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Morgan McAfee
University of Central Florida

Bobby Hoffman
University of Central Florida, bobby.hoffman@ucf.edu

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When teachers harbor misconceptions or unjustified beliefs about teaching, learning, and academic motivation, the pedagogical consequences can be severe. It is likely these teachers will unintentionally perpetuate such false beliefs upon students through ineffective teaching strategies or misinterpretations of learning science. Misconceptions among K-12 teachers are particularly deleterious due to the substantial influence teacher beliefs exert upon curriculum development, pedagogy, and the construction of effective learning environments. Prior research has explicated the prevalence of erroneous beliefs about general psychology and neuroscience among various populations but has rarely examined teachers' misconceptions about pertinent topics in educational psychology. Consequently, this review highlights theoretical, inferential, and measurement concerns specifically related to educational psychology misconceptions. Recommendations for future research and the development of appropriate instrumentation to measure and mitigate educational psychology misconceptions are also discussed.

Keywords

Misconceptions, Teacher Beliefs, Educational Psychology, Conceptual Change

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Morgan A. McAfee and Bobby Hoffman

University of Central Florida

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Abstract

When teachers harbor misconceptions or unjustified beliefs about teaching, learning, and academic motivation, the pedagogical consequences can be severe. It is likely these teachers will unintentionally perpetuate such false beliefs upon students through ineffective teaching strategies or misinterpretations of learning science. Misconceptions among K-12 teachers are particularly deleterious due to the substantial influence teacher beliefs exert upon curriculum development, pedagogy, and the construction of effective learning environments. Prior research has explicated the prevalence of erroneous beliefs about general psychology and neuroscience among various populations but has rarely examined teachers' misconceptions about pertinent topics in educational psychology. Consequently, this review highlights theoretical, inferential, and measurement concerns specifically related to educational psychology misconceptions. Recommendations for future research and the development of appropriate instrumentation to measure and mitigate educational psychology misconceptions are also discussed.

The summer 2020 issue of the journal *Educational Psychologist* (volume 55, issue 3) was entirely devoted to the identification, description, and elimination of the spread of false information, an increasingly prevalent phenomenon in the Internet age that is labeled as the communication of "post-truth." While conceptions of post-truth are dynamic and somewhat ambiguous, generally post-truth is defined as what happens when individuals prioritize personal beliefs and experience above facts and evidence, combined with the inability of individuals to decipher scientific fact from fiction (Barzilai & Chinn, 2020). The reason that false information perpetuates is primarily a consequence of individuals debating the existence or integrity of evidence while concurrently relying on emotionally charged opinions instead of upon evidence from replicable scientific studies (Sinatra & Lombardi, 2020).

Conspicuously absent from this volume of empirical research on post-truth was a discussion concerning the misconceptions held by current or prospective educators about their own discipline, educational psychology, which is devoted to the study of optimal methods for teaching, learning, and student motivation. Barzilai and Chinn (2020) indicated that "educators have been interested in how well students and teachers are prepared for dealing with post-truth phenomena and how to boost their preparedness" (p. 110). Yet many educators fail to realize, acknowledge, or discuss that the messages they send to their own students may not be evidence-based, but instead are of a personal nature, substantiated primarily by individual, group, or cultural experience and augmented by entrenched beliefs developed over a lifetime.

Unjustified beliefs, or beliefs explicitly contradicted by scientific evidence, are often termed "misconceptions," alternatively identified as preconceptions, personal epistemologies, alternative frameworks, naïve science, or mistaken and epistemically unwarranted beliefs, and motivated reasoning (Gardner & Brown, 2013; Hamza & Wickman, 2008; Hughes, Lyddy, & Lambe, 2013; Lobato, Mendoza, Sims, & Chin, 2014; Lombardi, Nussbaum, & Sinatra, 2016; Kowalski & Taylor, 2019; Muis et al., 2020, Sinatra, Kienhues, & Hofer, 2014). Misconceptions differ from scientific ambiguities, which are claims that do not have clear empirical support (G. M. Sinatra, personal communication, May 21, 2014), and exclude lack of domain knowledge and implicit self-beliefs. Misconceptions do not occur by lack of exposure to certain topics but materialize when fallacious knowledge must be 'unlearned' to create an evidence-based understanding of a phenomenon or concept.

The impact of misconceptions is profound. Misconceptions and science illiteracy among the general public leads to poor decision-making contrary to the best interests of society and the individuals within it (Sinatra et al., 2014), resulting in compromised judgment, irrational thinking, and the inability to learn new and accurate information (Chinn & Malhotra, 2002). Science misconceptions include dubious perceptions of climate change, questioning the suitability of genetically-modified organisms (GMOs) for the food supply, and parents circumventing vaccinations for their children, despite the confluence of contrary scientific evidence. Misconceptions both inside and outside the classroom have a significant impact on society, whether the belief is about human intelligence, brain-based instruction, or as simple as understanding how HIV/AIDS is transmitted and what the true outcome of infection is considering medical science (Johnson & Sinatra, 2014). Even highly educated K-12 in-service teachers with the best of intentions disseminate misconceptions about topics such as learning styles (Pashler, McDaniel, Rohrer, & Bjork, 2008), brain-based education initiatives (Dekker, Lee, Howard-Jones, & Jolles, 2012; Im, Cho, Dubinsky & Varma, 2018), and general student learning (Kirschner & van Merriënboer, 2013), despite a dearth of empirical support and substantial evidence to the contrary.

The misconceptions of teachers at all levels are especially egregious because teacher beliefs exert direct influence upon curriculum development, pedagogy, and the construction of effective learning environments (Woolfolk Hoy, Davis, & Pape, 2006). Teachers harboring misconceptions about teaching and learning may perpetuate those false beliefs upon their students (Hughes et al., 2015; Sadler & Sonnert, 2016). Extant research in educational psychology has frequently investigated teacher beliefs (Buehl & Fives, 2009; Fives & Buehl, 2008; Fives & Buehl, 2012) and prior research has established the existence of misconceptions in psychology (Gardner & Brown, 2013; Kowalski & Taylor,

2017; Lilienfeld, Lynn, Ruscio, & Beyerstein, 2010), science (Broughton, Sinatra, & Nussbaum, 2013; Cordova, Sinatra, Jones, Taasoobshirazi, & Lombardi, 2014; Heddy & Sinatra, 2013; Lombardi & Sinatra, 2012; Smolleck & Hershberger, 2011; Sinatra et al., 2014; Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001), mathematics (Green, Piel, & Flowers, 2008; Ryan & McCrae, 2005), and neuromyths (Dekker et al., 2012; Pickering & Howard-Jones, 2007; Im et al., 2018). However, to date, no published review on the development of pedagogical beliefs systems (Schommer, 1990) has addressed the existence, strength, description, measurement, or mediation of misconceptions about teaching, learning, and academic motivation (i.e., educational psychology) among pre-service teachers despite the substantial importance of "reflexive deliberation" upon teaching practice and effectiveness (Lunn Brownlee, Ferguson, & Ryan, 2017).

Thus, the purpose of this review is to highlight the literature gap regarding misconceptions by reviewing and evaluating what has already been learned about unjustified beliefs in psychology and education and applying that knowledge to educational psychology misconceptions. Thus, rather than provide an exhaustive review of the extant work in pseudoscience (e.g., ghosts, extraterrestrials, or the paranormal), public misconceptions of science, metaphysical beliefs, psychological misconceptions, post-truth or efforts to mediate these false beliefs, this review explores the educational psychology misconceptions potentially held by pre-service teachers and primarily, but not exclusively embraced by K-12 in-service teachers. The explicit purpose of this review is to create greater awareness concerning the types of educational psychology misconceptions educators may harbor, as the first step toward eradicating false beliefs about teaching, learning, and academic motivation. In addition, we highlight the practical implications associated with teacher misconceptions and outline key measurement criteria that will allow researchers to accurately assess existing educational psychology misconceptions.

METHODOLOGY

Inclusion and Exclusion Criteria

The concentration here is on existing literature and research on 'misconceptions,' 'myths,' and 'legends' within the psychology and education disciplines. The secondary emphasis is on the theoretical, inferential, and measurement concerns. Search procedures for existing work in misconceptions related to educational psychology constructs primarily included a review of articles published in four prominent educational psychology journals: *Contemporary Educational Psychology, Educational Psychologist, Educational Psychology Review,* and the *Journal of Educational Psychology*. To gather articles from the general education and psychology disciplines, broader searches of academic databases were performed through ERIC, EBSCOHost, and Google Scholar for the following terms both singularly and in various combinations: misconception(s), myth(s), legend(s), teacher(s), educator(s), learning, belief(s), epistemic and epistemological beliefs, and conceptual change.

