaw of educational neuroscience, it is also its strength. Ultimately, the benefits derived from teachers learning neurosciences principles outweigh any of the challenges encountered in the new discipline of educational neuroscience (Coch, 2018). Educational neuroscience must confront difficulties in interdisciplinary work. Siloes in the various disciplines associated with the neuroscience will only hinder progress in education.

Many researchers challenge the research of neuromyths because of its applicability to change education, while others see it as prudent to research how neuromyths influence practice. As Gardner (2020) contended, research about neuromyths must focus on the end goal of improving application of neuroscience principles, not simply addressing one's perceptions of neuromyths. Implementing neuromyths to further an agenda or disprove opposition is misguided and misleading. Neuromyth research should help researchers and practitioners better recognize how to collaborate and provide practical information to practitioners. Educational neuroscience does not promote all the answers but is a tool to help improve education and needs to be utilized discerningly (Fischer et al., 2007). Educators need to be informed about neuroscience to develop a working vocabulary that allows them to adequately access knowledge put forth from other disciplines such as neuroscience, cognitive science, and psychology.

Communication is imperative to any interdisciplinary field. This is particularly true for educational neuroscience, a field that does not attempt to encourage researchers from various disciplines to collaborate only but also proposes providing their research to practitioners and implement into practice. Not only is there a need for clear communication between the disciplines that connect theoretical, epistemological, and philosophical differences, but educators need instruction in these disciplines. Ultimately, findings need to be transformed into comprehensible language for educators. As suggested by research, teacher preparation programs lack the infrastructure to teach preservice teachers basic, accurate knowledge of the various learning science (Kim & Sankey, 2018). Helping provide teachers better familiarity with the learning sciences is important because of teachers and preservice teachers who believed in neuromyths such as hemispheric dominance (85% endorsed the myth), 63% identified these statements as important to consider when making pedagogical choices (Tardif et al., 2015). While preservice teachers need classes added to their curriculum to be able to access the research put forth by other disciplines, current teachers need professional development opportunities that do the same.

Preservice Teachers

Equipping new teachers with knowledge and skills that will provide research-based pedagogical choices is essential to improving learning experiences for students. However, the perpetuation of misinformation through teacher preparation programs and misinterpreted research leaves teachers without the scientific literacy to enact important curriculum and instructional choices. The lack of foundational knowledge about the mechanisms of how individuals learn is ironic considering teachers are tasked with student learning. The basis of this problem is teacher preparation programs that perpetuate neuromyths (Kim & Sankey, 2018; Rogers & Cheung, 2020). For example, preservice teachers acknowledged teachers and university courses using learning styles as a bases for instructional strategies (Kim & Sankey, 2018). In qualitative interviews, preservice teachers discussed how their teacher preparation courses explicitly taught neuromyths, such as learning styles, and how their instructors utilized myths in their instructional practice, validating the use of such debunked instructional practices (Rogers & Cheung, 2020).

The perpetuation of neuromyths might go beyond explicitly teaching these fallacies by failing to equip teachers with the resources to refute bad habits and teacher practices that have been ingrained into their pedagogical understanding. Himmele and Himmele (2021) purpose that many of the misinformed teaching practices that are counter to empirical findings are ingrained in teachers during their own time as students in the K-12 system and influence their pedagogical choices as teachers. Teacher preparation programs might not explicitly teach neuromyths but perpetuate the utilization of neuromyths by failing to develop preservice teachers' neuroscientific literacy so that they can reflect on their own preconceived notions of pedagogical practices and identify best teaching practices for their context. Neuroscientific literacy is about more than knowing best practices but being able to identify the use of misinformed teaching practices to replace them with evidence-based practices.

Preservice teachers show interest in learning about neuroscience (McMahon et al., 2019) but they need to be afforded the opportunity to receive adequate course work and instruction to help develop neuroscience literacy so they can interpret findings, better understand the mechanisms that underly learning, and be active participants in educational neuroscience conversations. Enrolling in an educational psychology class increases preservice educators' comprehension of neuroscience but their beliefs in neuromyths persist (Im et al., 2018). However, when neuroscience and cognitive sciences are integrated into preservice course work, beliefs in neuromyths are reduced; a pretest, posttest survey conducted by McMahon et al. (2019), showed that after coursework participants answered I don't know or correctly identified neuromyths, rather than endorsing neuromyths as they had prior to training. Additionally, in interviews participants' comments suggested that they had a better understanding of neuroplasticity, the brain's ability to change and integrate new information, and the acknowledgement of neuromyths in education (McMahon et al., 2019). Ultimately giving preservice teachers neuroscience instruction appears to better inform and equip them by helping them better recognize how the brain interacts with the environment to facilitate learning.

Coch (2018) argued that integration of neuroscience needs to advance beyond just scientific instruction but needs to address neuroscience from a philosophical perspective, helping teachers understand the implications and practicality of research because there is often a disconnect between research and the classroom. By developing more well-rounded educational philosophies and enriching them with the foundations of neuroscience, educators can make sense of scientific findings and develop strategies to incorporate them into practice. To do this, preservice teachers need to receive neuroeducation based coursework that allows them to have the foundational knowledge to read research so they can continually develop their perception of learning and development based on empirical findings over the course of their career.

Teacher Professional Development

Infusing preservice teacher training with neuroscience content will help to prepare new teachers to be more readily equipped for their roles in schools, but current teachers need opportunities to learn current research and how it applies to their instructional practices. New information promotes new curriculum standards and instructional practices, and professional development opportunities provide experienced teachers with an opportunity to interact with current research. While many professional development opportunities are focused on anecdotal lessons, Destimone (2009) argued that professional development should establish a clear content focus that allows teacher to actively engage in the lessons, apply professional development content to their instruction, and collaborate. Focused professional development can promote important changes in teacher practice. For example, lower endorsement of neuromyths among teachers was shown to have a strong positive correlation to teacher selection of effective pedagogical strategies, such as formative evolution, mnemonic strategies, and applied behavior analysis (Ruhaak & Cook, 2018). Therefore, professional development infused with neuroscience are a practical method for improving teacher practice by helping them understand how students learn in order to select effective pedagogical strategies. However, further research is needed to investigate how neuroscientific professional development would influence teachers and their practice.

Professional development should produce practical strategies for teacher practices that support student learning outcomes. Using a paired sample *t*-test, Howard-Jones and colleagues (2020) found that targeted professional development on the science of learning changed teachers’ perception of the perceived usefulness of the science of learning. Furthermore, a pretest, posttest study indicated that neuroscience instruction through professional development increased teachers' knowledge of educational neuroscience concepts on both a multiple-choice test and a free draw of two interconnected neurons (Schwartz et al., 2019). Additionally, qualitative data from Schwartz et al. (2019) indicated that following neuroscience instruction teachers felt they had better insight into the learning process and saw themselves as a facilitator of learning which changed their pedagogical choices to be more student-centered. Neuroscience advances teachers toward instructional practices put students at the center of the learning experience. Finally, a two-week workshop based on neuroscience principles demonstrated an increase of teachers correctly answering neuroscience questions by more than 20% ($p < .001$) and classroom observations of participants following the workshop perceived improved use of student-centered pedagogical choices (Dubinsky et al., 2013). Neuroscience appears to have the ability to change instructional practices because it helps educators better consider the foundational mechanisms of student learning.

