Spring 2018

Changing Pre-Service Teachers' Beliefs about Prevalent Brain-based Myths in Education

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CHANGING PRE-SERVICE TEACHERS' BELIEFS ABOUT PREVALENT BRAIN-BASED MYTHS IN EDUCATION

A Specialist Project
Presented to
The Faculty of the Department of Psychology
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
Of the Requirements for the Degree
Specialist in Education

By
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May 2018

CHANGING PRE-SERVICE TEACHERS' BELIEFS ABOUT PREVALENT BRAIN-BASED MYTHS IN EDUCATION

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ACKNOWLEDGMENTS

First and foremost, I would like to thank my thesis chair, Dr. Lisa Duffin, for her support throughout this process. I am thankful for the opportunity to have worked as her graduate research assistant, presented at conferences with her, and now finished my specialist project under her guidance. For the last three years, Dr. Duffin has helped me enhance my research and presentation skills, which will undoubtedly carry with me into my new career as a school psychologist. I am forever grateful for the professional relationship and advice that Dr. Duffin has provided throughout my time at Western Kentucky University.

In addition, I would like to thank Dr. Carl Myers and Dr. Martha Day for serving on my specialist project committee. Dr. Myers' perspective as a school psychologist and Dr. Day's perspective as a teacher educator have been invaluable contributions to my specialist project. Thank you for your time and assistance.

Finally, I would like to thank my friends and family for their support throughout my graduate career and the process of completing this specialist project. My school psychology cohort is a truly amazing group of women. The bond we have created is priceless and I would not have made it through graduate school without all of you. Thank you to my parents and Dillon for your consistent and endless advice, comfort, and optimism.

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The present study examined if a conceptual change intervention would decrease pre-service teachers' beliefs in four prevalent brain-based myths in education, including Visual-Auditory-Kinesthetic (VAK) learning styles, Gardner's multiple intelligences theory, left- or right-brained hemispheric dominance, and that humans only use 10% of their brains. Participants included 87 college students from one large, comprehensive university who were enrolled in an educational psychology course. All participants received the conceptual change intervention, which consisted of reading an article refuting the brain-based myths, submitting a paper showcasing evaluative thinking and reflection about the brain-based myths, and discussing cognitive development and the brain-based myths in class. All participants completed a measure of demographics and a pre-test, post-test, and delayed post-test measuring their beliefs in each of the brain-based myths. Cochran's Q Test revealed that there was a significant difference in the change of proportion of believers and non-believers between at least two of the tests. Results of McNemar's Test indicate that there was a significant difference in the change of proportion from believers to non-believers from the pre-test to the post-test, but not from the post-test to the delayed post-test. The relevance of these findings to current research, the implications for teacher education programs, limitations, and future directions are discussed.

Introduction

The National Council on Teacher Quality (2016) indicates that the mission of teacher education programs is to produce highly qualified teachers. To be considered "highly qualified," teachers must possess a bachelor's degree, be certified, and demonstrate content expertise (Department of Education, 2004). Critics, however, argue that content expertise is not enough for quality teaching (National Academy of Education, 2009). In fact, education experts agree that teachers must also possess extensive knowledge of learners and learning (e.g., Darling-Hammond, 2006; Darling-Hammond & Bransford, 2005; National Academy of Education, 2009; National Council on Teacher Quality, 2016) since "understanding children, how they develop, and how they learn is critical for effective instruction" (NAE, 2005, p. 9).

Unfortunately, pre-service teachers' conceptions about how people learn (i.e., epistemic beliefs) begin forming during what Lortie (1975) considered the apprenticeship of observation period. This period is the time spent critically observing and evaluating teaching professionals from the student's perspective. Pre-service teachers' epistemic beliefs are also highly influenced by their personal experiences and interactions with important others -- e.g., teachers, families, peers, popular culture (Buehl & Fives, 2009; 2016; Fives & Buehl, 2012; Holt-Reynolds, 1992; Lortie, 1975; Pajares, 1992). The epistemic beliefs serve as a filter through which new information is sorted and evaluated. Information that is consistent with their conceptions is integrated into their existing cognitive network and serves as the foundation for pedagogical decision-making (Pintrich, Marx, & Boyle, 1993). The greater challenge for teacher educators is when pre-service teachers' epistemic beliefs significantly differ from the scientifically-grounded content that *should be* encountered during teacher preparation programs. Thus, one challenge to teacher educators is to create learning opportunities that promote conceptual change (Hollingsworth, 1989; Jones & Vesilind, 1996; Patrick & Pintrich, 2001; Sinatra & Kardash, 2004; Yip, 2004). Stimulating conceptual change is an arduous process in large part because epistemic beliefs tend to be deeply rooted in existing cognitive structures, are implicit, and therefore not spontaneously and consciously questioned (Buehl & Fives, 2016; Pajares, 1992).

The second challenge for teacher educators is ensuring that the epistemic content is grounded in scientific research (Poulou, 2006) that is critically consumed (Wilson & Peterson, 2006). When considering how students learn, teacher education programs must be diligent in aligning the content with scientifically-grounded information gathered from the learning sciences -- e.g., educational psychology, cognitive psychology, neuroscience (Hoy, 2000). Unfortunately, many brain-based myths (i.e., neuromyths) have permeated the education system at alarming rates due to the misinterpretation of neuroscientific research about how the brain works (Goswami, 2006; Papadatou-Pastou, Haliou, & Vlachos, 2017; Tardif, Doudin, & Meylan, 2015). Even worse, these neuromyths gain further traction in classrooms with seemingly endless programs and assessments available claiming to be based on brain science that have intuitive and wide-spread appeal (Geake, 2008; Goswami, 2006; Hook & Farah, 2013).

Since “a functioning [society] relies on an educated and well-informed populace” (Lewandowsky, Ecker, Siefert, Schwarz, & Cook, 2012, p. 107), it is critical that teacher education programs illuminate the prevalence of pre-service teachers’ beliefs about these brain-based myths and take steps in changing them to be scientifically grounded.

Otherwise, pre-service teachers will enter the field of education using incorrect information to guide their instructional practices and thus, might thwart student development and learning rather than maximize it. Luckily, pre-service teachers typically enroll in an educational psychology course as part of their teacher preparation programs (Patrick, Anderman, Bruening, & Duffin, 2011; Poulou, 2005). Since educational psychology is one such field that contributes to the learning sciences and affords pre-service teachers the opportunity to explore the research and theory of how people learn (Hoy, 2000; Patrick et al., 2011; Poulou, 2005; Spencer, 2005), it would serve as an appropriate forum to address pre-service teachers' epistemic beliefs about how the brain works and correct misinformation to be more scientifically sound. Therefore, the purpose of this study is two-fold: 1) to expose the prevalence of pre-service teachers' beliefs about popular neuromyths and 2) to design and test the efficacy of a classroom-based intervention to correct misconceptions.