While empirical studies were of primary importance, we also evaluated existing literature reviews discovered through our search, viewing them as frameworks for the discipline. Using the above-listed search parameters, we discovered 135 peer-reviewed, English language articles of potential relevance to our inquiry. After excluding articles not explicitly related to misconceptions, education, conceptual change, beliefs, refutational text, or psychology, 96 articles remained for synthesis. We also performed footnote chases based on the bibliographic references for each manuscript in search of other potentially useful sources and to furnish a historical background to each discipline's approach to identifying, measuring, and mitigating misconceptions. We have not attempted to produce an exhaustive methodological review, as many of the early misconception instruments provided faulty inferences.

This review includes a discussion of the extant and occasionally intersecting attempts to study misconceptions in two distinct disciplines. We first define misconceptions, then discuss them in each respective field as studied in psychology and education. Thereafter, we examine issues and considerations for the development of methodologically appropriate instruments to identify misconceptions, and a summary and analysis of completed work. Additionally, we add a brief commentary on the importance of epistemic aims when developing teachers and include recommendations for future research in areas related to the formation, dissemination, and measurement of educational psychology misconceptions.

Definitions and Descriptions of Misconceptions

Over the past four decades, misconceptions have been labeled and defined in numerous ways. The psychology and education fields define misconceptions differently, often neglecting to indicate operationalized application or how the misconception influences professional practice. Simplistic definitions for misconceptions in psychology included "mistaken beliefs" (Gardner & Dalsing, 1986, p. 33; Gardner & Hund, 1983, p. 20), "common misbeliefs" (McCutcheon, 1991, p. 647), and "rules of thumb" (Chew, 2006, p. 212). In the field of psychology, misconceptions are defined as "widely held beliefs contradicted by established evidence" (Gardner & Brown, 2013, p. 211) and as "inaccurate claims that lack empirical support" (Hughes et al., 2015, p. 34). The science education literature defines a misconception as "a belief that conflicts with currently accepted scientific explanations" (Tippett, 2010, p. 953) and as "notions that are in sharp contrast to accepted scientific understanding" (Sinatra et al., 2014, p. 132). Neuromyths are strikingly similar to misconceptions, and commonly defined as "popular beliefs about what brain science can actually deliver to education" (Goswami, 2004, p. 2) or "popular accounts of brain functioning which originate in valid scientific evidence that has been extrapolated beyond the existing data" (Geake, 2008, p. 124).

Misconceptions are primarily researched in psychology and content-area education (e.g., misconceptions about mathematics concepts), however within educational psychology the bulk of empirical investigation is primarily focused on science education. Science education research primarily addresses misconceptions by investigating the constructs of epistemic cognition, epistemic beliefs, motivated reasoning, plausibility judgments, and conceptual change. In aggregate, these constructs represent individual beliefs, mental models, and worldviews about controversial or politically-motivated beliefs about topics such as climate change and genetically-modified organism labeling (Sinatra et al., 2014), the continued classification of Pluto as a planet (Broughton et al., 2013), HIV/AIDS (Johnson & Sinatra, 2014), and the ability to revise those beliefs when confronted with contradictory evidence (Sinatra et al., 2014).

Sinatra et al. defined *epistemic beliefs* as "the beliefs people hold about the nature of knowledge and knowing" (2014, p. 126), which function to some extent as a naïve or intuitive theory about scientific information and knowledge, not unlike popular but erroneous perceptions of psychology as nothing more than common sense (Furnham, Callahan, & Rawles, 2003). Epistemic beliefs play a critical role in an individual's interpretation of scientific material and are particularly relevant when faced with contradictory information or explanations that must be incorporated into their existing knowledge due to the influence these beliefs have upon the individual's ability to reason about that knowledge (Sinatra et al., 2014). One of the most prevalent examples regarding the influence of epistemic beliefs are attitudes related to evolution, with some teachers embracing absolutist, dogmatic religious beliefs (Trani, 2004) that inhibit the scientific understanding and teaching of natural selection (Sinatra, Southerland, McConaughy, & Demastes, 2003).

Aspiring and developing educators also harbor *epistemic stances* and *epistemic aims* that influence knowledge formation goals and the sustainability of their teaching beliefs. Epistemic aims refer to what principles and knowledge individuals deem important for teaching and learning success (Barzilai & Chinn, 2018), while epistemic stances justify the importance of developing pedagogical knowledge (Ferguson & Brownlee, 2018). These goals and aims are integral to the formation of teaching and learning strategies because the developing knowledge "mediates how they (*teachers*) conceive of and engage in teaching" (Lunn Brownlee et al., 2017, p. 242). From a lay perspective, epistemic stances and aims are worldviews that influence how thinking and reasoning intertwine to influence normative behavior inside and outside of the classroom. Educators who have epistemic aims that conflict with empirical evidence may use unreliable thinking and flawed reasoning during instructional episodes, thereby inspiring faulty epistemological perspectives in their developing students.

An additional factor contributing to people's misunderstanding of scientific information is *motivated reasoning*. According to Kunda (1990), motivation plays a role in the direction and intensity of cognitive processing. Sinatra et al. (2014) explained that although people can make a good faith attempt to be rational in scientific decision making, they may still be hampered by motivated reasoning as "motivations bias what information they attend to and what strategies they use to construct, assess, and evaluate that information" (p. 129). For instance, a teacher may believe in the concept of learning styles and revise their pedagogical approach under the false pretense that tailoring their instruction to individual learning styles will positively impact student learning outcomes. When faced with empirical data suggesting that the accommodation of learning styles has a null or negative effect on student learning outcomes (Willingham, Hughes, & Dobolyi, 2015), the teacher feels an immediate personal consequence posing a threat to their teaching efficacy. They are therefore likely to reject or ignore the evidence-based information and discount the scientific evidence (Chinn & Brewer, 1993). Even in the face of disconfirming evidence, teachers exhibit personal bias and filter out information inconsistent with their existing beliefs (Fives & Buehl, 2012). Further, basic human physiology underlies the maintenance of personal bias through the brain's perceptual filter that regulates the degree of attention allotted to incoming information (Lee & Sherman, 2008). To preserve an established (and inaccurate) belief, the teacher is likely to selectively ignore scientific evidence through both psychological and physiological information filtering.

Misconceptions are also influenced by flawed thinking processes (Lilienfeld, Lynn, Namy, & Woolf, 2009). Humans are vulnerable to logical and thinking fallacies often described as *cognitive biases*, because of the tendency to erroneously identify, categorize, evaluate, and interpret evidence. Misinterpretation primarily occurs when individuals attribute causality to events that are merely related (spurious correlation), when fixating on evidence that supports their beliefs while ignoring or rejecting contradictory evidence (confirmation bias), and when encountering evidence that implicates negative self-impressions (self-justification bias). In these situations, individuals discount objective knowledge and evidence because dissonance is perceived as a threat leading to stress and anxiety, feelings that abate when the misconception is embraced (Gregoire, 2003).

Misconceptions may also perpetuate due to structural misclassification of acquired information. Often described as an *ontological perspective* of mental representation, when an individual inappropriately relates new information to existing knowledge, distortions may develop. Thus, a teacher who is elated over the accomplishments of a struggling student may erroneously categorize the newfound success as the result of teaching the learner in the learner's preferred learning style, in contrast to categorizing student success based on the development of a flawless lesson plan. Individuals must possess both the ability and willingness to recognize misclassification as a prerequisite to modify representations and promote conceptual change (Alexander, 2017; Chi, 2005; Murphy & Mason, 2006).

The continued acceptance of misconceptions can be described as an evaluation of plausibility, in which *plausibility judgments* play a critical role in the maintenance and revision of misconceptions. An accurate explanation must first seem plausible to a misconception-bearing individual before they are willing to accept it as valid and consider altering their engrained although inaccurate belief. Lombardi et al., defined plausibility judgments as "a judgment of potential truthfulness when evaluating explanations" (2016, p. 35), such that if an individual does not find an explanation plausible, the potential for accepting the explanation is temporary at best. For instance, if a teacher doubts the plausibility of evidence-based information negating the belief that accommodating learning styles in the classroom facilitates academic achievement, what may result is only "provisional acceptance" of the explanation (Lombardi et al., 2016, p. 36). If teachers doubt the plausibility of evidence-based information related to effective instructional strategies or learning contexts, a tendency to disregard the accurate explanation and information follows.

Overcoming misconceptions comprise the emphasis of most conceptual change models. The conceptual change approach is often employed in science education to facilitate "the restructuring of individuals' knowledge to overcome their misconceptions and align their understanding with scientifically accepted ideas" (Sinatra et al., 2014, p. 132), and is successfully achieved through various instructional approaches including refutational text (Broughton, Sinatra, & Reynolds, 2010; Sinatra & Broughton, 2011; Tippett, 2010), lecture (Bensley, Lilienfeld, & Powell, 2014; Kowalski & Taylor, 2009; Taylor & Kowalski, 2017), dialogue-based refutation and argumentation (Braten, Muis, & Reznitskaya, 2017) and through conscious reflection and reflexivity whereby learners explicitly evaluate their thought processes and reasoning

(Alexander, 2017; Lunn Brownlee et al., 2017). Although multiple conceptual change models exist that are beyond the scope of this review (e.g., Dole & Sinatra, 1998; Gregoire, 2003; Pintrich, Marx, & Boyle, 1993; Posner, Strike, Hewson, & Gertzog, 1982), consistent elements appear across models that focus on how learners construct flawed representations and how those misrepresentations can be mediated.