For neuroscience-based professional development to be effective, teachers must experience the application of the knowledge. If the professional development is not pragmatic, then teachers will not engage or utilize the information. Adult learning theory suggests that adult learning must be practical and based on investigation to elicit participant buy-in and personalize learning (Knowles, 1972). As adult learners, teachers seek learning opportunities that will allow them to better accomplish their prescribed tasks. Additionally, teachers with confidence in their instructional practices, including their confidence in utilizing neuroscience in their teacher practice, are more apprehensive to change (Luzzato & Rusu, 2019); therefore, making it increasingly important to help teachers recognize their current limitations and the value in new knowledge put forth in the learning sciences.

For teacher professional development to be effective, it must also utilize teachers' prior knowledge to find strategies in order to internalize the information. Knowles (1972) suggested that adult learning must be anchored in prior knowledge and experience. Because adults have acquired more prior knowledge and experience than children, their learning must be based in experience. In theory, basing neuroscience professional development in prior knowledge allows teachers to connect their practice and new information, making it relevant and practical. For example, analogies appear to be particularly useful in helping teachers conceptualize, remember, and utilize neuroscience information. In a study by Tan and Amiel (2019), participants learned about the neural network theory, how new information is stored and structured in the brain, through the use of an analogy about a rose. Following their professional development, participants utilized the rose analogy in interviews to explain their understanding of how students construct knowledge (Tan & Amiel, 2019).

Summary

Educational neuroscience is rich with possibilities to help improve education. Neuroscience, cognitive psychology, neurobiology, and human development help identify the foundation of how individuals learn. The knowledge derived from these fields can help to identify and solve problems in application. However, the explanatory nature of neuroscience and related fields can only benefit education if the two fields find common ground and common communication to solve problems of practice. To achieve this, education practitioners, such as teachers and administration, need practical training in neuroscience and the related fields. By equipping teachers with a background in neuroscience, they are given a base of knowledge to improve their curriculum and instructional choices. Additionally, educators will be better prepared to participate in the conversation that will help educational neuroscience establish its place as an academic discipline. To improve teachers' interest and willingness to participate in neuroscientific training opportunities, further research is needed in how neuroscience literacy correlates to teacher practice. Researching the correlation between neuroscience literacy and teacher self-efficacy is an important step in communicate the viability of educational neuroscience as a practical field for improving teacher practice and student outcomes.

CHAPTER THREE: METHODS

Overview

The purpose of this cross-sectional, multivariate predictive correlational study was to determine if teacher self-efficacy can be predicted from a linear combination of neuroscience literacy factors for K-12 teachers. This chapter begins by introducing the design of the study, including full definitions of all variables. The research questions and null hypotheses follow. The participants and setting, instrumentation, procedures, and data analysis plans are presented.

Design

A cross-sectional quantitative, predictive correlational design was implemented because the purpose of this study was not to assess the change of teacher neuroscience literacy or change in teacher self-efficacy over time, but to measure a hypothesized predictive correlation between the two constructs at a specific point in time. A cross-sectional design allowed for data to be collected on current teacher's neuroscience literacy and how this relates to their current self-efficacy. Rather than collecting data longitudinally, cross-sectional research allowed the researcher to gather data from a diverse group at one time to investigate the research question. Cross-sectional design is applied to gathered data from a specific period in time and from a group that provides various points of development in the construct under investigation (Gall et al. 2007). For example, a longitudinal design would aim to collect data from a specific group over several points of development, while a cross-sectional design would investigate a group that represents the different points of development at a specific point in time. The cross-sectional design allows for more effective data collection and avoids many of the attrition and dropout problems of a longitudinal study.

A multivariate correlation study is appropriate because it advances beyond the investigation of two variables, as in a bivariate correlation study, and allows an investigation of the interrelationship between three or more variables (Gall et al. 2007). When investigating the current literature, it was suggested that new educational neuroscience-based studies need to advance beyond simply investigating neuromyths' influence on teacher practice and include a more holistic approach of neuroscience literacy including both neuromyths and perspective about the form and function of the brain (Dekker et al., 2012).

Correlational studies are widely applied in education research because they are broadly applicable and flexible for illustrating the relationship between two or more variables and the design offers valuable graphics (Cohen et al., 2003). Specifically, a predictive correlational design was applied because little research has been conducted in the field of educational neuroscience designed to investigate how neuroscience literacy influences teachers' traits such as teacher self-efficacy. According to Gall et al. (2007), a predictive design is appropriate for studies investigating such new and understudied relationships as neuroscience literacy and teacher self-efficacy. Haphazardly including variables without a strong theoretical foundation can lead to finding significant results; however, they will present little meaning without a sufficient rationale established by a theoretical foundation. Furthermore, a predictive correlational study cannot establish a cause-and-effect relationship; however, such designs are valuable in providing a basis for further investigation and theorizing the nature of relationships between the predictor and criterion variables (Gall et al., 2007).

The predictive correlational design that was implemented in this study endeavors to measure a hypothesized causal relationship between neuroscience literacy and teacher self-efficacy based on current literature findings. As an individual develops mastery over specific content, his or her efficacy in that material increases (Bandura, 1977). Since neuroscience provides explanations of the mechanisms that underlie students learning, it is feasible that teacher efficacy to support student learning would increase with high neuroscience literacy. However, the relationship between neuroscience literacy and teacher self-efficacy has not been explicitly investigated. The theoretical grounding of this study establishes the justification for the investigation and provides purpose to why the variables are not correlated by chance alone. Therefore, a predictive design is an appropriate research design to investigate the hypothesized connection between the predictor variables (scientific concept of learning and memory and belief in neuromyths) and the criterion variable (teacher self-efficacy).

Teachers' neuroscience literacy is comprised of a combination of two separate predictor variables, their scientific concept of learning and memory and belief in neuromyths. The predictor variable of belief in neuromyths represents common misconceptions about the form and function of the brain, leading to misunderstandings of how the brain functions during learning (Gardner, 2020). Misconceptions about the brain was measured by participants' agreement with 11-question survey, using a 4-point Likert scale (Grospietsch & Mayer, 2019). Scientific concept of learning and memory, the second predictor variable, represents knowledge about the function, structure, and anatomy of the brain, including how the brain influences students' learning and development (Grospietsch & Mayer, 2019). Scientific concept of learning and memory were measured by participants' agreement with 11-question survey, using a 4-point Likert scale (Grospietsch & Mayer, 2019). The criterion variable, teacher self-efficacy is an educator's confidence in his or her ability to execute the necessary actions to achieve desired teaching goals and objectives (Tschannen-Moran & Hoy, 2001). Teacher self-efficacy was measured by self-reported responses to a 12-question survey, using a 9-point Likert scale, asking participants to identify their confidence in their ability to implement instructional practices, manage a classroom, and engage students in learning activities (Pfitzner-Eden et al., 2014).