Literature Review

Highly Qualified Teachers

While highly qualified teachers are defined as having a bachelor's degree, certification, and content expertise (Department of Education, 2004), knowledge of learners and learning is also critical (National Council on Teacher Quality, 2016). The conventional view of teaching is that teachers should know the subject matter and simply transmit the information to students (National Academy of Education Committee on Teacher Education [NAECTE], 2007). However, effective teaching requires much more, including assessing how students learn and what they know in order to create engaging lessons that advance them to where they need to be (NAECTE, 2007). The Framework for Teaching adopted by Kentucky's Department of Education (2017) states that, in order for teachers to be rated as "Accomplished" or "Exemplary", they must understand the nature of student learning and seek knowledge about their students' levels of development. However, beginning teachers vary widely in the preparation they have been given to accomplish these standards (NAECTE, 2007). Improving teacher quality entails early preparation during teacher education programs (National Academy of Education, 2009).

Therefore, teacher education programs must equip pre-service teachers to understand the basics of learning and development. The curriculum should be organized in a way that supports teacher development; specifically, "moving from a focus on self to a focus on student learning and from the foundations of learning theories to their implications for teaching" (NAECTE, 2007, p. 115). Furthermore, teachers must acquire a skill set that allows them to use what they have been taught in their teacher education programs, but also to seek out new strategies so that they can continue to be effective in the classroom (NAECTE, 2007). Essentially, teachers must learn how to become lifelong learners. One way teacher education programs can equip pre-service teachers to become lifelong learners and thus high-quality teachers is to address their beliefs and misconceptions about teaching and learning (NAECTE, 2007).

Pre-Service Teachers' Epistemic Beliefs

Understanding teachers' beliefs and how they are related to teaching practices may help teacher educators to plan instruction that will support the development of teachers' understanding of how students learn (Fives & Buehl, 2008). A belief is an "individual's judgment of the truth or falsity of a proposition" (Pajares, 1992, p. 316). Teachers' beliefs can include beliefs about self, context or environment, content or knowledge, specific teaching practices, teaching approach, and students (Fives & Buehl, 2012). Beliefs influence how teachers perceive and interpret information; new information is understood through the filter of existing beliefs (Fives & Buehl, 2012). In addition, teachers' beliefs about learning influence their behavior in the classroom (Fives & Buehl, 2008; Patrick & Pintrich, 2001).

Beliefs and knowledge are considered to be different, but interwoven constructs (Fives & Buehl, 2012). In contrast to beliefs, teaching knowledge is an individual's information, skills, experiences, beliefs, and memories related to teaching (Fives & Buehl, 2008). Beliefs underlie knowledge in that knowledge requires you to have a belief in the "authority of its source, in one's logic, or in one's own sense" (Pajares, 1992, p. 312). Beliefs about teaching knowledge may be important if they guide teachers to value or not value information presented during teacher education programs (Fives & Buehl, 2008). While personal beliefs can be valuable, teacher education programs need to inform teaching knowledge by teaching the value of research-based practices and provide teachers with the skills to use them (Fives & Buehl, 2012).

As prefaced, it is important to intervene with pre-service teachers during teacher education programs. Experienced teachers are often resistant to new ideas about teaching and learning, while pre-service teachers' beliefs may be more malleable (Patrick & Pintrich, 2001). Some researchers have stated that it may be difficult to change pre-service teachers' beliefs because they may have commitments to prior beliefs due to their own experiences in school (Pajares, 1992; Patrick & Pintrich, 2001). If brain-based myths were promoted in their own educational experiences, pre-service teachers are likely to enter a teacher education program believing in those brain-based myths (Patrick & Pintrich, 2001). However, Buehl and Fives (2009) stated that pre-service teachers' epistemic beliefs can change as a result of instruction. Yough, Herron, Richards, and Ware (2015) recommended that educational psychology courses promote perspectives of learning that are different than the beliefs that have been promoted in previous educational experiences.

Research and theory on conceptual change offers guidance about how to change pre-service teachers' beliefs to being scientifically sound. Conceptual change is defined as overcoming misconceptions and restructuring conceptions so that they are consistent with widely accepted scientific viewpoints (Taasoobshirazi, Heddy, Bailey, & Farley, 2016). There are several important features of conceptual change. What students already know about a concept influences how they perceive information and to what information they pay attention. It can also influence how they process, understand, and use that information (Patrick & Pintrich, 2001). Students' conceptions may be implicit and they may exist because they make sense or seem useful. Misconceptions may interfere with learning more appropriate conceptions and they may be difficult to change (Patrick & Pintrich, 2001). Finally, the process of conceptual change is "assumed to be difficult, time-consuming, and long term and to require a high level of student cognitive and metacognitive engagement as well as persistence (Patrick & Pintrich, 2001, p. 118).

Two types of conceptual change include assimilation and accommodation (Posner, Strike, Hewson, & Gertzog, 1982). Assimilation is using existing concepts to deal with new information. If someone knows little about a concept, new information is likely to be combined easily with existing ideas (Pintrich, Marx, & Boyle, 1993). As previously mentioned, however, pre-service teachers may have commitments to prior beliefs about brain-based myths from their own experiences in school. If a student has well-developed concepts about the brain-based myths and the concepts conflict with what is understood to be true, it will be more difficult to change that students' beliefs (Pintrich et al., 1993). When presented with evidence refuting brain-based myths, pre-service teachers are more likely to experience accommodation than assimilation.

Accommodation occurs when current concepts are not adequate for students to understand new information. The student would have to replace or reorganize their central concepts about the brain-based myths (Posner et al., 1982). Several conditions are necessary for accommodation to occur. First, there must be dissatisfaction with existing conceptions. When new conceptions are presented, the student must understand and give meaning to the new concept. The student needs to be able to see how the new concept offers a better explanation than their previous beliefs. Finally, the concept should have the potential to lead to new insights (Cinici & Demir, 2013; Pintrich et al., 1993; Posner et al., 1982; Yip, 2004).

Other factors that influence whether conceptual change occurs are cognition and motivation. Important cognitive factors include metacognition, deep processing, and scientific thinking. Metacognitive skills require thinking about one's thinking, so students have to become aware that their existing beliefs may not be sufficient, use reflection, and become dissatisfied enough with their beliefs to change them (Patrick & Pintrich, 2001). In addition, deep processing should occur instead of shallow processing. Students have to be engaged with the content. Rather than simply memorizing content, students need to use elaborative rehearsal to associate the content with more meaning and understand it more fully (Patrick & Pintrich, 2001). Finally, scientific thinking requires students to question ideas and theories and hypothesize new ideas (Patrick & Pintrich, 2001).