Mental models represent a conglomerate of various beliefs and emotions that individuals employ to appraise the legitimacy of the information with their current beliefs. These models focus on characteristics of the learner such as strength, coherence, and commitment to their existing conception, motivation to process new information (Pintrich et al., 1993), social context (Dole & Sinatra, 1998), and affective factors when attempting to change the beliefs of teachers (Gregoire, 2003; Muis et al., 2018). Additionally, the complexity, coherence, and plausibility of the accepted scientific explanations for various phenomena are important considerations during the change process. Most of the research in the conceptual change literature is designed to determine which strategies or instructional techniques are best for fostering accurate comprehension (Kendeou & van den Broek, 2005; Chinn, Rinehart, & Buckland, 2014) and potentially eliminating the misconception.

Based on the totality of the literature in epistemic cognition, epistemic beliefs, motivated reasoning, plausibility judgments, and conceptual change research, misconceptions have been addressed in a multitude of ways. Across these topics, the general theme encompasses false beliefs that require revision and methods for creating belief change. The cross-discipline diversity in misconceptions research warrants a clear definition here. Therefore, based upon the variation in misconceptions emphasis within and across strands of literature, for the purposes of this paper we defined educational psychology misconceptions as *entrenched beliefs related to teaching, learning, and academic motivation that are explicitly refuted by multiple strands of methodologically-sound empirical evidence*.

Psychology

Misconceptions. Various psychology misconceptions have been proposed including a variety of items related to personality, the nature of mental illness, and abnormal human behavior. Misconceptions found in the psychology literature often include: (a) the efficacy of inkblot tests in revealing personality traits, (b) the conception of schizophrenics as harboring multiple personalities, (c) the influence of a full moon on psychiatric hospital admissions and crimes, (d) the utility of polygraph tests in detecting dishonesty, (e) the folk notion that opposites attract, and (f) the effectiveness of hypnosis in helping individuals retrieve forgotten memories (Hughes et al., 2013b; Standing & Huber, 2003). Additional psychological misconceptions specifically related to human learning included the myth that human brains operate at a capacity of only 10%, playing classical music to infants will increase their intelligence (the Mozart effect), individuals are exclusively left- or right-brained (hemisphericity), and that people can learn new information while they sleep (Bangerter & Heath, 2004; Brown, 1983; Della Sala, 1999; Higbee & Clay, 1998; Hughes et al., 2013b; Lyddy & Hughes, 2012; Standing & Huber, 2003). Although prior work in psychology has superficially investigated some misconceptions tied to concepts of educational psychology, there has not been a clear delineation of one branch of psychology from the other.

History. The study of psychological misconceptions is not a novel or contemporary endeavor. Although superstitions were studied in the early 1900s (Conklin, 1919; Dresslar, 1910), misconceptions about psychology were formally addressed beginning in the 1920s (Garrett & Fisher, 1926), and formal tests to measure misconceptions of psychology were developed continuously into the 1970s (Holley & Buxton, 1950; McKeachie, 1960; Vaughan, 1977). These early instruments were composed of 80 to 100 inaccurate statements related to psychology and required respondents to indicate whether each statement was true or false, setting the stage for future research on psychology misconceptions. The later 1970s and 1980s witnessed a proliferation of research about psychology misconceptions among diverse samples including high-performing college students (Best, 1982), introductory psychology students (Brown, 1983), university faculty (Gardner & Hund, 1983), and undergraduate students (Gardner & Dalsing, 1986; Lamal, 1979).

The 1990s led to an abundance of misconception research, including a new and improved test of misconceptions (McCutcheon, 1991), examinations of critical thinking, academic achievement, and misconception frequency (McCutcheon, Apperson, Hanson, & Wynn, 1992), the existence of misconceptions among prospective psychology students (Furnham, 1992), a comparison of misconceptions among psychology and non-psychology students (Furnham, 1993), and a cross-national investigation of misconceptions between American and British students (McCutcheon, Furnham, & Davis, 1993). Although the studies varied in population and measurement approaches, the prolific nature of misconceptions about psychology were reported across studies. The literature during this era focused primarily on measuring the existence of misconceptions rather than mitigating the inaccurate beliefs or making inferences about other constructs related to the maintenance of these misconceptions.

Contemporary Application. Accordingly, it has long been established that misconceptions and popular myths about psychology have been examined using diverse samples (Lilienfeld et al., 2010). As exhibited in Table 1, psychological misconceptions have often been examined among undergraduate students in terms of their existence and frequency (Amsel, Baird, & Ashley, 2011; Glass, Bartels, Ryan, & Stark-Wroblewski, 2008; Higbee & Clay, 1998; Kowalski & Taylor, 2004; Kuhle, Barber, & Bristol, 2009; Standing & Huber, 2003; Thompson & Zamboanga, 2004). More recently, the area of psychological misconceptions has trended toward sub-disciplinary areas such as behavior analysis (Arntzen, Lokke, Lokke, & Eilertsen, 2010; Lamal, 1995) and forensic psychology (Shaw & Woodworth, 2013). Additional work has also included misconceptions about psychology as a science (Amsel et al., 2011), the efficacy of a psychology course in remediating misconceptions about psychology (Glass et al., 2008; Standing & Huber, 2003), the predictive ability of misconceptions on course performance (Kuhle et al., 2009), and prior knowledge, aptitude, critical thinking, and ability as predictors of misconceptions (Kowalski & Taylor, 2004; Thompson & Zamboanga, 2004). It is well-established that misconceptions about psychology exist, and the shift in recent literature has been toward more effective measurement of the misconceptions as well as predicting and correcting the inaccurate beliefs. Prior instruments have been criticized based upon validity concerns related to dichotomized true/false response formats as well as ambiguously phrased and outdated items. Additionally, research has found the frequently employed true/false format to

Table 1. Empirical studies of psychology misconceptions

Citation	Year	Purpose(s)	Measurement	Finding(s)	Sample
Standing & Huber	2003	Determined the extent of myth acceptance as it related to the amount of college-level psychology education	20-item Test Your Psychology IQ questionnaire, true/false response format	Rejection of myths increased with university psychology courses, but decreased considerably with the number of psychology courses taken at a junior college	n = 94 Undergraduates at a liberal-arts college enrolled in at least one psychology course at either a junior college or university
Kowalski & Taylor	2004	Evaluated whether psychological misconceptions decreased upon completion of an introductory psychology course, and whether GPA and critical thinking ability predicted decreases in post-test misconceptions	36-item questionnaire to assess psychological misconceptions, true/false response format	A statistically significant change in students' misconceptions occurred after completing the introductory psychology course. Students who thought more critically and performed at higher academic levels were less likely to harbor psychological misconceptions.	n = 90 Introductory psychology students enrolled at a small, private university
Glass, Bartels, Ryan, & Stark-Wroblewski	2008	Generalized Standing and Huber's (2003) findings	20-item Test Your Psychology IQ questionnaire, true/false response format	Findings indicated that Midwestern Americans were more prone to myth acceptance and there were no significant differences between the university and junior college student samples, and were inconsistent with Standing and Huber's (2003) findings.	N = 295 Midwestern Americans enrolled in a university (n = 171), junior college (n = 79), as well as a local community (n = 45) sample
Amsel, Johnston, Alvarado, Kettering, Rankin, & Ward	2009	Determined existence of students' misconceptions about core beliefs in psychology, and whether their psychology knowledge was changed via conceptual change post-instruction; assessed whether scientific and intuitive beliefs about the discipline could be prompted in alternate contexts (professor perspective vs. self-perspective)	15-item Psychology as a Science (PAS) Questionnaire, seven-point Likert agreement scale response format	Found that students in the randomly assigned professor perspective group rated psychology as more scientific than those in the self-perspective condition.	n = 227 Introductory psychology students enrolled in six different class sections
Kuhle, Barber, & Bristol	2009	Evaluated whether psychology undergraduates harbored misconceptions about psychology, and related the misconceptions to performance in the introductory psychology course.	10-item Knowledge of Psychology Test (adapted from Vaughan, 1977), true/false response format	A significant negative correlation was found between number of misconceptions held and the course grade, as 83% of all students maintained five or more misconceptions.	n = 178 Undergraduate students enrolled in introductory psychology courses
Amsel, Baird, & Ashley	2011	Determined beliefs about the scientific nature of psychology as a discipline, and assessed those beliefs as a function of year in college and academic status in psychology	15-item Psychology as a Science (PAS) Questionnaire, seven-point Likert agreement scale response format	Found that more academically advanced students and students who were potential or actual psychology majors harbored stronger beliefs in the discipline of psychology as a science, after accounting for gender and number of psychology courses completed.	n = 438 American undergraduate psychology students
Lyddy & Hughes	2012	Examined students' beliefs about psychology at different stages of their undergraduate careers, and determined whether belief in psychology as a scientific discipline increased with experience in the subject.	15-item Psychology as a Science (PAS) Questionnaire, seven-point Likert agreement scale response format 26-item Revised Paranormal Beliefs Scale (R-PBS), seven-point Likert agreement scale response format 20-item psychology misconceptions questionnaire, seven-point Likert agreement scale response format	No relationship was found between misconception endorsement and greater appreciation of psychology as a science, and misconceptions were still endorsed even after substantial experience in the field of psychology. However, students with more experience in psychology did have stronger beliefs in psychology as a science, but still endorsed about half of the misconceptions.	N = 178 Undergraduate students enrolled in introductory psychology courses for various time frames including four months (n = 83), 18 months (n = 55), and 30 months (n = 40)
Taylor & Kowalski	2012	Compared true/false and forced choice response formats and determined whether different formats led to different estimates of misconception endorsement among students.	39-item questionnaire, true/false response format 39-item questionnaire, forced choice (A or B) format	Accuracy levels were different between the true/false format (33.05%) and the forced choice format (41.29%), indicating that the true/false format led to overestimation of students' misconceptions. A statistically significant difference was found for accuracy when comparing the true/false and forced choice formats.	n = 155 Introductory psychology students