Research Question

RQ: How accurately can teacher self-efficacy be predicted from a linear combination of neuroscience literacy factors (scientific concept of learning and memory and belief in neuromyths) for K-12 teachers from a large school district in the southeastern United States?

Hypothesis

The null hypothesis for this study is:

H_0: There will be no significant predictive relationship between teacher self-efficacy and the linear combination of neuroscience literacy (scientific concept of learning and memory and belief in neuromyths) for K-12 teachers from a large school district in the southeastern United States as measured by the Concept of Learning and Memory instrument and Scale for Teacher Self-Efficacy.

Participants and Setting

K-12 certified teachers were invited to participate from a large school district in East Tennessee. Teacher population and sample demographics are discussed in this section.

Population

The participants for this study came from a convenience sample of K-12-recruited teachers in a large school district within the southeastern United States during the spring semester of the 2021-2022 school year. The school district was invited to participate because of the district's accessibility and size; the district includes 4391 teachers serving 58,880 students in 91 schools (X School District, 2021). For this present study, only K-12 teachers with a current valid license (traditional or alternative), who are currently the primary instructor, or teacher of record, were included. Both general education and special education teachers of all subjects were be included. Administrators, paraeducators, instructional coaches, and supervisors were excluded from this present study.

Participants

As part of a convince sample, 110 participants were recruited and included, exceeding the minimum recommendation of 106 participants (Warner, 2012). Participants included 31 male (28.2%) and 79 female (71.8%). 93 (84.5%) participants were white, 4 (3.6%) were Black/African American, 4 (3.6%) were two or more ethnicities, 3 (2.7%) were Latino or Hispanic, 2 (1.8%) were Asian, and 4 (3.6%) identified as other or declined to state. Participants' years of service as a teacher varied with 9 (8%) teaching for less than 5 years, 27 (24.5%) for 5-10 years, 45 (40.9%) for 11-20 years, and 29 (26.4%) for more than 20 years. All participants possessed at least a bachelor's degree, with 71 (64.5%) having a master's degree, 8 (7.3%) having an education specialist's degree, and 9 (8.2%) having a doctoral or terminal degree. 20 (18.2%) of participants taught elementary school (Kindergarten-fifth grade), 11 (28.2%) taught middle school (sixth through eighth grade), and 79 (71.8%) taught high school (ninth through twelfth grade). Finally, 94 (85.5%) were general education teachers and 12 (10.9%) were special education teachers, and 4 (3.6%) responded other. Frequencies and percentages of demographics are presented in Table 1 below.

Table 1

Demographics Frequency Table

Demographic	*n*	%
Gender		
Male	31	28.2
Female	79	71.8
Race/Ethnicity		
White	93	84.5
Black/African American	4	3.6
Two or more	4	3.6
Latino or Hispanic	3	2.7
Asian	2	1.8
Other/Decline to State	4	3.6
Years of Service		
Less than 5 years	9	8
6-10 years	27	24.5
11-20 years	45	40.9
More than 20 years	29	26.4
Highest Level of Education		
Bachelor's Degree	22	20
Master's Degree	71	64.5
Education Specialist Degree	8	7.3
Doctor or Terminal Degree	9	8.2
Grade Level Taught		
Elementary (K-5th Grade)	20	18.2
Middle School (6th-8th Grade)	11	10
High School (9th-12th Grade)	79	71.8
Educator's Role		
General Education Teacher	94	85.5
Special Education Teacher	12	10.9
Other	4	3.6

Note. Due to rounding, percentages may not equal 100%

Setting

Data was collected through an online survey during the spring semester of the 2021-2022 school year. Teachers accessed the survey via a hyperlink provided through the invitation email. While the survey took about 10 minutes, participants were able to complete the survey at their own pace. Due to the online nature of the survey participants were able to complete the survey when and where they chose.

Instrumentation

Data was collected via internet-delivered, self-report questionnaires. Scientific concept of learning and memory and belief in neuromyths, the predictor variables, were measured via the Conception of Learning and Memory survey, while teacher self-efficacy, the criterion variable, was measured via the Scale for Teacher Self-Efficacy.

Conception of Learning and Memory

The Conception of Learning and Memory (CLM) instrument is a 22-question survey designed to measure participants' neuroscience literacy. See Appendix A for instrument. The CLM was designed to build on previous surveys that measure educator's belief in neuromyths and knowledge about the brain (Bellert & Graham, 2013; Dekker et al., 2012; Howard-Jones et al. 2009; Schletter & Bayrhuber, 1998). Building from these previous instruments, and recommendations made by Macdonald et al. (2017), phrasing of selected survey items was refined, and new items were added to address current research and trends in education. The CLM addresses 8 neuroscientific topics: (a) memory, (b) hemispheric asymmetry, (c) brain activity, (d) development, (e) sensory modalities, (f) learning techniques, (g) neuroplasticity, and (h) gender differences. The CLM is comprised of two subscales: (a) scientific concept scale used to measure general knowledge about the brain, learning, and memory, and (b) misconception scale to measure belief in neuromyth. Eleven of the items address scientific concepts (i.e., general knowledge about the brain, learning, and memory), while the remaining 11 are commonly held neuromyths, as defined by Organization for Economic Co-operation, and Development (2002). Scientific concept of learning and memory are theoretical assumptions, lines of argumentation, and conclusions about the brain, learning, and memory that are supported by empirical findings;

while neuromyths are theoretical assumptions, lines of argumentation, and conclusions about the brain, learning, and memory that are not supported by empirical research (Grospietsch and Mayer, 2019).

Because the CLM was originally developed for use in German, all items used from previous surveys were translated into German and then back translated to English to verify items clarity in measuring the desired construct. The version of the CLM that was used in this present study is an English translation of the original German version used in Grospietsch and Mayer (2018).

The CLM has been used in numerous studies (Grospietsch and Mayer, 2018; Grospietsch and Mayer, 2019; Grospietsch and Mayer, 2021); furthermore, the survey items presented in the CLM have been utilized in various studies about scientific understanding and misconceptions about the brain (Betts et al., 2019; Herculano-Houzel, 2002; Im et al., 2012; Janati Idrissi, et al., 2020; Papadatou-Pastou et al., 2017; van Dijk & Lane, 2020). Thirteen of the survey items were taken from Dekker et al. (2012), two items were taken from Bellert and Graham (2013), and one item was taken from Macdonald et al. (2017). The remaining five items were new items added in line with current research and educational trends. To certify that the CLM measures neuroscience literacy, participants' scientific concept of learning and memory and belief in neuromyths, survey items are evidence-based statements supported by current research. The accuracy and validity of the claims of each survey item were verified by experts (Betts et al., 2019; Dekker et al., 2012; Grospietsch and Mayer, 2019; Howard-Jones et al. 2009). For the scientific concept subscale, a Cronbach's α of .74 indicates an acceptable internal consistency. For the misconception subscale, a Cronbach's α of .78 indicates an acceptable internal consistency (See Table 1), establishing the CLM as a valid and reliable survey for measuring neuroscience literacy (Grospietsch & Mayer, 2018).