Motivation interacts with cognition to impact conceptual change (Taasoobshirazi Heddy, Bailey, & Farley, 2016). Some motivational factors that can influence cognitive factors and lead to conceptual change include mastery goals, interest and value, and control beliefs. Students have a mastery goal when they are more concerned with understanding the concepts than with grades or performing better than others (Patrick & Pintrich, 2001). If pre-service teachers have a mastery goal orientation, they are more likely to think deeply about concepts and revise their own conceptions (Patrick & Pintrich, 2001; Taasoobshirazi et al., 2016). Having a personal interest in the content being taught is related to "learning, comprehension, and understanding as well as deeper cognitive engagement and metacognition (Patrick & Pintrich, 2001, p. 133). While the process of conceptual change is assumed to be difficult and time-consuming, personal interest can influence effort and willingness to persist in the gaining of knowledge (Pintrich et al., 1993). In addition, if students see value in the content, they may be more likely to consider how they can change their own conceptions (Patrick & Pintrich, 2001). Moreover, if students believe information is interesting, important, and useful, they are more likely to use deeper processing strategies (Pintrich et al., 1993).

Control beliefs also influence conceptual change. If students do not believe they have control over their learning, they might be less willing to try to resolve conflicts between prior information about brain-based myths and new information. If students do believe they have control over their learning, they may actively try to resolve the conflicts (Pintrich et al., 1993). Based on how conceptual change is fostered, an intervention that targets conceptual change in pre-service teachers' beliefs should include several components. First, an intervention should require pre-service teachers to use metacognitive skills, whereby they would become aware that their beliefs are not sufficient and use reflection to change beliefs. Another cognitive component an intervention should include is requiring engaging deep processing, which could be accomplished by discussing misconceptions and scientifically-based content in class. A third cognitive component that should be included is scientific thinking, which would include pre-service teachers' use of research to support conceptual change.

An intervention that targets conceptual change in pre-service teachers' beliefs should include motivational components as well, including developing mastery goals, personal interest, and control beliefs. First, an intervention should foster a mastery goal by focusing on the comprehensiveness of ideas and quality of the students' work that is produced. Second, the intervention should target conceptual change about beliefs that are directly related to pre-service teachers' fields within education, thus presumably sparking personal interest. Finally, the intervention should include control beliefs by allowing pre-service teachers a menu of choices on which misconceptions they want to pursue based on interest and their own educational fields.

Popluar Brain-Based Myths in Education

Brain-based myths, also known as neuromyths, are misconceptions about the brain and its functions (Organisation for Economic Co-operation and Development, 2002). Some of the most popular brain-based myths in education that can be targeted for a conceptual change intervention include: Visual-Auditory-Kinesthetic (VAK) learning styles, left- or right-brained thinking, multiple intelligences theory, and that we use 10% of our brain (Geake, 2008).

VAK learning styles. There are a multitude of learning styles theories, but a prominent one in the education field that should be targeted in a conceptual change intervention is the VAK learning styles theory. This theory purports "that the information gained through one sensory modality (visual, auditory, and kinesthetic) is processed in the brain to be learned independently from information gained through another sensory modality" (Geake, 2008, p. 130). If a teacher can discover each student's learning style – or dominant sensory modality, they can then tailor instruction to match; thereby increasing student learning outcomes. The VAK learning styles theory has appeal in educational practice as it can explain why students are doing well or poorly (Pashler, McDaniel, Rohrer, & Bjork, 2009). For example, supporters of this theory could state that a visual learner did poorly on a test on information that was taught in a lecture, or auditory format, because the way the information was presented was not in the way that the student learns best.

Cognitive neuroscientific research provides evidence to refute the VAK learning styles myth. The presumption that individuals process sensory information independently in the brain is a complete fallacy and flies in the face of the brain's natural neural interconnectivity (Geake, 2004; Singh & O'Boyle, 2004; Walsh & Pascual-Leone, 2003). In fact, the brain has the capacity to modify its neural networks in response to experience through the process of neuroplasticity (Bruel-Jungerman et al., 2007a, 2007b; Van Dam, 2013). Likewise, learning requires the coordinated use of the visual, auditory, and kinesthetic modalities in combination with cognitive functioning such as memory, decision-making, and emotion (Geake, 2008). Furthermore, bimodal processing occurs when the brain receives congruent information through both visual and auditory channels suggesting the supra-additive effect (Calvert, Campbell, & Brammer, 2000). In other words, when one simultaneously hears and sees the same information, the brain is more efficient in processing the information rather than seeing it first and then hearing it (Thompson & Paivio, 1994). Thus, educators should use multi-sensory pedagogies that help students "grow their brains," rather than trying to limit the experiences students encounter.

While the VAK learning styles theory seems intuitive, a number of research studies and meta-analyses have come to the conclusion that matching learning styles to teaching styles does not improve learning outcomes (Arter & Jenkins, 1977; Coffield, Moseley, Hall, & Ecclestone, 2004; Constantinidou & Baker, 2002; Cuevas, 2015; Kampwirth & Bates, 1980; Kavale & Forness, 1987; Krätzig & Arbuthnott, 2006; Massa

& Mayer, 2006; Pashler et al., 2009; Rogowsky, Calhoun, & Tallal, 2015; Tarver & Dawson, 1978). Studies that have found support for learning styles have methodological limitations that call into question the validity of the findings (Arter & Jenkins, 1977; Cuevas, 2015; Kampwirth & Bates, 1980; Kavale & Forness, 1987; Pashler et al., 2009). Similarly, learning styles inventories typically have poor reliability and may assess abilities rather than learning style preferences (Krätzig & Arbuthnott, 2006; Stahl, 1999). For example, some students prefer auditory presentations because they have poor reading skills. Therefore, using an auditory teaching style prohibits students from developing reading comprehension skills, further inhibiting students' abilities to learn from multiple sensory modalities.

Despite evidence that the VAK learning styles theory is not representative of the way students learn, belief in the myth is prevalent in the education field and has become a world-wide epidemic. Studies have found that, among practicing teachers, 93% in the United Kingdom (n = 137), 90% in the Netherlands (n = 105), 90% in Portugal (n = 583), and 91% in Spain (n = 284) reported believing in VAK learning styles (Dekker, Lee, Howard-Jones, & Jolles, 2012; Ferrero, Garaizar, & Vadillo, 2016; Rato, Abreu, & Castro-Caldas, 2013). A similar pattern can be found in a sample (n = 283) consisting of pre-service teachers, in-service teachers, and teacher trainers with 96% of the group believing in this myth (Tardif, Doudin, & Meylan, 2015). At the pre-service teacher level, 82% in England (n = 158) and 94% in Greece (n = 573) reported believing in VAK learning styles (Howard-Jones, Franey, Mashmoushi, & Liao, 2009; Papadatou-Pastou, Haliou, & Vlachos, 2017).