Hughes et al. (Study 1)	2015	Examined the extent to which students in various stages of education endorsed false claims about psychology.	30-item questionnaire, seven-point Likert agreement scale response format	Doctoral students endorsed fewer misconceptions than master's and undergraduate students, with level of misconception rejection varying significantly across educational level.	N = 670 International sample of undergraduate (n = 49), master's (n = 83), and doctoral (n = 538) students
Hughes et al. (Study 2)	2015	Attempted to determine whether misconception endorsement varied as a function of training in psychology.	42-item Psychology Misconception Questionnaire (PMQ), using a true/false response format with an additional "unsure" option	Students enrolled in graduate programs rejected significantly more misconceptions and endorsed fewer misconceptions than the undergraduate students. Graduate students also expressed less uncertainty than undergraduate students.	N = 557 Convenience sample of international students enrolled in psychology undergraduate (n = 519), master's (n = 7), or doctoral (n = 31) programs.
Kowalski & Taylor	2017	Compared refutational vs. direct instruction to determine stability of misconception change	39-item questionnaire, forced choice (A or B) format	Students instructed using a refutational approach had more enduring accuracy of psychological concepts than those instructed with traditional lecture.	N = 111 Convenience sample of primarily female students (84%) enrolled in psychology undergraduate programs.

be highly vulnerable to acquiescence and correct guesses (Griggs & Ransdell, 1987; Hughes, Lyddy, & Kaplan, 2013; Ruble, 1986; Taylor & Kowalski, 2012).

Across the contemporary psychology literature three misconception themes emerged: (a) the interest in perceptions of psychology as a science, (b) the relationship between discipline-specific knowledge levels and frequency of disciplinary misconceptions, and (c) the impact of discipline-based instruction in effectively correcting misconceptions. Five of the listed studies utilized a true/false response format to identify misconceptions among the various populations, while four studies employed a Likert-type scale to identify and measure the intensity of the misconceptions. However, even among college samples, ambiguity prevails regarding differences in misconception frequency. Similarities among studies included the heightened perception of psychology as a science among those with more advanced education, and decreased acceptance of misconceptions among those with higher course grades and critical thinking skills.

Summary. Although many definitions and approaches for measuring misconceptions of psychology have been devised over the years, the same thread of inquiry has been maintained and ties the literature together: the identification and measurement of inaccurate beliefs about empirically-supported findings in the field of psychology. While this brief review of the existing literature in psychology misconceptions exhibits the clear disciplinary interest in the topic of misconceptions, a gap remains for misconceptions about educational psychology among teachers, specifically related to topics of teaching, learning, and academic motivation. Recently, the gap has narrowed by research on educational 'neuromyths,' discussed next.

Neuroscience and Education

The improvement of education and student learning outcomes is an often addressed topic of social concern. However, many people harbor misguided notions about how to effectuate improvement in these areas, and seemingly simple ideas to improve the student learning experience and outcomes are sensationalized through popular media, social media, and word-of-mouth. The term 'neuromyth' describes the false beliefs developed about the human brain related to learning resulting from the intersection of neuroscience and education (Organisation for Economic Cooperation, and Development, 2002). In the more specific field of educational psychology, 'urban legends' and 'urban myths' are addressed, comprising neuromyths and myths about learning, technology in learning, and educational policy (de Bruyckere, Kirschner, & Hulshof, 2015; Kirschner & van Merriënboer, 2013). Due to the similarities and paucity of other research in this area, the fields of neuroscience and education are thus addressed as one topic here. Neuromyths proliferate because they are often initiated by an empirical principle with some underlying neuroscientific substantiation but are misinterpreted and subsequently communicated to the layperson. The underlying neuroscience is embellished and misapplied to educational endeavors with the intention of advancing teaching and learning outcomes, resulting in further proliferation of these seemingly easy-to-understand concepts among the general public and teachers alike. Individuals lacking domain-specific knowledge of neuroscience propagate myths about the brain's role in learning by inaccurately applying neuroscientific findings to the field of education for purposes typically unintended by the original researchers.

Misconceptions. The crossover between neuroscience and education results from the attempted and improper application of neuroscientific research findings to education. Misconceptions found in this hybrid literature often investigated beliefs related to: (a) the efficacy of brain-based education, (b) hemispheric and modality dominance, (c) learning styles, and (d) multiple intelligences (Dekker et al., 2012; Geake, 2008). While not expressly addressing topics of educational psychology, the misconceptions in many of these studies inch ever closer to the field and encompass a variety of learning strategies and beliefs about intelligence and memory, while falling short on topics related to academic motivation, as displayed in Table 2.

The field of education has primarily focused on what are labeled "neuromyths," "urban myths," and "urban legends," which encompass the inappropriate application of educational psychology principles to enhance classroom learning (de Bruyckere et al., 2015; Kirschner & van Merriënboer, 2013). Three broad urban myths encountered in the field of educational psychology include: (a) learners as digital natives, (b) learners and their learning styles, and (c) learners as self-educators (2013), the crux of which is students are not the best judge of what constitutes effective learning. Similar to neuroscientific findings, the myths and legends apply results from synthetic research contexts and tend to generalize the findings. For instance, Tardif, Doudin, and Meylan (2015) found in a sample of teachers and teachers-in-training that 85% believed

people use one brain hemisphere more often than the other, and 96% believed people learn better when information is provided in their preferred learning style. Studies also show that teachers who claim to know more about the brain and have greater interest in neuroscience are also more likely to endorse neuromyths (Dekker et al., 2012; Gleichgerrcht, Luttges, Salvarezza, & Campos, 2015). More recently, attention has been directed toward specific myths related to education including: (a) myths related to learning, (b) neuromyths, (c) myths related to technology in education, and (d) myths related to educational policy (de Bruyckere et al., 2015).

History. Even during the late 1990s the error in applying brain-based research to educational practice was made, alleging that allowing neuroscience to guide educational practice was a faulty approach (Bruer, 1997). The distinction between cognitive neuroscience and the subsequent enthusiastic promotion is clearly made as well, further indicating that sometimes the "scientific evidence flatly contradicts the brain-based claims" (Geake, 2008, p. 124). Geake noted the various misconceptions about neuroscience as applied to education, although he did not clearly identify the need for an instrument to identify, much less mitigate, such faulty beliefs (2008). The field of neuroscience has proliferated wildly in recent years, driving great public interest in neuromyths related to 'brain-based' education initiatives, programs, and learning strategies (Beck, 2010; Pasquinelli, 2012), despite the lack of direct empirical evidence to support such beliefs. A review of empirical work in neuromyths is exhibited in Table 3. Such neuromyths include the perception that individuals can effectively train their brain using commercial tools such as Brain Gym® and brain-based education initiatives.

Interest in educational myths and legends has taken hold in the field of educational psychology in the last several years. In 2006, an entire issue of *Educational Psychologist* was dedicated to a scholarly dialogue about the efficacy of multiple intelligences theory, the Mozart effect, and emotional intelligence, with evidence to refute and support these theories presented by several scholars in the field (Alexander, 2006; Cherniss, Extein, Goleman, & Weissberg, 2006; Gardner & Moran, 2006; Rauscher & Hinton, 2006; Waterhouse, 2006a, 2006b). Clear evidence has been presented to refute these mistaken educational psychology beliefs on a conceptual basis, but no instrument has been developed to quantitatively measure the existence of these beliefs among teachers or other populations of interest.