Table 2

The Conception of Learning and Memory instrument

Subscale	Cronbach's α
Scientific Concept	α = .74
Misconceptions	α = .78

Note. Grospietsch & Mayer, 2018

In accordance with the methodological recommendation put forth by Macdonald et al. (2017), a 4-point Likert scale was used instead of the three-choice scale of *correct, incorrect, or I don't know* used by Dekker et al. (2012) and other neuromyth research. For each question participants were asked to choose from *strongly agree, somewhat agree, somewhat disagree, and strongly disagree.* Scores are calculated using the Likert scale giving 1 point for "strongly disagree", 2 points for "somewhat disagree", 3 points for "somewhat agree", and 4 points for "strongly agree". Scores are presented for each subscale independently, (i.e., scientific concept subscale and misconception subscale) as a composite score. For belief in neuromyths scores ranged from 11 to 44. A score of 44 indicates strong agreement with the presented neuromyths and a high level of beliefs in neuromyths. A score of 11 indicates low agreement with the presented neuromyths and a low level of belief in neuromyths. For scientific concept subscale scores range from 11 to 44. A score of 44 indicates high agreement with the general concepts presented and a high level of general knowledge about the brain. A score of 11 indicates low agreement with the general concepts presented and a low level of general knowledge about the brain.

The CLM was distributed digitally and taken independently by participants using Google

Forms®. Presentation of questions were randomized. Completing the 22-question survey is estimated to take approximately 20 minutes. Data was automatically collected via Google Forms®, then converted to an excel spreadsheet and uploaded to SPSS 27.0 for analysis. This work is licensed under a creative commons license (http://creativecommons.org/licenses/by/4.0/).

Scale for Teacher Self-Efficacy

The Scale for Teacher Self-Efficacy (STSE) developed by Pfitzner-Eden et al. (2014), is a 12-question survey designed to measure teacher self-efficacy. Based on the recommendations for measuring self-efficacy suggested by Bandura (2006), the STSE was adapted from the widely administered Teacher Sense of Self-Efficacy Scale (Tschannen-Moran & Hoy, 2001). Verbiage was adjusted to meet standards for constructing self-efficacy measures Bandura (2006). Six items were selected by experts from each of the three subscales included in the TSES. After analysis of initial responses, four items that best represented each subscale were selected and included in the STSE. The STSE was used in a study of preservice Australian teachers, finding that preservice teachers with lower teacher self-efficacy reported a lack of experience as a contributing factor of their efficacy (Ma & Cavanagh, 2018). Pfitzner-Eden (2016) administered the STSE to investigate contributing factors to the change of teacher self-efficacy over time. Findings indicated that mastery experiences were the main contributing factor to an increase in teacher self-efficacy.

Construct validity was established using a three-factor confirmatory factor analysis model with 3 separate populations, reporting latent inter-factor correlations ranging from .45 to .82 (Pfitzner-Eden et al., 2014). This suggests that all three samples viewed construct consistently across each question. Manifest correlations reported *r* statistics ranging from .35 to .45 (Pfitzner-

Eden et al., 2014). Internal consistency was reported with a Cronbach's α = .90 (See Table 2) (Weißenfels et al, 2021), establishing the STSE as a valid and reliable survey for measuring teacher self-efficacy

Table 3

Scale for Teacher Self- Efficacy Reliability Table

Subscale	Cronbach's α
Instructional Strategies	α = .74
Classroom Management	α = .87
Student Engagement	α = .80
Total	α = .90

Note. Weißenfels et al, 2021

Participants are asked to respond to 12 questions using a 9-point scale ranging from "not at all certain can do" to "absolutely certain can do." There are 3 subscales: (a) instructional strategies, (b) classroom management, and (c) student engagement. Each subscale consists of four questions. Scores are calculated using the Likert scale giving 1 point for "not at all certain" up to 9 points for responses of absolutely certain can do". Scores ranged from 12, indicating little teacher self-efficacy, to 108, which indicates a high level of teacher self-efficacy.

The STSE was distributed digitally and taken independently by participants using Google Forms®. Presentation of questions were randomized. Estimated completion of the 12-question instrument is 10 minutes. Data was automatically collected via Google Forms®, then converted to an excel spreadsheet and uploaded to SPSS 27.0 for analysis. Permission was granted for non-commercial, educational purposes but cannot be reproduced.

Procedures

First, the target school district's research and evaluation department was contacted via email for permission to distribute a recruitment email containing a survey link to district employees (See Appendix A). Once the target school district agreed to allow distribution of the survey, IRB approval was requested through Liberty University. Once approval was granted by Liberty University and the target school district, a study recruitment email was sent by the researcher to all current principals for distribution to all current K-12 teachers at their schools. The recruitment email was distributed to teachers contained information about participating in the study, including (a) an introductory email explaining the study, (b) the two-week window for the study, (c) request for participation, and (d) a hyperlink for the survey (See Appendix B). The survey preface comprised of the consent form for participation with an option to agree to terms by clicking continue or an option to exit the survey (See Appendix C). The consent form was also attached to all recruitment emails for participants to keep for their records.

The study's survey was presented as a continuous, single-page survey with four sections. The four sections include (a) 2 screening question (b) 6 demographic questions, (c) the 22 questions of the CLM (randomized), and (d) the 12 questions of the STSE (randomized). Participants answered demographic questions by marking all check boxes that apply for each question. CLM questions were randomized using Google Forms ® for each participant. The CLM comprises 22 statements and participants were prompted to mark the check box that best corresponds to the statement from a 4-point Likert scale. STSE questions were also randomized using Google Forms ® for each participant. The STSE comprises 12 statements. Participants were prompted to mark the check box that best corresponds to the statement from a 9-point Likert scale ranging from "not at all certain can do" to "absolutely certain can do." Once participants completed all questions, they submitted the survey by clicking the “submit” button after the final question of the survey.

Surveys were self-report and administered via Google Forms®, a web-based survey software, to ensure anonymity and to minimize input errors. Anonymity is important to protect participants’ privacy and encourage honest participation on the survey (Gall et al., 2007). During collection, access to the Google Forms® were limited to the researcher. Following collection, data was downloaded and stored on the researcher’s password-protected computer for no more than five years. All web-based data was deleted after download. Once data is collected, the researcher assigned participants a participant number for organizational purposes. Data was inspected for missing entries and incomplete surveys. After cleaning data, data was managed and analyzed via SPSS 27.0. A minimum sample size of 108 was used for an α of .05 and power of .7, aligned to Warner’s multiple regression (2012) recommendation. Exclusion statistics were reported using frequencies. Exclusion criteria includes (a) participants who are not currently classroom teachers, (b) participant with missing data on the CLM and STSE, and (c) outliers. For included participants, descriptive statistics were reported using mean, standard deviation, and range; for categorical and dichotomous data, percentages were reported. CLM were scored using the 4-point Likert scale. Scores are calculated using the Likert scale giving 1 point for “strongly disagree”, 2 points for “somewhat disagree”, 3 points for “somewhat agree”, and 4 points for “strongly agree”. For scientific concept of learning and memory and belief in neuromyths scores will range from 11 to 44. STSE was scored using the 9-point Likert scale. Responses of "not at all certain can do" will receive 1 point. For each step up on the Likert scale participants received 1 additional point up to 9 points for "absolutely certain can do." Scores range from 12 to 108.