Together these studies indicate that the VAK learning styles myth is prevelant in European countries with both in-service and pre-service teachers. However, the prevalance of the VAK learning styles myth in the United States has yet to be documented. Likewise, if the prevalance of the VAK learning styles myth is as daunting with pre-service teachers in the U.S. as it has been in Europe, it would be critical to intervene during teacher preparation to promote conceptual change before they enter the classroom as practicing teachers.

Left- or right-brained thinking. A second popular brain-based myth in education that should be targeted for a conceptual change intervention is left- or right-brained hemispheric dominance. Left-brained or right-brained thinking is the idea that hemispheric dominance dictates learning capabilities. For example, those deemed as “left-brained” are better at analytic tasks and “right-brained” people are better at creative tasks. This myth presumes that the left and right hemispheres of the brain have entirely separate functions and operate individually. Research has demonstrated that some functions or activities are largely under control of one side of the brain, but that does not translate into the phenotypic differences associated with this myth (Nielsen, Zielinski, Ferguson, Lainhart, & Anderson, 2013). Left- or right-brained thinking is appealing in the education field because it provides a neurological basis for explaining students’ strengths and weaknesses. For example, one could state that a student excels in art class but struggles in math class because they are “right-brained.”

Under normal circumstances, the left and right hemispheres of the brain work together, not independently (Banich, 1998; Geake, 2008; Goswami, 2006; Harris, 1988; Hellige, 2000; Lindell & Kidd, 2011; Nielsen et al., 2013; OECD, 2002; Sperry, 1982).

Research that has found support for separate functioning of the left and right hemispheres is inconsistent (Harris, 1988) and the results are often oversimplified (Holmes, 2016). One MRI study found that there are local areas of the brain that are dominant, but there was no evidence that there is global lateralization, or that one hemisphere is dominant over the other (Nielsen et al., 2013). Several research studies have found that creativity involves both hemispheres, not just the right hemisphere (Carlsson, Wendt, & Risberg, 2000; Katz, 1997; Lindell & Kidd, 2011; Runco, 2004).

While research supports that the left and right hemispheres work together, the belief that hemispheric dominance controls learning capabilities is widespread among teachers. Studies have found that, among practicing teachers, 91% in the United Kingdom (*n* = 137), 86% in the Netherlands (*n* = 105), 76% in Portugal (*n* = 583), and 67% in Spain (*n* = 284) reported believing in left- or right-brained thinking (Dekker et al., 2012; Ferrero et al., 2016; Rato et al., 2013). In Switzerland, a similar pattern is again found with a sample of people (*n* = 283) comprised of pre-service teachers, in-service teachers, and teacher trainers with 85% of the sample believing in the myth (Tardif et al., 2015). At the pre-service teacher level, 60% (*n* = 158) in England and 55% (*n* = 573) in Greece reported believing in left- or right-brained thinking (Howard-Jones et al., 2009; Papadatou-Pastou et al., 2017). Again, research documenting the prevalance of the left- or right-brained myth with educators in the United States is warranted. Likewise, an intervention to help correct false beliefs among pre-service teachers during the teacher preparation process is needed.

Multiple intelligences theory. A third prevalent brain-based myth in the education field is multiple intelligences theory. Multiple intelligences theory, developed by Gardner (1991), is the idea that our brain consists of eight independent, self-sufficient processes – or intelligences. The types of intelligences include musical-rhythmic, visual-spatial, verbal-linguistic, logical-mathematical, bodily-kinesthetic, interpersonal, intrapersonal, and naturalistic. It is purported that each type of intelligence has its own set of core operations in the brain, which supports different activities (Klein, 1997). Similar to VAK learning styles theory and left- or right-brained thinking, multiple intelligences theory provides an explanation for differences among learners. If a student has excellent communication skills and delivers presentations well, but has a weakness in geometry, it may be explained that he or she has verbal-linguistic intelligence. It would be assumed that the student would not be able to make adequate progress in geometry because he or she does not have visual-spatial or logical-mathematical intelligences.

Multiple intelligences theory has not been supported by research. On the contrary, different parts of the brain are highly interconnected and are involved in many different abilities (Barnett, Ceci, & Williams, 2006; Geake, 2008; Roberts & Lipnevich, 2012; Waterhouse, 2006). Transfer of learning occurs from one type of intelligence to others, which should not happen if the intelligences are independent (Klein, 1997). One research study examined the relationships among each of the intelligences (Visser, Ashton, & Vernon, 2006). Participants took two tests for each of Gardner's eight intelligences and there were significant positive correlations for verbal-linguistic, visual-spatial, logical-mathematical, naturalistic, and interpersonal intelligences. The aforementioned intelligences also correlated with a measure of general ability. These relationships should not have occurred if the intelligences are independent from one another.

Furthermore, the definition of intelligence in the context of multiple intelligences theory deviates from what research currently supports as the construct of intelligence. Cattell-Horn-Carroll (CHC) theory is an empirically supported theory of intelligence that refutes the idea that "intelligences" are independent processes (McGrew, 2005). CHC theory is a hierarchical model of intelligence. There is an overarching *g*, or general intelligence that includes all abilities and is the most representative of intellectual functioning. Under the umbrella of *g* are broad abilities (e.g., fluid reasoning, short-term memory, processing speed, etc.). Broad abilities are further broken down into narrow abilities (e.g., fluid reasoning includes induction, general sequential reasoning, and quantitative reasoning). The most pertinent difference between multiple intelligences theory and CHC theory is that narrow and broad abilities are interwoven abilities that interact to contribute to an individual's *g*, or general intelligence (McGrew, 2005).

There has been little research assessing the prevalence of the belief in multiple intelligences theory in teachers. Rato et al. (2013) reported that 87% of Portugeuse teachers (n = 583) provided incorrect or uncertain responses about multiple intelligences theory. Therefore, more research is needed to determine the prevalance of pre-service teachers' and in-service teachers' beliefs in multiple intelligences theory.

10% brain usage. The 10% brain usage myth purports that, simply, we only use 10% of our brains during any given activity. For educators, the idea that we only use 10% of our brain means that 90% of the brain is untapped potential. There is no evidence to suggest that there are unused portions of the brain (Geake, 2008; Jarrett, 2015). The idea that we use our whole brain has been confirmed by thousands of brain scans (Jarrett, 2015). Jarrett (2015) reasoned that evolution offers an explanation for the use of the whole brain as well. The brain makes up two percent of our body mass, but uses 20% of our energy. Evolution would weed out an organ that uses so much energy but has little function.