Contemporary Application. The term neuromyths is somewhat misleading, because the actual misconceptions are not faulty beliefs about neuroscience specifically, rather the misconceptions arise from the inappropriate lay application of neuroscience to the field of education. The misguided translation between neuroscientific research findings and the application of such findings to education is the basis of these misconceptions: substantiated, confluent findings in neuroscience research are mistakenly transformed and applied in ways unintended by the researchers. Ultimately, the misconception source (neuroscience) is not the issue, rather the breakdown occurs when consumers of research filter empirical evidence to support their beliefs (i.e., confirmation bias), leading to subjective evaluation and erroneous application of empirical data.

Although not nearly as prolific as the psychological misconception literature, the neuromyth and education literature reveals great insight into the reasons underlying the proliferation of such beliefs among both the general public (Beck, 2010; Herculano-Houzel, 2002; Pasquinelli, 2012) and educators (Dekker et al., 2012; Pickering & Howard-Jones, 2007; Im et al., 2018). Neuromyths are often disseminated to consumers as brain-based research alongside images of the brain that lead the reader to more readily accept the claims as fact (McCabe & Castel, 2008), promoting the perceived legitimacy of such beliefs. Prior work in this area has aptly acknowledged the misapplication of neuroscience research to education initiatives, including concepts of hemisphericity, brain plasticity, and the danger of selling unsubstantiated brain-based learning strategies to unwitting teachers, school districts, and parents (Lindell & Kidd, 2011).

Empirical research into the prevalence of neuromyths is minimal, however Dekker et al. published findings from their study of 242 primary and secondary teachers in the United Kingdom and the Netherlands who expressed an existing interest in the neuroscience of learning (2012). Aside from investigating the prevalence of neuromyths among this population, the authors also examined potential predictors of such beliefs (2012). Participants were presented with 32 statements about the brain and learning, of which 15 of the statements were neuromyths that were endorsed by 49% of the participating teachers on average and were frequently predicted by higher levels of general knowledge and interest in neuroscience (2012). Findings included embracing false beliefs such as the efficacy of learning styles in the classroom, the utility of exercises to improve left- and right-brain coordination, the effect of food and water intake upon brain functioning and academic achievement, and the pervasive myth that humans use only 10% of their brain (2012). Most importantly, the results of this study suggested that additional general knowledge related to the brain did not exert a protective effect against belief in pseudoscientific beliefs. Though this study is closely tied to our suggestion to develop an instrument to identify misconceptions of educational psychology among a population of teachers, Dekker et al.'s (2018) findings indicated the necessity of evaluating in greater depth the prevalence and predictors of misconceptions related to teaching and learning in a population of teachers in the United States.

Summary. Much of the education literature specifically addressed the alleged tie between neuroscience and the field of education, often questioning the validity of such initiatives, programs, and strategies (Dekker et al., 2012; Pickering & Howard-Jones, 2007; for reviews, see also Geake, 2008; Goswami, 2004; Lindell & Kidd, 2011; Purdy, 2008; Sylvan & Christodoulou, 2010). Pasquinelli extended this description to include the clarification that neuromyths "tend to survive the circulation of correct information, and to be inflated by sensationalist press releases" (2012, p. 90), not unlike scientific misconceptions discussed in great depth within the educational psychology literature (e.g., Sinatra et al. 2014). Thus, neuromyths and misconceptions are conceptually indistinguishable as presented in both the education and psychology literatures. Though one study did specifically investigate the prevalence of neuromyths among primary and secondary school teachers (Dekker et al., 2012), it was conducted in the UK and Netherlands and may not necessarily generalize to the population of teachers in other countries.

If teachers are riddled with misconceptions about scientific knowledge and facts, their ability to teach effectively is undoubtedly compromised. The problem extends beyond the teachers and is carried through to their students and their students' parents, creating an even broader social problem. Thus, we believe that

Table 2. General Psychology Misconceptions and Neuromyths Based on Educational Concepts	
Misconception Description	**Source(s)**
Accommodating the multiple intelligences: Teachers should tailor their instruction to accommodate their students' different types of intelligence (e.g., linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, intrapersonal, interpersonal).	de Bruyckere, Kirschner, and Hulshof (2015) Waterhouse (2006a)
Behaviorism concepts: Negative reinforcement is equivalent to punishment.	Arntzen, Lokke, Lokke, and Eilertsen (2010) Kuhle, Barber, and Bristol (2009)
Brain development and stimuli: Children exposed to environments rich in stimulus have better-developed brains.	Dekker, Lee, Howard-Jones, and Jolles (2012)
Brain size and intelligence: There is a correlation between brain size and intelligence.	Herculano-Houzel (2002)
Brain training: One can improve their cognitive abilities by playing brain training games such as Brain Gym®	de Bruyckere, Kirschner, and Hulshof (2015)
Clarity under pressure: Human beings think most clearly when they are under pressure.	de Bruyckere, Kirschner, and Hulshof (2015)
Creativity and schooling: The schooling process ruins children's innate ability to be creative.	de Bruyckere, Kirschner, and Hulshof (2015)
Critical periods for learning: Childhood includes critical periods after which children are no longer able to learn certain things.	Dekker, Lee, Howard-Jones, and Jolles (2012)
Developmental differences in brain function and learning: Education cannot mitigate learning problems in students with developmental differences in brain function.	Dekker, Lee, Howard-Jones, and Jolles (2012)
Digital natives, technology, and education: The new generation of learners inherently know how to learn from developing technologies and media and old methods of instruction do not work for them.	de Bruyckere, Kirschner, and Hulshof (2015) Kirschner and van Merriënboer (2013)
Efficacy of discovery and self-guided learning: Students will learn better if they discover things for themselves rather than having their teacher explain everything to them. Instruction with minimal guidance produces better learning outcomes than does direct instruction. Students should be given control over what and how they are learning.	de Bruyckere, Kirschner, and Hulshof (2015) Holmes (2016) Kirschner and van Merriënboer (2013)
Efficacy of rote memorization: Repeated exposure to the same information, also known as rote learning, improves learning	Holmes (2016) Kuhle, Barber, and Bristol (2009)
Efficacy of teaching to students' learning style: Students will learn material better and academic achievement will increase if instruction is presented to students in their preferred learning style.	de Bruyckere, Kirschner, and Hulshof (2015) Dekker, Lee, Howard-Jones, and Jolles (2012) Kirschner and van Merriënboer (2013)
First- and second-language acquisition: It is important that a child acquires their native language before attempting to learn a second language, otherwise neither language will be learned.	Dekker, Lee, Howard-Jones, and Jolles (2012)
Gender and learning differences: Males and females have fundamentally different brains and therefore do not learn in the same ways.	de Bruyckere, Kirschner, and Hulshof (2015)
Gender difference in math achievement: Boys are inherently better at mathematics than girls.	de Bruyckere, Kirschner, and Hulshof (2015)
Hemisphericity of the brain: People are either left-brained and analytical or right-brained and creative. Coordination exercises can improve integration between a student's left- and right-brain to facilitate learning.	de Bruyckere, Kirschner, and Hulshof (2015) Dekker, Lee, Howard-Jones, and Jolles (2012) Lyddy and Hughes (2012)
Intelligence and heredity: Intelligence is the result of genetics and cannot be changed by education or life experience.	Herculano-Houzel (2002)
Knowledge obsolescence: Knowledge has become obsolete with the advent of the internet.	de Bruyckere, Kirschner, and Hulshof (2015)
Learning while asleep: People have the ability to learn new information while they are sleeping.	Brown (1983) Lyddy and Hughes (2012) Standing and Huber (2003)
Memory and age: Adults cannot memorize information as easily as children can.	Kuhle, Barber, and Bristol (2009)
Multitasking: People are capable of effectively multitasking with more than one thinking tasks without a loss of concentration or loss of accuracy.	de Bruyckere, Kirschner, and Hulshof (2015)
Nature of human memory: Human brains have a single memory system where every memory is permanently stored.	de Bruyckere, Kirschner, and Hulshof (2015) Herculano-Houzel (2002) Standing and Huber (2003)

identifying whether these ill-supported beliefs also exist among teachers is a worthwhile pursuit. The clear delineation of these urban legends provides a lens through which the field should pinpoint more specific misconceptions that can be effectively measured quantitatively. Kirschner and van Merriënboer clearly asserted "that educators, educational policymakers and educational researchers should reject educational approaches that lack sufficient scientific support and methodologically sound empirical evidence" (2013, p. 178), however, to our knowledge there is no such instrument to identify the acceptance or rejection of such errant beliefs about educational psychology.