Data Analysis

For a multivariate predictive study, a multiple linear regression is an appropriate data analysis for supporting an investigation of the relationship between three or more variables (Gall et al., 2007). Multiple regression analysis allows for the researcher to identify the significance of change in the criterion variable, that must be measured on a continuous scale, for an incremental increase of a predictor variable when controlling for the other predictor and control variables. When interpreting the data, a predictive correlational design is not an end; further research and theorizing are needed to develop a full understanding of the criterion variable (Gall et al. 2007). Multiple regression was conducted to measure the relationship between the continuous criterion variable, teacher self-efficacy, and a combination of the predictor variables, belief in neuromyths and scientific concept of learning and memory.

Multiple regression was selected because of its general applicability to education research and its ability to show a depth of information about the relationship between two or more predictor variables on a criterion variable (Gall et al., 2007). Multiple regression was conducted to investigate teacher's perception of neuroscience. Luzzatto and Rusu (2019) conducted multiple regression to investigate the correlation of a linear combination of teachers' perception of neuroscience factors and teachers' attitude towards change; findings indicated that preservice teachers perceived role in using neuroscience, the amount of time they were willing to spend integrating neuroscience into their practice, and their personal efficacy of using neuroscience significantly accounted for 47.2% of the variance in their attitude towards change.

Multiple regression was used to test and reject the null hypothesis with a 95% confidence interval and an alpha of .05. The multiple correlation coefficient (R) was interpreted to determine the strength and relationship between the criterion variable and the linear combination of predictor variables, while the coefficient of determination (R^2) was interpreted to examine what percentage of the criterion variable is explained by a combination of the predictor variables (Gall et al., 2007). An *F*-ratio was interpreted to determine the significance of the overall fit of the combination of predictor variables. Finally, the individual relationship between each predictor variable and the criterion variable was examined using the *t*-value and checked for statistical significance (Cohen et al., 2003).

A scatterplot was constructed depicting all pairs of independent variables and also the predictor variables and criterion variable to verify the assumption of bivariate outliers (Gall et al., 2007). A scatterplot of each combination of independent variables and also the predictor variables and criterion variable were used to investigate the assumption of multivariate normal distribution; each scatter plot was examined for the classic cigar shape (Gall et al., 2007). The predictor variables was compared to check for the absence of multicollinearity to verify that the variables did not essentially provide the same information (Gall et al., 2007). Variance inflation factor (VIF) was conducted to check for collinearity between the predictor variables, determining a score no higher than 10 (Cohen et al., 2003).

CHAPTER FOUR: FINDINGS

Overview

The purpose of this quantitative, predictive correlational study was to determine if a linear combination of neuroscience literacy factors could predict teacher self-efficacy. The predictor variables scientific concept of learning and memory scores and belief in neuromyths scores. The criterion variable was teacher self-efficacy scores. A multiple linear regression was used to test the hypothesis. The Results section includes the research question, null hypothesis, data screening, descriptive statistics, assumption testing, and results.

Research Question

RQ: How accurately can teacher self-efficacy be predicted from a linear combination of neuroscience literacy factors (scientific concept of learning and memory and belief in neuromyths) for K-12 teachers from a large school district in the southeastern United States?

Null Hypothesis

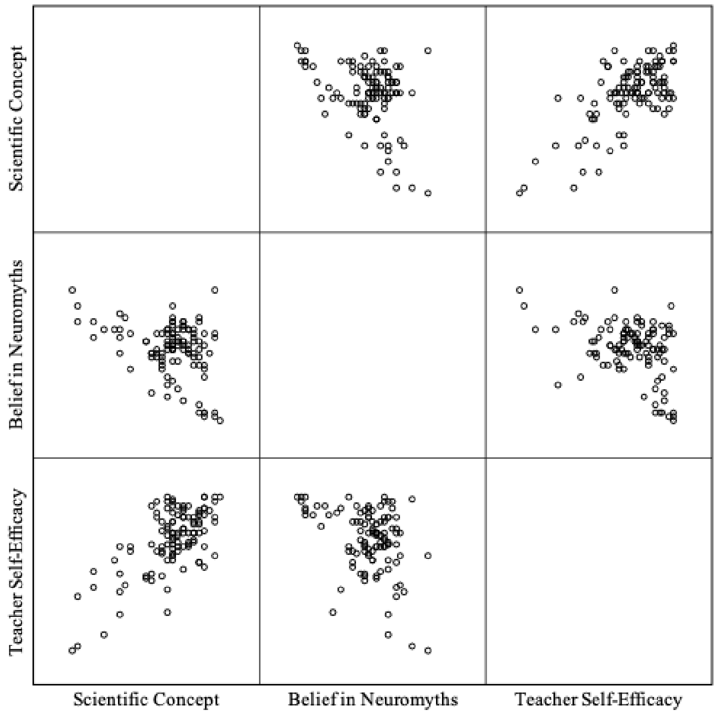
H_0: There will be no significant predictive relationship between teacher self-efficacy and the linear combination of neuroscience literacy (scientific concept of learning and memory and belief in neuromyths) for K-12 teachers from a large school district in the southeastern United States as measured by the Concept of Learning and Memory instrument and Scale for Teacher Self-Efficacy.

Data Screening

The researcher sorted the data and scanned for inconsistencies on each variable. No data errors or inconsistencies were identified. A matrix scatter plot was used to detect bivariate outliers between predictor variables and the criterion variable. No bivariate outliers where identified. See Figure 1 for the matrix scatter plots.

Figure 1

Matrix Scatter Plot



Descriptive Statistics

Descriptive statistics were obtained on each of the variables. The sample consisted of 110 participants. Score for scientific concept of learning and memory and belief in neuromyths were measured using the Concept of Learning and Memory instrument. Scores on the scientific concept of learning and memory scale measure from 11 to 44. A high score of 44 is a perfect score on the scale and means that the participant had complete understanding of the scientific concepts about learning and memory presented, whereas a low score of 11 means that the participant has no understanding of the scientific concepts presented. Scores on the belief in neuromyth scale measure from 11 to 44. A high score of 44 means that the participant fully endorsed all neuromyths presented, whereas a low score of 11 means that the participant did not endorse any of the neuromyths presented. Teacher self-efficacy was measured using the Scale for Teacher Self-Eddicacy. A high score of 108 means the participants had high efficacy towards their teaching, whereas a low score of 11 means that the student had extremely low efficacy towards teaching. Table 4 provides the descriptive statistics for each variable.

Table 4

Descriptive Statistics

	n	Min.	Max.	*M*	*SD*
Scientific Concept	110	16	44	34.85	5.82
Belief in Neuromyth	110	11	44	29.16	6.77
Teacher Self-Efficacy	110	40	108	89.15	14.12
Valid *n* (listwise)	110				

Assumptions Testing

Assumption of Linearity

The multiple regression requires that the assumption of linearity be met. Linearity was examined using a scatter plot. The assumption of linearity was met. See Figure 1 for the matrix scatter plot.