Despite evidence that we use our whole brain, the 10% brain usage myth remains popular in the education field. In studies of in-service teachers, 48% in the United Kingdom (n = 137), 46% in the Netherlands (n = 105), 44% in Spain (n = 284), 40% in Argentina (n = 204), and 62% in Portugal (n = 583) believed that we use 10% of our brain (Dekker et al., 2012; Ferrero et al., 2016; Hermida, Segretin, Garcia, & Lipina, 2016; Rato et al., 2013). Approximately 74% (n = 573) of pre-service teachers in Greece reported believing or being unsure that we only use 10% of our brains (Papadatou-Pastou et al., 2017). While the 10% brain usage myth is seemingly not as widespread as the aforementioned myths, it still exists throughout several cultures and would be appropriate to include in a conceptual change intervention for pre-service teachers.

Purpose of Current Study

Previous research has indicated that beliefs in brain-based myths are prevalent amongst teachers across a variety of cultures (Dekker et al., 2012; Ferrero et al., 2016; Hoard-Jones et al., 2009; Rato et al., 2013). However, no research was found in a review of the literature about the prevalence of pre-service or in-service teachers' beliefs in brain-based myths in the United States. Because of the prevalence of beliefs in other cultures, the lack of research in the United States, and the role beliefs play in teaching and learning, an intervention specifically targeting brain-based myths in teacher education is needed. The factors that influence teachers' beliefs and whether conceptual change occurs in pre-service teachers should be considered when developing an intervention. There was no research found in a literature review that examined the effectiveness of interventions targeting specific brain-based myths within a pre-service teacher population. The present study aims to expose and change preservice teachers' beliefs about popular educational brain-based myths and evaluate whether the intervention produces a lasting effect on pre-service teachers' beliefs. Specifically, the guiding research questions are:

1. What is the prevalence of believers in brain-based myths amongst pre-service teachers at the beginning of the semester, at the end of the intervention, and the end of the semester?
    - Hypothesis: At the beginning of the semester, there will be a high prevalence of believers in brain-based myths amongst pre-service teachers, like the results of prior research. At the end of the intervention, the prevalence of believers will be reduced. The prevalence of believers at the end of the semester will be similar to the rates at the end of the intervention.
2. Is there a change in the proportion of believers in brain-based myths amongst pre-service teachers following the intervention and at the end of the semester?
    - Hypothesis: There will be a significant change in the proportion of believers in brain-based myths from pre-test to the end of the intervention. There will not be a significant change in the proportion of believers from the end of the intervention to the end of the semester.

Methodology

Participants

College students (*n* = 87) who were enrolled in one of the educational psychology courses during the Spring 2016 and Fall 2016 semesters taught by Dr. Duffin – an educational psychology professor in the Department of Psychology at one large comprehensive university -- were recruited to participate in the study. The participants were 21.45 years of age on average with a mean GPA of 3.39 (*n* = 83) on a 4.0 scale and a mean ACT composite score of 25.22 (*n* = 77) on a 0-36 scale. The total number of participants differs from the number of participants noted in Table 1 because some participants joined the class after the beginning of the semester and some participants dropped the class before the end of the semester. Table 1 highlights other key demographic information for the participants.

Measures

Neuromyth beliefs. Pre-service teachers' beliefs about the four popular neuromyths were measured using one item for each neuromyth, adapted from Dekker et al. (2012) and Rato et al. (2013). To reduce response bias, participants were given a list of ten statements and they were to determine whether each statement was True or False. Appendices A, B, and C depict each form of the ten statements that were administered. Responses were recorded in the dataset dichotomously as either Correct (1) or Incorrect (0). Research suggests that one-item measures can be used if the construct being measured is unambiguous (Rossiter, 2002; Wanous, Reichers, & Hudy, 1997). Some studies have found that single-item measures demonstrate adequate reliability, concurrent validity, construct validity,and predictive validity when compared to multiple-item measures (Bergkvist & Rossiter, 2007; Dolbier, Webster, McCalister, Mallon, &

Table 1

Participants' Demographic Information

	N	Percent
Sex (*n* = 83)		
Female	63	75.9
Male	20	24.1
Race (*n* = 83)		
Asian	2	2.4
Black/African American	4	4.8
White	76	91.6
Other	1	1.2
Status (*n* = 83)		
Freshman	7	8.4
Sophomore	39	47.0
Junior	33	39.8
Senior	4	4.8
Major (*n* = 83)		
Agriculture	4	4.8
Art Education	1	1.2
Biology	4	4.8
Education	6	7.2
Elementary Education	25	30.1
English for Secondary Teachers	4	4.8
Exceptional Education	1	1.2
Geology	1	1.2
History	1	1.2
International Affairs	1	1.2
Mathematics	12	14.5
Middle Grades Education	1	1.2
Middle Grades Mathematics	12	14.5
Middle School Science Education	4	4.8
Music	5	6.0
Physical Education	1	1.2

Steinhardt, 2005; Nagy, 2002). In addition, single-item measures are often easier to understand and can be completed more quickly (Dolbier et al., 2005). Furthermore, single-item measures are preferable when aiming to measure change over time (Dolbier et al., 2005; Wanous et al., 1997), such as beliefs in neuromyths from the beginning of the semester to the end of the semester. Wording on some of the items were revised for clarification purposes after the first administration to ensure each item was unambiguous and focused on a false belief in how the brain processes information according to the neuromyth. Table 2 showcases the items by administration.

Table 2

Items by Time of Administration

Brain-Based Myths	Spring 2016 Pre-Test	Spring 2016 Post-Test	Spring 2016 Delayed Post-Test/All Fall 2016 Measures
VAK Learning Styles	Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic).	Learning is maximized when individuals receive information in their preferred "learning style" or sensory modality (e.g., auditory, visual, kinesthetic).	Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic).
Left- or Right-Brained Thinking	Differences in hemispheric dominance can help explain individual differences amongst learners (e.g., People who are left-brained thinkers are good in tasks that require logic or analysis while right-brained thinkers are more creative and intuitive).	People who are left-brained thinkers are good in tasks that require logic or analysis while right-brained thinkers are more creative and intuitive.	Differences in hemispheric dominance can help explain individual differences amongst learners.
Multiple Intelligences Theory	There are at least eight independent types of intelligence according to Gardner's theory.	There are at least eight independent types of intelligence.	Our brain is wired to have at least 8 different kinds of intelligences (e.g., musical, mathematical, visual, physical, verbal).
10% Brain Usage	We only use 10% of our brain.	We only use 10% of our brain.	We only use 10% of our brain.