MEASUREMENT CONSIDERATIONS

Although the development of an instrument to identify misconceptions is certainly not a new endeavor, existing instruments have methodological criticisms that must be considered and addressed prior to the development of new instruments. Criticisms include the response format, out-of-date items negated by new scientific findings, test items that address topics outside the scope of

introductory psychology textbooks, ambiguously worded items, and vulnerability of the true/false format test to acquiescence and correct guessing due to chance alone (Griggs & Ransdell, 1987; Hughes, Lyddy, & Kaplan, 2013; Ruble, 1986; Taylor & Kowalski, 2012). A major drawback in prior measurement of misconceptions is the overuse of true/false response formats, items which do a poor job of detecting misconceptions (McCutcheon, 1991), in addition to constraining responses to be wholly true or false and inflating estimates of misconceptions due to acquiescence (Bensley et al., 2014). Additionally, aside from the difficulty of constructing effective true/false questions, they are also more likely to yield response bias and potential overestimation of misconceptions (Taylor & Kowalski, 2012).

Four decades ago, recommendations were advanced for future researchers to construct less ambiguous items and to include study findings "hotly debated by psychologists" (Ruble, 1986, p. 36). We concur, and contend that our proposed definition of misconceptions allows for the inclusion only of items that are explicitly refuted by empirical evidence. We also note that misconceptions by definition do not comprise a relative lack of domain knowledge, therefore a response option indicating the participant's lack of knowledge should be conspicuous and distinct from the ordinary Likert-scale (e.g., Lyddy & Hughes, 2012). Conflating a 'neutral' scale response and 'don't know' response into a single scale point undoubtedly skews the results, generating faulty interpretations and misguided inferences.

While earlier work led to the development of a new psychology misconceptions instrument that remedied many such criticisms of Vaughan's widely-used Test of Common Beliefs (McCutcheon, 1991; Vaughan, 1977), these criticisms have been explicitly addressed in more recent studies evaluating the impact of response format and item language upon misconception frequency (Hughes et al., 2013a; Taylor & Kowalski, 2012). Recent efforts have been made to quantitatively address earlier criticisms concerning the assessment of misconceptions. Taylor and Kowalski (2012) studied introductory psychology students and compared the efficacy for accurately assessing psychology misconceptions of true/false versus forced choice formats in which respondents were asked to select the 'most true' of two provided options. Their study revealed that the true/false format resulted in an accuracy rate of only 33.05%, while the forced choice format resulted in a 41.29% accuracy rate, suggesting that the true/false format resulted in an overestimation of misconceptions among their sample. It was also inferred that misconception prevalence may fluctuate over time and samples, suggesting that future researchers conduct a pretest of their instrument and consider the possibility of cohort effects within their results (2012). Meanwhile, other psychology misconceptions researchers were concurrently examining analogous methodological concerns in this area.

Similar to Taylor and Kowalski's measurement study, Hughes et al. (2013a) conducted a systematic investigation of the impact of response format and item language upon endorsement of psychological misconceptions. Their study included four alternative 40-item questionnaires composed of 30 misconceptions and 10 filler items tested among a population of undergraduates in the United States and Europe. Question phrasing (ambiguous versus non-ambiguous) and response format (true/false versus seven-point Likert scale) were manipulated by the researchers among the randomly assigned groups, and the results indicated both the response format of the instrument and the item language independently inflated the estimation of misconceptions. The authors suggested that future researchers include items based upon distinct criteria rather than subjective judgment and employ alternate techniques beyond the narrow realm of self-report questionnaires (2013b). Taken together, Taylor and Kowalski (2012) and Hughes et al.'s (2013a) findings suggest that much improvement can be made in the construction of such instruments to measure misconceptions.

For the past six years, the authors have worked toward developing a validated instrument to identify misconceptions about various educational psychology concepts to conceivably be used with populations of both pre-service and in-service teachers (McAfee & Hoffman, 2014; McAfee, Xu, & Hoffman, 2015; McAfee, Xu, & Hoffman, 2016a; McAfee, Xu, & Hoffman, 2016b, Hoffman & McAfee, 2017). Several iterations of the proposed instrument have included as few as 15 to as many as 60 misconception items. The response format has consistently incorporated a seven-point Likert-scale for level of respondent agreement, although the first iteration also included a response for the respondent's level of confidence in each item. Requesting respondent confidence level reduced the response rate and thus confidence assessments were eliminated in future iterations. All instruments to date have included a response option for "I have no knowledge" to ensure that lack of knowledge was not conflated with genuine misconceptions.

As a result of the piloted studies, we have identified 15 particularly pervasive misconceptions about educational psychology. Although factor structure instability has stalled the final validation of our instrument with pre-service teachers, we believe our efforts are a first step toward the development of a reliable measure of educational psychology misconceptions. Concurrently, while using a repeated measures design, we are investigating whether effective measurement of misconceptions is influenced by item valence (exclusively positive vs. mixed, positive and negative), scale type (true/false vs. Likert-type), or order of presentation (true/false vs. Likert-type).

DISCUSSION

Within this review, we summarized misconceptions in the fields of psychology and education and highlighted the theoretical, inferential, and measurement concerns specifically related to the field of educational psychology, revealing several themes. In the field of psychology, misconceptions are frequently addressed among various populations, but attention to measurement concerns are minimal and many findings are ambiguous. While misconceptions in the field of educational psychology are often studied, they are too often focused exclusively upon scientific and metaphysical misconceptions and neglect to address misconceptions among teachers-in-training regarding effective teaching strategies. Ironically, educational psychologists conduct a great deal of science misconceptions research on teacher populations but fail to consider the misconceptions those same individuals hold about their own field. Significant research has been conducted to determine the most effective methods for eliminating misconceptions, however, to initiate the process of eliminating educational psychology misconceptions, appropriate instrumentation must first be developed.

Misconceptions have broad social impacts, regardless whether the ill-founded belief is related to the nature of learning, the validity of brain-based education, or medically-based, such as choosing whether to vaccinate a child. However, misconceptions

Table 3. Empirical studies of neuromyths

Citation	Purpose(s)	Measurement	Finding(s)	Sample
Herculano-Houzel (2002)	Identified misconceptions about neuroscience among the general public	95-item survey, using a yes/no/I don't know response format	Neuroscience literacy was improved by level of education, in addition to reading of popular science magazines, with the worst neuroscience illiteracy occurring on topics related to learning and memory.	n = 2,158 Members of the general public in Rio de Janeiro, Brazil
Dekker, Lee, and Howard-Jones (2012)	Investigation to determine the prevalence and predictors for belief in neuromyths	32-item questionnaire with statements related to the brain and learning, including 15 neuromyth items, using a correct/incorrect/do not know response format	An average of 49% of teachers in the study believed in the neuromyths and were particularly prone to belief in neuromyths perpetuated by commercialized education programs, and additional general knowledge among the teachers predicted increased endorsement of the neuromyths.	n = 242 Primary and secondary school teachers from the UK and Holland with an expressed interest related to the neuroscience of learning
Gleichgerrcht, Luttges, Salvarezza, and Campos (2015)	Attempted to evaluate belief in neuromyths among a specific population of teachers.	Used a revised version of Dekker et al.'s (2012) instrument, including 12 neuromyth items, using a correct/incorrect/do not know response format	Findings were consistent with prior research in other geographic areas that neuroscience misconceptions were frequently endorsed, and often related to factual information about brain structure and function. Additional self-reported knowledge about the brain predicted likelihood for belief in neuromyths as well.	N = 3,451 Teachers in Latin America from Argentine (n = 551), Chile (n = 598), Peru (n = 2,222) and other Latin American countries (n = 80)
Tardif, Doudin, and Meylan (2015)	Evaluation of beliefs in neuromyths among teachers and student teachers, specifically in terms of hemispheric dominance, modality dominance, and the Brain Gym© method.	15-item neuromyth questionnaire, using a four-point Likert scale for agreement, utility, and frequency of use	Findings were consistent with prior studies, and extended Dekker et al.'s (2012) findings by establishing that teachers and student teachers expressed belief in hemispheric and modality dominance claims and recommendations were made to provide close collaboration between neuroscience and educators to produce critical evaluation of pedagogical approaches.	n = 283 Teachers and student teachers in Switzerland, including in-service high school teachers (n = 44), college teachers (n = 57), first-year primary student teachers (n = 160), teachers' trainers (n = 22)
Furnham (2018)	Examined the prevalence of psychological misconceptions in developmental and neuro-psychology based on surveys derived from two published books	Largely a descriptive study that employed both a T/F option and the ability to indicate "no knowledge" of a misconception.	Findings indicated that up to 50% of items were indicated as true (indicating a misconception).	n = 220 51.8% were men and 48.2% were women. They ranged in age from 19 to 66 years, with the mean age was 35.74 years
Im, Cho, Dubinsky and Varma (2018)	Sought to determine if taking an educational psychology course would mitigate neuromyths.	60 neuroscience literacy and belief in neuromyth items, 47 items were adapted from Dekker et al. (2012).	Findings revealed that participants in the experimental group (M = 5.84) believed more neuromyths than participants in the control group (M = 4.47). Leading the authors to conclude that taking an educational psychology course does not mediate misconceptions.	n = 99 Korean sophomore pre-service teachers. 50 experimental subjects (35=female, age = 20.86 years) with a control group of 49 participants (37 female, M age = 20.27 years).

are particularly deleterious for educators because they are highly resistant to extinction, can affect the ability of students to learn new information, and may signal the need for additional critical thinking training (Hammer, 1996; Hughes et al., 2013a; Muis, Sinatra, Pekrun, Winne, Trevors, Losenno, & Munzar, 2018). When teachers carry misconceptions of educational psychology into their classroom, the risk of using poorly informed techniques and instructional tools becomes problematic. It therefore stands to reason that misconceptions about educational psychology among teachers are particularly harmful and direct efforts should be taken to mitigate these misconceptions.