Assumption of Bivariate Normal Distribution

The multiple regression requires that the assumption of bivariate normal distribution be met. The assumption of bivariate normal distribution was examined using a scatter plot. The assumption of bivariate normal distribution was met. Figure 1 provides the matrix scatter plot.

Assumption of Multicollinearity

A Variance Inflation Factor (VIF) test was conducted to ensure the absence of multicollinearity. This test was run because if a predictor variable (x) is highly correlated with another predictor variable (x), they essentially provide the same information about the criterion variable. If the Variance VIF is too high (greater than 10), then multicollinearity is present. Acceptable values are between 1 and 5. The absence of multicollinearity was met between the variables in this study. Table 5 provides the collinearity statistics.

Table 5

Collinearity Statistics

		Collinearity Statistics	
Model		Tolerance	*VIF*
1	Scientific Concept	0.854	1.171
	Belief in Neuromyths	0.854	1.171

Dependent Variable: Teacher Self-Efficacy

Results

A multiple regression was conducted to see if there was a relationship between a linear combination of neuroscientific literacy factors and teacher self-efficacy scores K-12 teachers. The predictor variables were scientific concept of learning and memory and belief in neuromyth. The criterion variable was teacher self-efficacy scores. The researcher rejected the null hypothesis at the 95% confidence level where $F(2, 107) = 50.04$, $p < .001$. There was a significant relationship between the predictor variables (neuroscientific literacy factors) and the criterion variable (teacher self-efficacy scores). Table 6 provides the regression model results.

Table 6

Regression Model Results

Model		*SS*	*df*	*MS*	*F*	Sig.
1	Regression	10496.05	2	5248.03	50.04	<.001
	Residual	11222.32	107	104.88		
	Total	21718.37	109			

a. Dependent Variable: Teacher Self-Efficacy
b. Predictors: (Constant), Scientific Concept, Belief in Neuromyths

The model's effect size was large where $R = .70$. Furthermore, $R^2 = .48$ indicating that approximately 48% of the variance of criterion variable can be explained by the linear combination of predictor variables. Table 7 provides a summary of the model.

Table 7

Model Summary

Model	*R*	R^2	Adjusted R^2	*SEM*
1	0.70	0.48	0.47	10.24

a. Predictors:(Constant), Scientific Concept, Belief in Neuromyths

Because the researcher rejected the null, analysis of the coefficients was required. Based on the coefficients, it was found that scientific concept of learning and memory was the best predictor of teacher self-efficacy scores where $p < .001$. Table 8 provides the coefficients.

Table 8

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	*SE*	B	*t*	Sig.
1	(Constant)	*45.793*	9.190		4.98	<.001
	Scientific Concept	*1.510*	.182	.623	8.28	<.001
	Neuromyths	-*.318*	.157	-.152	-2.03	.045

a. Dependent Variable: Teacher Self-Efficacy

CHAPTER FIVE: CONCLUSIONS

Overview

Chapter Five will discuss the implications of the study results and their relevance to current literature on the topic. Implications of the study results on education practice and teacher training are discussed. Study limitations and future studies are also discussed.

Discussion

The purpose of this quantitative correlational study was to explore how K-12 teachers' self-efficacy correlates to their neuroscience literacy factors. The target population was certified K-12 teachers from a large school district in the southeastern United States, teaching at least one class. The goal of this study was to address a gap in the literature addressing how teachers' knowledge about learning, memory, and the brain influences their teacher self-efficacy. The predictor variables, scientific concept of learning and memory and belief in neuromyths, were measured by the Concept of Learning and Memory instrument and the predictor variable, teacher self-efficacy, was measured using the Scale for Teacher Self-Efficacy. Multiple regression was used to test the relationship between the predictor variables and the criterion variable.

Null Hypothesis

The null hypothesis of this study stated that there would be no significant predictive relationship between teacher self-efficacy and the linear combination of neuroscience literacy (scientific concept of learning and memory in neuromyths). Multiple regression was used to test the null hypothesis. A statistically significant relationship was found between teacher self-efficacy and the linear combination of neuroscientific literacy factors. Results indicated a positive relationship between scientific concept of learning and memory and teacher self-efficacy. Additionally, results indicated a negative relationship between belief in neuromyths and teacher self-efficacy. Higher scientific concept of learning and memory and a lower number of beliefs in neuromyths indicate a higher neuroscientific literacy because both demonstrate a better overall understanding of learning and memory. These findings suggest that the higher a teacher's neuroscientific literacy, the higher their teacher-self efficacy. As a result of the analysis the researcher was able to reject the null hypothesis.

As suggested by Macdonald et al. (2017), this study moved beyond the use of a true/false paradigm to better understand participants certainty of their answers. Results from this study's survey showed a similar prevalence in neuromyths as past studies (Dekker et al., 2012; Gardner, 2020; Kim & Sankey, 2017; Papadatov-Pastou et al., 2017, Ruhaak & Cook, 2018), however it was able to capture the nuance of participants' certainty. In this study, the use of a gradient to measure neuroscientific literacy factors allowed for an investigation of how the certainty of a belief, not just its existence, correlated to their efficacy. Documentation of neuromyth prevalence was an important first step in raising awareness of the issues but not enough has been done to understand the implications of how fervency of neuromyth belief influences teacher practice and teacher characteristics. For example, interventions to dispel neuromyths have lowered the occurrence of neuromyths but not eliminated them (Im et al.,2012, Macdonald et al. 2017, Howard-Jones et al., 2020). The gradation of certainty in answers used in this study could help to explain why some neuromyths are so difficulty to dispel. A more holistic understanding of the fervency and implications of neuromyth beliefs needs to be investigated to move forward in addressing the issue. This study looked to address this gap in literature by beginning to build an understanding of how neuroscientific knowledge affects teacher characteristics and their practice.

Theoretical Framework

To understand the target behaviors required to achieve a desired outcome, it is necessary for an individual to understand the interaction between behavior and the environment (Bandura & Walters, 1977). Understanding the behavior, environment interaction in a setting allots and individual the ability to identify target behaviors to achieve desired outcomes, given environmental context. Self-efficacy is a person's confidence in their ability to enact a target behavior (Bandura, 1977). Bandura (1997) found that the largest contributing factor to a person's efficacy in a particular domain is their past experiences with the target behavior.

For a teacher, their goal is to understand what behaviors will help facilitate a learning environment that will supports achieving learning objectives. Teacher self-efficacy is a teacher's belief in their ability to enact target behaviors to achieve educational goals (Pfitzner-Eden, 2016; Tschannen-Moran & Hoy, 2001). This study operationalized teacher self-efficacy as a composite of three key target behaviors to facilitating educational objectives; these three subscales were instructional strategies, classroom management, and student engagement (Weißenfels et al, 2021). The findings of this study are complementary to Bandura's theory of self-efficacy. As teacher's neuroscientific literacy increased, so did their teacher self-efficacy. A higher neuroscientific knowledge means a deeper understanding of how learning and memory take place and support academic objectives (Schwartz et al., 2019). Therefore, higher neuroscientific knowledge likely gives teachers the tools they need to understand what target behaviors will yield desired outcomes and the confidence to enact those target behaviors, therefore raising teacher self-efficacy.