The intervention. The intervention was designed to include components of conceptual change that were identified by previous research (see Table 3). Specifically, participants were first required read Geake (2008), which discusses the four prevalent brain-based myths in education outlined above and the refuting evidence. Then, participants selected one of the myths that they believed to be the most popular neuromyth in their education fields and wrote a paper (see Appendix D) that highlighted the refuting evidence along with a plan for changing other educators' beliefs to being more scientifically sound. Finally, the brain-based myths were discussed throughout the first unit of the course which included content on the brain and cognitive development.

Table 3

Components of Conceptual Change in the Intervention

Theoretical Component	Application in the Intervention
Cognition	
Metacognitive Skills	• Students became aware that their existing beliefs about neuromyths were not sufficient and used reflection by reading Geake (2008) and writing the assigned paper.
Deep Processing/ Engagement	• Students discussed neuromyths throughout the first unit of the course. • Writing the paper required students to think about the meaning and evidence refuting the neuromyth they chose.
Scientific Thinking	• Students were required to use research as support to describe their methods for how they would attempt to change other educators' beliefs to being more scientifically sound.
Motivation	
Mastery Goals	• Grading was based on comprehensiveness of ideas (i.e., completeness of ideas and clarity of communication) and quality of writing; not on correctness of understanding the scientific evidence.
Personal Interest & Control Beliefs	• Students were given choice on which neuromyth they believed to be the most prevelant in their fields of education (increase perceived value). • Students were asked to create a plan to change other educators' beliefs to being scientifically sound

Procedure and Experimental Design

The study employed a pre-test post-test design where participants took the pre-test on the first day of the semester. The participants during the Spring 2016 semester took a pencil-and-paper pre-test, while the participants during the Fall 2016 semester took an online pre-test. During the first week of class, participants were asked to complete the first part of the intervention (i.e., reading the article and submitting a 1-2 page paper showcasing evaluative thinking and reflection about the neuromyths). This paper was to be completed independently and was not supplemented by in-class discussions or activities. In the third week of the semester, participants explored the chapter on Cognitive Development (e.g., brain development, theories of cognitive development) and the brain-based myths and refuting evidence were revisited during class discussions and activities. In the fourth week of the semester, participants' beliefs were assessed on the first exam of the semester via a paper-and-pencil format. The delayed post-test occurred at the end of the semester via an online quiz.

Analyses

To determine prevalence of beliefs in neuromyths, descriptive statistics were calculated. The percentage of participants identified as believers or non-believers were calculated for each neuromyth for the pre-test, post-test, and delayed post-test.

To determine if statistically significant differences exist between the proportion of believers in brain-based myths among the three tests, Cochran's Q test was conducted using the IBM SPSS 23 statistical program. Cochran's Q test is an extension of McNemar's test, which is the only test that can be used when both conditions use the nominal scale (Morrison, 2010). Cochran's Q test is a non-parametric statistical test that is used when three categorical variables measuring the presence or absence of a characteristic (i.e., believer or nonbeliever) collected from each participant at three different time points (Huedo-Medina, 2010; Pallant, 2010). Cochran's Q test detects if a change in proportion between at least two of the time points ocurred, but not which time points.

To determine if statistically significant differences exist between the proportion of believers in brain-based myths between the pre-test and the post-test and between the post-test and the delayed post-test, McNemar's test was conducted. McNemar's test is used when there are two categorical variables measuring the presence or absence of a characteristic (i.e., believer or nonbeliever) collected from each participant at two different time points (Pallant, 2010). Specifically, McNemar's test revealed how many participants changed from believer to nonbeliever, changed from nonbeliever to believer, remained a believer at both time points, and remained a nonbeliever for each myth at both time points.

Results

Descriptive statistics for the percentage of believers and non-believers at the pre-test, post-test, and delayed post-test are presented in Table 4. At the pretest, participants reported believing in VAK learning styles (82%), multiple intelligences theory (87%), and left- or right- brained thinking (81%). Only 48% of participants reported believing that we only use 10% of our brain. At the post-test, the majority of participants (range 88-100%) reported being non-believers of all four neuromyths. At the delayed post-test, the majority of participants (range 81%-100%) continued to report being non-believers of all four neuromyths.

Table 4

Descriptive Statistics of Percentage of Believers and Nonbelievers

	VAK Learning Styles	10% Brain Usage	Multiple Intelligences	Left- or Right-Brained Thinking
Pre-Test (*n*=84)				
Believers	82%	48%	87%	81%
Non-Believers	18%	52%	13%	19%
Post-Test (*n*=86)				
Believers	10%	0%	12%	6%
Non-Believers	90%	100%	88%	94%
Delayed Post-Test (*n*=78)				
Believers	6%	0%	19%	6%
Non-Believers	94%	100%	81%	94%

To determine the proportion of change from believers to non-believers across all three time points (i.e., pre-test, post-test, and delayed post-test), a Cochran's Q Test was used. For all four neuromyths, a statistically significant proportion of participants' beliefs were changed: VAK learning styles, Q(2) = 102.46, p = .000; 10% usage, Q(2) = 68.00, p = .000; Multiple intellences, Q(2) = 79.61, p = .000; and Left- vs. Right-brain hemispheric dominance, Q(2) = 98.44, p = .000. The results demonstrate that there was a significant change in the proportion of the participants' beliefs between two time points, but not at which two time points.

Table 5 depicts the results of McNemar's Test, which was conducted to determine the proportion of change from believers to non-believers from pre-test to post-test. The proportion of change was statistically significant at the $p < 0.1$ level, indicating a significant proportion of participants' beliefs were changed from pre-test to post-test. There was a shift in the number of participants who reported being believers to non-believers from pre-test to post-test for VAK learning styles (n = 60), 10% brain usage (n = 40), multiple intelligences theory (n = 65), and left- or right-brained thinking (n = 63). Each number in Table 5 represents the number of participants in each category, but McNemar's Test calculates the significance of the change in proportion.

Table 5

McNemar's Test from Pre-Test to Post-Test

Pre-Test	Post-Test	VAK Learning Styles	10% Brain Usage	Multiple Intelligences	Left- or Right-Brained Thinking
Believer	Believer	9	0	7	5
Non-Believer	Non-Believer	14	43	8	15
Believer	Non-Believer	60*	40*	65*	63*
Non-Believer	Believer	0	0	3	0

Note: Change in neuromyth proportions from pre-test to post-test are marked with an asterisk (*) and differ at the $p < 0.1$ level.