Strategies to Mitigate Misconceptions

We rely on conceptual change literature and advocate a six-step process to mitigate educational psychology misconceptions. First, to overcome these damaging misconceptions we must be able to effectively measure the prevalence and depth of these misconceptions, a task that requires the production of a pragmatic and operationalized definition of misconceptions, as we proposed earlier. Second, misconceptions about various topics exist among a variety of populations and are typically overcome through a conceptual change or argumentation protocol that incorporates some sort of cognitive conflict or dissatisfaction with an existing belief (Gregoire, 2003; Muis et al., 2018), motivation to change that belief, and a plausible, comprehensible, and coherent piece of accurate information (Dole & Sinatra, 1998). While various conceptual change models have been validated, we assert Gregoire's Cognitive-Affective Model of Conceptual Change (CAMCC; 2003) is the most appropriate model to employ when attempting to change the beliefs of pre-service teachers about educational psychology topics. The CAMCC is beneficial in this circumstance because it addresses typical conceptual change processes (e.g., dissonance and plausibility and intelligibility of correct conception) while also incorporating affective and motivational factors relevant to changing the belief (Gregoire, 2003; Muis et al., 2018).

Third, to facilitate such conceptual change from these misconceptions to evidence-supported conceptions of educational psychology, a refutational text or lecture seems most appropriate given its prior success in knowledge restructuring in psychology and education research (Bensley et al., 2014; Broughton, Sinatra, & Reynolds, 2010; Kowalski & Taylor, 2009, 2017; Sinatra & Brough-

ton, 2011; Tippett, 2010). The conditions under which refutational instruction will facilitate conceptual change include the learner's recognition of the inadequacy of their prior knowledge to solve a new problem, along with intelligibility, plausibility, and utility of the incoming information (Tippett, 2010). Such a protocol would include a statement of the misconception followed by the creation of doubt through the explanation of why that misconception is invalid and a statement of an evidence-based accurate claim about the topic and why that claim is acceptable and valid (Hynd, 2001).

Fourth, considering the recent evidence amassed on the precarious, yet influential nature of pre-service teacher epistemic cognition, beliefs, stances, and aims on knowledge formation and conceptual development (Barzilai & Chinn, 2018; Braten et al., 2017; Lunn Brownlee et al., 2017; Ferguson & Brownlee, 2018) a focus on *how* pre-service teachers evaluate, assess, and understand the credibility of evidence is essential. This aspect of misconception mediation is especially crucial because pre-service teacher candidates are inclined to place more emphasis on the certainty of knowledge (Ferguson & Brownlee, 2018), and implicitly trust in-service teachers, while also deferring to personal experience when learning (Bråten & Ferguson, 2015). Accurate conceptions of teaching and learning are hindered by the tendency of pre-service teachers to gravitate toward popular trends that result in "jumping on the band wagon every time a new research report or educational product is launched" (Ferguson & Brownlee, 2018, p. 107). Like Lunn Brownlee et al. (2017), we advocate emphasis on epistemic reflexivity that examines the internal dialogues of teacher candidates as an important misconception mitigation strategy.

Fifth, mitigating misconceptions, regardless of the field in which the mistaken belief exists, must be conducted by facilitating conceptual change in the individual to overcome the inaccurate belief and *replace it* with a new and accurate belief. The conceptual change process is particularly challenging because pre-instructional, inaccurate conceptions are likely to interfere with the process of learning accurate information (Chinn & Malhotra, 2002). Anomalous data that clearly refutes the belief has been used extensively in the facilitation of conceptual change to remediate misconceptions. Thus, it seems that providing teachers with anomalous data that directly contradicts their existing conception of an inappropriate teaching practice should in theory combat their misconception immediately. However, this is unlikely to occur because individuals will often resist this change and instead persistently retain their existing conception while rejecting the new, accurate information to protect their entrenched belief, often satisfying a robust personal or social goal (Chinn & Brewer, 1993). Prior research has revealed that emotions dominate the restructuring of knowledge when individuals are confronted with evidence that conflicts with their belief, moderating learning strategies (Muis et al., 2018; Sinatra et al., 2014). Thus, simply presenting pre-service teachers with information that contradicts their belief is insufficient to initiate belief change. We thus suggest the development of a conceptual change protocol that considers affective and motivational factors relevant to teacher belief systems. This type of approach was proposed by Gregoire (2003) and is pivotal in mitigating inaccurate beliefs about educational psychology among teachers.

Last, the conceptual change process is often tested in the field of educational psychology on prospective teachers to overcome these potentially harmful beliefs. As suggested by Hughes et al. (2013b), various methods beyond simple self-report questionnaires should be employed to truly understand the origin and nature of these inaccurate beliefs. In addition, based on the proclivity of psychology research to rely almost exclusively on *WEIRD* (Western, educated, industrialized, rich, and democratic) research samples (Rad, Martingano, & Ginges, 2018), we advocate inclusion of more diverse research populations to determine whether conceptual change efforts related to teaching, learning, and motivation are culturally determined and nuanced.

The information gleaned from qualitative inquiries related to these misconceptions would also provide a useful baseline to inform the development of techniques to restructure understandings of these important topics of educational psychology. For instance, operational conceptual change protocols could be developed after careful evaluation of the origin and nature of these misconceptions and the values and epistemic aims these teachers tie to their mistaken beliefs. Such protocols could be employed in undergraduate teacher education coursework to mitigate these misconceptions and obstruct deeper entrenchment of the beliefs. A review of teacher education programs and in-service teacher trainings should help teachers become more aware of their personal beliefs and how those beliefs influence pedagogy and motivational strategies. By continuing to adhere to absolutist beliefs (Schommer, 1990), teachers are shortchanging their students and perpetuating their own personal biases onto their students rather than promoting empirically-supported constructs. However, any change to be implemented among teachers will require the buy-in of school administrators and districts who should be charged with reevaluating the teaching methods employed in their classrooms, schools, and districts.

It therefore follows that mitigating misconceptions may benefit from a mixed-methods approach. Such an approach should include a validated instrument to measure the misconceptions, followed by think-aloud protocols with the appropriate population of individuals to determine their underlying values and motives as applied to their mistaken beliefs. The development of refutational texts to overcome such misconceptions is facilitated by the qualitative information gathered through the think-aloud protocols that provide insight regarding general beliefs, misunderstandings, and origins of the misconceptions, which can be used to specifically argue against the faulty conception. Eventually, the use of appropriate refutational texts that incorporate key epistemic emotions (Muis et al., 2018) can be used in conjunction with the instrument to more immediately overcome the misconceptions through simple instruction in teacher professional development sessions.

LIMITATIONS

As is the case with most research endeavors, this review is not without limitations. As mentioned previously, this was not intended to be an exhaustive review of the literature. Because of the expansiveness and breadth of fields in which misconceptions occur, we limited our search to the fields of psychology and education. Within these fields, we found an abundance of research to guide our inquiry and believe it is sufficient to make an informed decision about the necessity of future inquiries in this line of research. Additionally, the literature search was restricted to peer-reviewed publications in English and did not include other potentially relevant searches such as dissertations, popular media such as Psychology Today, or other trade magazines due to the

difficulty of performing an exhaustive search of all potentially relevant sources outside the scope of academic publications.

CONCLUSION

Altogether, this review has led to insight regarding the state of misconceptions in educational psychology. The first step toward mediating misconceptions among teacher populations is to develop methodologically sound instrumentation. Without solid measurement, an explicit remediation strategy remains untenable. Using such an instrument to identify the prevalence and strength of these misconceptions should also lead to necessary improvements in teacher training where many of these misconceptions likely originate. This review has also revealed that many studies clearly identify the problem of myths, legends, and misconceptions, but there is a paucity of literature concerning misconceptions among teachers. Thus, we advocate refutational approaches to discipline-specific conceptual change efforts rather than those that exclusively attempt to mitigate science misconceptions. Finally, we encourage researchers to explore new areas of inquiry that identify under which conditions misconception revision is enhanced. Currently our own research is examining whether epistemic stances toward various instructional modalities (face-to-face, online, blended) are preferential to induce durable knowledge revision. As suggested above, we are also using populations other than undergraduate education majors for the source of our data collection. We encourage others to extend our efforts.