Pas et al. (2012), found that it wasn't school environment factors that influences a teacher's self-efficacy but rather a teacher's sense of preparedness. As teacher's felt more prepared their efficacy was increased because they felt they could enact target behaviors to yield desired outcomes. Similarly, the findings of this study show that the higher their teacher neuroscientific knowledge, the higher their teacher self-efficacy. In this case, a higher neuroscientific literacy likely helps teachers feel more prepared in the classroom by understanding the behavior and environment interactions taking place and how to identify and implement effective target behaviors.

Neuroscientific knowledge could influence a teacher's self-efficacy in two ways. First, neuroscientific knowledge helps teachers enact effective behaviors and attaining more mastery experiences. Previous mastery experiences with a target behavior increases teacher self-efficacy by giving them a sense of agency and ability to enact effective behaviors in the future (Pfitzner-Eden, 2016). Higher neuroscientific knowledge is associated with student centered learning and achieving academic goals (Schwartz et al., 2019). These positive teacher practices likely lead to mastery experiences and raise teacher self-efficacy. Second, the development of self-efficacy also happens through vicarious experiences (Bandura, 1977). As individuals witness others' interactions with the environment, they develop their own sense of ability to effectively navigate a situation (Bandura, 1986). A higher neuroscientific literacy gives teachers a base of knowledge to interpret, reflect, and assess the outcomes of a situation and how to best interact in the future. Schunk (2019) concludes that much of learning about behavior and the environment happens through a combination of mastery experiences and vicarious learning. A higher neuroscientific knowledge helps navigate both experiences and helps to yield a positive perception of one's teacher efficacy.

Implications

Belief in neuromyths have been well established among teachers in the United States;

however, there has been debate about their implication on teacher practice (Bowers, 2016; Campbell, 2011; Edelenbosch et al., 2015; Samuel, 2009). Gardner (2020) argues that findings about neuromyths need to move past the observation of their prevalence in education but focus on practical application. This study provides valuable findings on the implications of teachers' neuroscientific knowledge and its effect on teacher self-efficacy. Because belief in neuromyths negatively affects teacher self-efficacy, it shows the importance of dispelling neuromyths to improve their efficacy in the classroom. Additionally, scientific concept of learning and memory positively affects teacher's self-efficacy, therefore, improving teachers' scientific concept is also important to improving teacher self-efficacy. Teacher self-efficacy is an important measure because of its association with instructional practices, student success, classroom quality, and inclusive practices (Henson, 2001; Kim & Seo, 2018; Zee & Koomen, 2016). This study shows that there are practical ways to help teachers improve their efficacy.

Additionally, this study shows the importance of educational neuroscience and its practical importance to education and teacher practice. As Fischer et al. (2007) argues, educational neuroscience does not provide all the answers but is a practical tool in understanding and solving problems in education. Educators need to be given practical knowledge of learning, memory, and the brain to help them make informed instructional decisions. Providing educational neuroscience courses work for preservice teachers and educational neuroscience based in-service learning opportunities for existing teachers are two of the ways that educational neuroscience could help better support teachers and their efficacy.

Limitations

This study met the minimum requirements to support acceptable results; however, there were limitations to the study. Because this study used a convivence sample from one school district in East Tennessee, the generalizability of this study is limited. This study was limited in its ability to attain a national sample that would better represent the United States teacher population and their diverse contexts. There are unique challenges and supports for different contexts (e.g., urban schools, suburban schools, and rural schools) that could also impact teacher neuroscientific knowledge and teacher self-efficacy. Additionally, the sample participants varied from the larger population in race/ethnicity, grade level taught, and education. The sample population was disproportionately white and high school educators.

Another limitation of this study was the time of year the survey was distributed. After receiving IRB approval, the survey was distributed immediately. However, this occurred in the last two weeks of the target school districts spring semester. While the minimum number of participants was accrued, participation was likely lower because of the stresses during the end of the year for teachers. Also, the end of the year complicated the ability to send follow-up emails to teachers to help encourage further participation.

A final limitation of the study was the procedure of distributing the survey. The target district had the researcher contact teachers through building level principals. While the request to distribute the survey was sent to every principal in the district, distribution of the survey was optional and not every principal distributed the survey to their teachers. This means that not every teacher had the opportunity to choose to participate. This lowered the number of potential participants and the diversity that comes with more participants.

Recommendations for Future Research

The following are recommendations for future studies. First, while the results for this study were collected from one district as a convivence sample and a start to building a theory of the relationship between neuroscientific literacy and teacher self-efficacy, future studies need to incorporate a national sample that addresses the diversity of teachers and the contexts in which they teach. This would allow for a better understanding of the relationship between the variables. Additionally, a larger, national sample would allow for cross group comparisons, such as elementary, middle, and high school teachers or by subject matter taught.

To further build on the theorized relationship of neuroscientific literacy and teacher self-efficacy, future studies need to test the efficacy of preservice and in-service interventions. Future studies need to build on the work of researchers like Ruhaak and Cook (2018) that investigate the relationship between neuroscientific knowledge and teacher practice. Future research needs to investigate how developing teachers' neuroscientific knowledge affects teacher self-efficacy and other teacher characteristics. To truly understand how educational neuroscience can impact teacher practices, more studies need to investigate neuroeducation interventions.

Finally, future studies need to move beyond teacher self-efficacy and look at other teacher characteristics. Teacher self-efficacy is a key component to teacher practice, but it only offers a glimpse into the impact that neuroscientific knowledge can have on the overall teacher. By better understanding the effects that neuroscientific knowledge has on teacher characteristics, educators will see the importance of building their understanding of learning and memory. Unless teachers see neuroscientific knowledge as pragmatic, they are unlikely to participate in interventions and professional development opportunities. The more of a rationale researchers can make for the influence neuroscientific knowledge has on teachers and education practice, the more investment they will receive from key education stake holders and teachers.

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APPENDIX A

English translation of the German instrument on conceptions of learning and memory.