Table 6 depicts the results of McNemar's Test from post-test to delayed post-test. There were no significant changes in proportion for any of the neuromyths. Most participants reported being non-believers at the post-test and the delayed post-test for VAK learning styles (n = 67), 10% brain usage (n = 77), multiple intelligences theory (n

= 58), and left- or right-brained thinking (*n* = 70). As in Table 5, each number in Table 6 represents the number of participants in each category.

Table 6

McNemar's Test from Post-Test to Delayed Post-Test

Post-Test	Delayed Post-Test	VAK Learning Styles	10% Brain Usage	Multiple Intelligences	Left- or Right-Brained Thinking
Believer	Believer	3	0	4	2
Non-Believer	Non-Believer	67	77	58	70
Believer	Non-Believer	5	0	5	2
Non-Believer	Believer	2	0	10	3

Discussion

Research has demonstrated that VAK learning styles, multiple intelligences theory, 10% brain usage, and left- or right-brained thinking are myths that do not accurately explain how students learn (Banich, 1998; Barnett et al., 2006; Geake, 2004; Geake, 2008; Goswami, 2006; Harris, 1988; Hellige, 2000; Holmes, 2016; Jarrett, 2015; Klein, 1997; Lindell & Kidd, 2011; Nielsen et al., 2013; Pashler et al., 2009; Roberts & Lipnevich, 2012; Singh & Boyle, 2004; Visser et al., 2006; Walsh & Pascual-Leone, 2003; Waterhouse, 2006). However, teachers across countries outside of the United States have reported high rates of beliefs in each of these neuromyths (Dekker et al., 2012; Ferrero et al., 2013; Hermida et al., 2016; Howard-Jones et al., 2009; Papadatou-Pastou et al., 2017; Rato et al., 2013; Tardif et al., 2015). Given the high prevalence of beliefs that are not grounded in scientifically based content, teacher education programs must equip pre-service teachers to understand the basics of learning and development. Understanding pre-service teachers' epistemic beliefs and how conceptual change occurs are important components of an intervention to decrease beliefs in neuromyths. Thus, the aim of the present study was to expose and change pre-service teachers' beliefs about popular educational neuromyths and evaluate whether the intervention produced a lasting effect on their beliefs.

The first hypothesis was that, at the beginning of the semester, there would be a high prevalence of believers in brain-based myths amongst pre-service teachers, similar to the results of previous research. At the end of the intervention, the prevalence of believers would be significantly reduced. At the end of the semester, the prevalence of believers would remain similar to the prevalence at the end of the intervention. That is, the prevalence of believers would decrease at the post-test and remain at a similar prevalence across time. The results indicated that 48%-87% of participants believed in the neuromyths at the pre-test. At the post-test, the prevalence of believers was 0%-12% across the neuromyths. At the delayed post-test, the prevalence of believers was 0%-19% across the neuromyths. The descriptive statistics indicate that the prevalence of believers at the pre-test was a similar rate to results of previous research (e.g., Dekker et al., 2012; Ferrero et al., 2016; Hoard-Jones et al., 2009; Rato et al., 2013). The prevalence of believers at the post-test and delayed-post test were significantly reduced, indicating the hypothesis was supported.

The second hypothesis was that there would be a significant change in the proportion of believers in brain-based myths from pre-test to the end of the intervention. Furthermore, there would not be a significant change in the proportion of believers from the end of the intervention to the end of the semester. In other words, the intervention would maintain its effects across time. The results indicated that the proportion in change of believers and non-believers was statistically significantly different from pre-test to post-test. There were few participants who remained believers or changed from a non-believer to a believer. A small percentage of participants were initially non-believers and remained non-believers. The greatest change was from believer to non-believer. This indicates that the hypothesis was supported and the intervention was successful. In addition, the proportion in change of believers was not significantly statistically different from post-test to delayed post-test. Essentially, the majority of participants were non-believers at the post-test and remained non-believers at the delayed post-test. This also indicates that the hypothesis was supported and that the intervention had lasting effects.

One interesting finding was that some participants changed from a non-believer to a believer from pre-test to post-test and from post-test to delayed post-test. Specifically, three participants reported being non-believers in multiple intelligences theory at the pre-test and believers in the theory at the post-test. From post-test to delayed post-test, the number of participants who reported being non-believers at the post-test and believers at the delayed post-test include two for VAK learning styles, 10 for multiple intelligences theory, and three for left- or right-brained thinking. For these participants, the intervention did not appear to have a lasting effect. Participants may have been exposed to the neuromyths in other classes or influenced by other extraneous variables, such as peers or popular culture. Another reason, specifically for multiple intelligences theory, could have been that the wording of the item was ambiguous.

Conclusion and Implications

Overall, the intervention was effective at reducing the number of believers in VAK learning styles, multiple intelligences theory, 10% brain usage, and left- or right-brained thinking. The participants were engaged in an intervention that required the use of metacognitive skills, deep processing of the content, and scientific thinking. Participants were given choice in the neuromyth they wrote about, which aided personal interest and control beliefs. Grading practices involved in the intervention encouraged the participants to adopt a mastery goal about the content. Each of these components, rooted in conceptual change theory, likely led the participants to change their epistemic beliefs to being more scientifically sound.

It is encouraging that the pre-service teachers decreased their beliefs in prevalent neuromyths after participating in one intervention. Knowledge of learners and learning is critical (National Council on Teacher Quality, 2016) and the intervention allowed pre-service teachers to add to that important knowledge base. Engaging with scientifically grounded content sets pre-service teachers on a path to being highly qualified teachers that understand how students learn and how they can aid in student development. Because of the widespread beliefs in the neuromyths in prior research and in the current study, one can delineate that many teachers have not been adequately equipped to be critical consumers of research surrounding how students learn. Even though educators are typically less likely to believe in neuromyths than the general public (Macdonald, Germine, Anderson, Christodoulou, & McGrath, 2017), beliefs in neuromyths among educators are still highly prevalent. For this reason, teachers should be taught to be critical consumers of research while in their teacher education programs. While their personal beliefs and prior knowledge are valuable, teaching knowledge should ultimately be informed by research-based practices (Fives & Buehl, 2012). Educational psychology courses are an appropriate medium for conceptual change interventions in the larger scope of teaching teachers how to use research-based practices because it is typically the course that discusses brain development and theories of cognitive development.

Limitations

There are several limitations to this study that should be taken into consideration. One limitation is the limited generalizability. This study used 87 participants from one university enrolled in different sections of one professor’s educational psychology courses. This limits the representativeness of the sample, indicating different results could occur with more participants from various universities with various professors. A second limitation is that there was no control group. All participants received the intervention as part of their educational psychology course. Although adding a control group to the existing participant pool would be difficult because it would add the necessity splitting instruction and assignments, a control group would have strengthened the results of the study.