Title of the instrument	**Conceptions on learning and memory**
Introductory text	Questionnaire on Learning and the Brain. The following statements concern learning and the brain. Please read through the following statements carefully, marking your level of agreement with each. Please answer honestly and select only one answer option for each statement. Make sure not to skip any statements.
Scale: Scientific concepts scale	
To what extent do you agree with the following statements?	
MEM	Learning occurs through modification of the brains' neural connections.[1]
MEM	The forging of new connections in the brain can continue into old age.[2]
HEM	The left and right hemispheres of the brain always work together in processing information.[2]
BA	Our brains are active 24 h a day.[2]
BA	Processes to consolidate what we have learned occur during sleep.
DEV	There are sensitive periods in childhood when it's easier to learn things.[1]
SEN	Individual learners show preferences for the mode in which they receive information (e.g., visual, auditory, kinesthetic).[1]
LT	Learners' cognitive abilities can improve with intensive training.
LT	Learning material can be remembered longer when it is actively worked through rather than read.
NEU	When one brain region is damaged due to injury, other parts of the brain can take up its function.[2]
GEN	Male brains are bigger than female brains.[2]
	Cronbach's alpha (α) 0.66
Scale: Misconceptions scale (neuromyths)	
To what extent do you agree with the following statements?	
MEM	The brain works like a hard drive. Information is stored at specific locations.[3]
MEM	Our genetically determined number of brain cells determines the maximum level at which we can learn.[4]
HEM	The right brain hemisphere is more involved in creative thought processes, and the left in logical thought processes.
HEM	Every person uses the right and left hemispheres to a different extent. This can explain differences amongst learners.[2]

HEM	Short bouts of co-ordination exercises can improve the interaction between the left and right hemispheres.[2]
BA	It is possible to learn while we sleep via the acoustic channel (e.g., audio recordings of vocabulary lists).
DEV	If the brain is not sufficiently supported in early childhood, learning problems that can no longer be remediated by education can occur.[2]
DEV	Learners are most receptive to learning processes from birth to the third year of life.[4]
SEN	Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic).[1]
LT	Learners perform better when they are able to study different topics systematically one-by-one rather than intermingled with one another.
NEU	We only use 10% of our brain.[1]
	Cronbach's alpha (α) 0.76

NOTE. answer format = 4-point Likert scale (1 – disagree, 2 – somewhat disagree, 3 – somewhat agree, 4 – agree); [1]according to Dekker et al. (2012).; [2]concretized on the basis of items from Dekker et al. (2012); [3]based on Howard-Jones et al. (2009), concretized in accordance with Schletter and Bayrhuber (1998); [4]developed on the basis of Bellert and Graham (2013); MEM = memory; HEM = hemispheric asymmetry; BA = brain activity; DEV = development; SEN = sensory modalities; LT = learning techniques; NEU = neuroplasticity; GEN = gender differences

APPENDIX B

District Permission Request Email

Dear [School District's] Research and Evaluation Department:

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for a PhD degree. The title of my research project is Predicting K-12 Teacher Self-Efficacy from Neuroscience Literacy Factors. The purpose of this survey is to better understand the correlation between teacher's neuroscience literacy and teacher self-efficacy.

I am writing to request your permission to contact members of your school district to invite them to participate in my research study.

Participants will be asked to click on the link provided and complete the attached survey. Participants will be presented with informed consent information prior to participating. Taking part in this study is completely voluntary, and participants are welcome to discontinue participation at any time.

Thank you for considering my request. If you choose to grant permission, please provide a signed statement on official letterhead indicating your approval. A permission letter document is attached for your convenience.

Sincerely,

Tobey Nichols
Ph.D. Student
Liberty University

APPENDIX C

Email Recruitment Letter

Dear Teacher:

My Name is Tobey Nichols, and I am a graduate student in the School of Education at Liberty University. I am conducting research as part of the requirements for a PhD degree. I am writing to request your participation in a Teacher Knowledge and Self-Efficacy Survey of licensed teachers. The purpose of this survey is to better understand the correlation between teachers' neuroscience literacy and teacher self-efficacy.

To participate, you must be a current, K-12, credentialed Tennessee teacher of record for at least one course. Participants, if willing, will be asked to take an online survey. The survey will take approximately 10 minutes to complete. Your participation in this study is completely voluntary and all your responses will be anonymous. No personal, identifying information will be collected, and none of the responses will be connected to identifying information.

To participate, please click on the following link: survey link

If you have any questions about this survey or difficulty in accessing the site or completing the survey, please contact me, Tobey Nichols, at [redacted]

A consent document is provided as the first page of the survey and is attached to this email. The consent document contains additional information about my research. Because participation is anonymous, you do not need to sign and return the consent document unless you would prefer to do so.

Thank you in advance for providing this important feedback.

Note: This survey has been approved by Liberty University IRB. The survey is being conducted using Google Forms ®, a cloud-based software. All data will be downloaded and stored on the researcher's hard drive at the conclusion of the survey.

Sincerely,
Tobey Nichols
Ph.D. Student
Liberty University

APPENDIX D

Consent

Title of the Project: Predicting K-12 Teacher Self-Efficacy from Neuroscience Literacy Factors
Principal Investigator: Tobey Nichols, PhD student, Liberty University

Invitation to be Part of a Research Study

You are invited to participate in a research study. To participate, you must be a current K-12, credentialed Tennessee teacher of record for at least one course. Taking part in this research project is voluntary.

Please take time to read this entire form and ask questions before deciding whether to take part in this research.

What is the study about and why is it being done?

The purpose of this quantitative correlational study is to explore how K-12 teachers' self-efficacy correlates to their neuroscience literacy factors.

What will happen if you take part in this study?

If you agree to be in this study, I will ask you to do the following things:

1. Complete the survey, answering all questions truthfully and to the best of your ability. This should take approximately 10 minutes.

How could you or others benefit from this study?

Participants should not expect to receive a direct benefit from taking part in this study.

Benefits to society include an increased understanding of neuroscientific literacy's correlation to teacher self-efficacy. Additionally, this study can show the potential benefits of neuroeducation and neuroscientific literacy on teacher practice.

What risks might you experience from being in this study?

The risks involved in this study are minimal, which means they are equal to the risks you would encounter in everyday life.

How will personal information be protected?

The records of this study will be kept private. Research records will be stored securely, and only the researcher will have access to the records.

- Participant responses will be anonymous
- Data will be stored on a password-locked computer and may be used in future presentations. After three years, all electronic records will be deleted.

How will you be compensated for being part of the study?

Participants will not be compensated for participating in this study.

Is study participation voluntary?

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with Liberty University. If you decide to participate, you are free to not answer any question or withdraw at any time prior to submitting the survey without affecting those relationships.

What should you do if you decide to withdraw from the study?

If you choose to withdraw from the study, please exit the survey and close your internet browser. Your responses will not be recorded or included in the study.

Whom do you contact if you have questions or concerns about the study?

The researcher conducting this study is Tobey Nichols. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact him at [redacted] You may also contact the researcher's faculty sponsor, Jeffrey Savage, at [redacted].

Whom do you contact if you have questions about your rights as a research participant?

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board, 1971 University Blvd., Green Hall Ste. 2845, Lynchburg, VA 24515 or email at irb@liberty.edu.

Disclaimer: The Institutional Review Board (IRB) is tasked with ensuring that human subjects research will be conducted in an ethical manner as defined and required by federal regulations. The topics covered and viewpoints expressed or alluded to by student and faculty researchers are those of the researchers and do not necessarily reflect the official policies or positions of Liberty University.

Your Consent

Before agreeing to be part of the research, please be sure that you understand what the study is about. You will be given a copy of this document for your records. If you have any questions about the study later, you can contact the researcher using the information provided above.

By continuing this survey you confirm that you consent to participate in the study.