A third limitation is that the items on the tests changed over time. While research supports the reliability and validity of single-item measures (Bergkbist & Rossiter, 2007; Dolbier et al., 2005; Nagy, 2002; Rossiter, 2002; Wanous et al., 1997), changing the wording of the measures could have affected the reliability and validity. It can be argued that the wording of the VAK learning styles and left- or right- brained thinking items remained semantically the same. The 10% brain usage item remained the same across all measures. However, the changes in the multiple intelligences theory items could have led to changes in interpretation. Specifically, the item originally stated, “There are at least eight independent types of intelligences according to Gardner’s theory.” The aim of the item was that if participants answered “True”, they were believers in the neuromyth and that if they answered “False”, they were non-believers. However, the phrase “according to Gardner’s theory” makes the statement true, regardless that multiple intelligences theory is a neuromyth. The second and third versions of the item removed this phrase, thus eliminating ambiguity.

Future Research

Previous research coupled with the results, strengths, and limitations of the current study warrant further investigation on the topic of using conceptual change interventions to decrease the beliefs in prevalent neuromyths among pre-service teachers. The results indicate that a conceptual change intervention can be effective in reducing beliefs in neuromyths. Future studies should include more participants with various professors from various universities. Future research should also utilize a control group with which to compare the results of the experimental group.

Future studies should also utilize longitudinal research methods to determine whether the effects of the intervention continue once the participants become in-service teachers. It would be valuable to investigate whether the intervention affects pre-service teachers' actual teaching practices. Extraneous variables such as the experiences pre-service teachers have in future education courses and under teacher mentors should be taken into consideration.

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Appendix A: Spring 2016 Pre-Test

1.	Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic).	True	False
2.	The left and right hemispheres of the brain always work together.	True	False
3.	We only use 10% of our brain.	True	False
4.	There are at least eight independent types of intelligence according to Gardner's theory.	True	False
5.	If only 10% of your brain was active, you would be in a vegetative state.	True	False
6.	Differences in hemispheric dominance can help explain individual differences amongst learners (e.g., People who are left-brained thinkers are good in tasks that require logic or analysis while right-brained thinkers are more creative and intuitive).	True	False
7.	Visual, auditory, and kinesthetic learning styles have been shown to remain stable over time for most students.	True	False
8.	Every cognitive skill employs a network of brain areas spread across both hemispheres of the brain.	True	False
9.	Several brain areas are active for any given activity, and even when we are doing nothing.	True	False
10.	Using Gardner's multiple intelligences theory is one of the most important steps to improve student learning.	True	False

Appendix B: Spring 2016 Post-Test

1.	Learning is maximized when individuals receive information in their preferred “learning style” or sensory modality (e.g., auditory, visual, kinesthetic).	True	False
2.	Every cognitive skill employs a network of brain areas spread across both hemispheres of the brain.	True	False
3.	We only use 10% of our brain.	True	False
4.	There are at least eight independent types of intelligence.	True	False
5.	Several brain areas are active for any given activity, and even when we are doing nothing.	True	False
6.	People who are left-brained thinkers are good in tasks that require logic or analysis while right-brained thinkers are more creative and intuitive.	True	False

Appendix C: Spring 2016 Delayed Post-Test/All Fall 2016 Measures

1. Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic).	True	False
2. The left and right hemispheres of the brain always work together.	True	False
3. We only use 10% of our brain.	True	False
4. Our brain is wirded to have at least 8 different kinds of intelligences (e.g., musical, mathematical, visual, physical, verbal).	True	False
5. If only 10% of your brain was active, you would be in a vegetative state.	True	False
6. Differences in hemispheric dominance can help explain individual differences amongst learners.	True	False
7. Visual, auditory, and kinesthetic learning styles have been shown to remain stable over time for most students.	True	False
8. Every cognitive skill employs a network of brain areas spread across both hemispheres of the brain.	True	False
9. Several brain areas are active for any given activity, and even when we are doing nothing.	True	False
10. Using Gardner's multiple intelligences theory is one of the most important steps to improve student learning.	True	False

Appendix D: Myths Paper Assignment

<u>MYTHS PAPER</u>

(Worth 25 points)

Based on your critical reading of the article, "Neuromythologies in education" (Geake, 2008) answer the following questions:

1) What myth (or misconception) <u>outlined in this article</u> do you think is most commonly held by educators in your field?
2) Why do you think it is the most commonly held misconception for your field? (You might have this misconception too!)
3) The scientific research provides evidence to "disprove" these myths. Using the research as support, describe your method for how you would attempt to change the educators' beliefs to being more scientifically sound?

Note. Make sure you explicitly talk about the myth and the research that "disproves" the myth in your paper so that a person who knows nothing would understand what you are discussing.

Evaluation is based on comprehensiveness of ideas and quality of writing.

TARGET AUDIENCE: A person who knows nothing, so write to educate!

FORMATTING:

- PAGE LENGTH: 1-2
- SPACING: Single
- MARGINS: 1"
- FONT SIZE: 12-point (Times New Roman or Calibri)
- FILE NAME: lastname_firstinitial_myths
- FILE FORMAT: .doc, .docx, or .rtf

DUE: 11:59 p.m. on the date outlined on the Course Schedule (see syllabus). Please make sure to upload your paper to the correct link in the ASSIGNMENTS section of our Blackboard course site.

Geake, J. (2008). Neuromythologies in education. *Educational Research, 50,* 123-133. doi: 10.1080/00131880802518

Myth Paper Rubric

Please copy and paste this rubric as the first page of the assignment.

Name:

1. Comprehensiveness	**/22**
2. Quality of Writing	**/2**
3. Rubric 1 = complete; 0 = incomplete	**/1**
TOTAL POINTS	**/25**

Comments:

RUBRIC & GRADING KEYS

	Excellent (22)	Good (18)	Fair (14)	Poor (10)
Comprehensiveness *Did you answer each question completely and thoroughly where a person who knows nothing would be able to understand what you mean?*	Responses to all 3 questions were complete and clear. No elaboration is needed.	Elaboration is needed in response to 1 of the questions.	Elaboration is needed in response to 2 of the questions.	Elaboration is needed in response to all 3 of the questions.
	Excellent (2)	Good (1.5)	Fair (1)	Poor (.5)
Quality of Writing	The author used a professional tone with sophisticated language and standard English. Minimal errors were detected.	The author used primarily standard English and overall, had a professional tone. Some errors were noticeably detected.	The author used a blend of standard and non-standard English, but it did not detract from the points being made. Errors were noticeably detected and were somewhat distracting.	The author used conversational language or non-standard English in the majority of the paper or was not as effective at communicating his or her message as he or she could have. Errors were noticeably detected and were very distracting.