Correspondence concerning this article should be addressed to: bobby.hoffman@ucf.edu

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REFERENCES

Alexander, P. A. (2006). Evolution of a learning theory: A case study. *Educational Psychologist, 41*, 257-264. doi: 10.1207/s15326985ep4104_6

Alexander, P. A. (2017). Reflection and reflexivity in practice versus in theory: Challenges of conceptualization, complexity, and competence. *Educational Psychologist*, *52*(4), 307-314. doi: 10.1080/00461520.2017.1350181

Amsel, E., Baird, T., & Ashley, A. (2011). Misconceptions and conceptual change in undergraduate students' understanding of psychology as a science. *Psychology Learning and Teaching, 1*(1), 3-10. doi: 10.2304/plat.2011.10.1.3

Arntzen, E., Lokke, J., Lokke, G., & Eilertsen, D-E. (2010). On misconceptions about behavior analysis among university students and teachers. *The Psychological Record, 60,* 325-336.

Bangerter, A., & Heath, C. (2004). The Mozart effect: Tracking the evaluation of a scientific legend. *British Journal of Social Psychology, 43,* 605-623. doi: 10.1348/0144666042565353

Barzilai, S. & Chinn, C. (2018). On the goals of epistemic education: Promoting apt epistemic performance. *Journal of the Learning Sciences*, *27*(3), 353-389,

Barzilai, S., & Chinn, C. A. (2020). A review of educational responses to the "post-truth" condition: Four lenses on "post-truth" problems. *Educational Psychologist*, *55*(3), 107-119.

Beck, D. M. (2010). The appeal of the brain in the popular press. *Perspectives on Psychological Science, 5,* 762-766. doi: 10.1177/1745691610388779

Bendixen, L. D., & Rule, D. C. (2004). An integrative approach to personal epistemology: A guiding model. *Educational Psychologist, 39,* 69-80. doi: 10.1207/s15326985ep3901_7

Bensley, D. A., Lilienfeld, S. O., & Powell, L. A. (2014). A new measure of psychological misconceptions: Relations with academic background, critical thinking, and acceptance of paranormal and pseudoscientific claims. *Learning and Individual Differences, 36,* 9-18. doi: 10.1016/j.lindif.2014.07.009

Best, J. B. (1982). Misconceptions about psychology among students who perform highly. *Psychological Reports, 51,* 239-244. doi: 10.2466/pr0.1982.51.1.239

Bråten, I., Muis, K. R., & Reznitskaya, A. (2017). Teachers' epistemic cognition in the context of dialogic practice: A question of calibration? *Educational Psychologist*, *52*(4), 253-269. doi: 10.1080/00461520.2017.1341319

Broughton, S. H., Sinatra, G. M., & Nussbaum, E. M. (2013). "Pluto has been a planet my whole life!" Emotions, attitudes, and conceptual change in elementary students' learning about Pluto's reclassification. *Research in Science Education, 43*(2), 529-550. doi: 10.1007/s11165-011-9274-x

Broughton, S. H., Sinatra, G. M., & Reynolds, R. E. (2010). The nature of the refutation text effect: An investigation of attention allocation. *The Journal of Educational Research, 103,* 407-423. doi: 10.1080/00220670903383101

Brown, L. T. (1983). Some more misconceptions about psychology among introductory psychology students. *Teaching of Psychology, 10,* 207-210. doi: 10.1207/s15328023top1004_4

Buehl, M. M., & Fives, H. (2009). Exploring teachers' beliefs about teaching knowledge: Where does it come from? Does it change? *The Journal of Experimental Education*, *77*, 367–407.

Cherniss, C., Extein, M., Goleman, D., & Weissberg, R. P. (2006). Emotional intelligence: What does the research really indicate? Educational Psychologist, 41, 239-245. doi: 10.1207/s15326985ep4104_4

Chew, S. L. (2005). Seldom in doubt but often wrong: Addressing tenacious student misconceptions. In D. S. Dunn, S. L. Chew, D. S. Dunn, S. L. Chew (Eds.), *Best Practices for Teaching Introduction to Psychology* (pp. 211-223). Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.

Chi, M. T. H. (2005). Commonsense conceptions of emergent processes: Why some misconceptions are robust. *The Journal of the Learning Sciences, 2,* 161–199.

Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research, 63*, 1-49.

Chinn, C. A., & Malhotra, B. A. (2002). Children's responses to anomalous scientific data: How is conceptual change impeded? *Journal of Educational Psychology, 94*(2), 327-343.

Chinn, C. A., Rinehart, R. W., & Buckland, L. A. (2014). Epistemic cognition and evaluating information: Applying the AIR model of epistemic cognition. In D. Rapp & J. Braasch (Eds.), *Processing inaccurate information: Theoretical and applied perspectives from cognitive science and the educational sciences* (pp. 425–453). Cambridge, MA: MIT Press.

Conklin, E. S. (1919). Superstitious belief and practices among college students. *The American Journal of Psychology, 30,* 83-102. doi: 10.2307/1413662

Cordova, J. R., Sinatra, G. M., Jones, S. H., Taasoobshirazi, G., & Lombardi, D. (2014). Confidence in prior knowledge, self-efficacy, interest and prior knowledge: Influences on conceptual change. *Contemporary Educational Psychology, 39*(2), 164-174. doi: 10.1016/j.cedpsych.2014.03.006

De Bruyckere, P., Kirschner, P. A., & Hulshof, C. D. (2015). *Urban myths about learning and education*. London: Academic Press

Dekker, S., Lee, N. C., Howard-Jones, P., & Jolles, J. (2012). Neuromyths in education: Prevalence and predictors of misconceptions among teachers. *Frontiers in Psychology, 3*, 1-8. doi: 10.3389/fpsyg.2012.00429

Della Sala, S. (1999). *Mind myths: Exploring popular assumptions about the mind and brain.* Chichester: Wiley. doi: 10.1080/10508406.2017.1392968

Dole, J. A., & Sinatra, G. M. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist, 33,* 109-128. doi: 10.1207/s15326985ep3302&3_5

Dresslar, F. B. (1910). Suggestions on the psychology of superstition. *American Journal of Insanity, 67,* 213-226. doi: 10.1176/ajp.67.2.213

Ferguson, L. E., & Lunn Brownlee, J. (2018). An investigation of preservice teachers' beliefs about the certainty of teaching knowledge. *Australian Journal of Teacher Education*, *43*(1), 94-111. doi: 10.14221/ajte.2018v43n1.6

Feucht, F. C., Lunn Brownlee, J. & Schraw, G. (2017). Moving beyond reflection: Reflexivity and epistemic cognition in teaching and teacher education. *Educational Psychologist*, *52*, 234-241. doi: 10.1080/00461520.2017.1350180

Fives, H. & Buehl, M. (2012). Spring cleaning for the "messy" construct of teachers' beliefs: What are they? Which have been examined? What can they tell us? In K.R. Harris, S. Graham, & T. Urdan (Eds.). *APA Educational Psychology Handbook: Volume 2 Individual differences and Cultural and Contextual Factors* (pp. 471-499). Washington: American Psychological Association.

Fives, H., & Buehl, M. M. (2008). What do teachers believe? Developing a framework for examining beliefs about teachers' knowledge and ability. *Contemporary Educational Psychology, 33*, 134-176. doi: 10.1016/j.cedpsych.2008.01.001

Furnham, A. (1992). Prospective psychology students' knowledge of psychology. *Psychological Reports, 70,* 375-382. doi: 10.2466/PR0.70.2.3750382

Furnham, A. (1993). A comparison between psychology and non-psychology students' misperceptions of the subject. *Journal of Social Behavior and Personality, 8,* 311-322.

Furnham, A. (2018). Myths and misconceptions in developmental and neuro-psychology. *Psychology*, *9*(2), 249-259.

Furnham, A., Callahan, I., & Rawles, R. (2003). Adults' knowledge of general psychology. *European Psychologist, 8*(2), 101-116. doi: 10.1027//1016-9040.8.2.101

Gallup (2005). Paranormal beliefs come (super) naturally to some. Retrieved on April 1, 2020, from: http://www.gallup.com/poll/19558/paranormal-beliefs-come-supernaturally-some.

Gardner, H., & Moran, S. (2006). The science of multiple intelligences theory: A response to Lynn Waterhouse. *Educational Psychologist, 41,* 227-232. doi: 10.1207/s15326985ep4104_2

Gardner, R. M., & Brown, D. L., (2013). A test of contemporary misconceptions in psychology. *Learning and Individual Differences, 23,* 211-215. doi: 10.1016/j.lindif.2012.12.008

Gardner, R. M., & Dalsing, S. (1986). Misconceptions about psychology among college students. *Teaching of Psychology, 13,* 32-34. doi: 10.1207/s15328023top1301_9

Gardner, R. M., & Hund, R. M. (1983). Misconceptions of psychology among academicians. *Teaching of Psychology, 10,* 20–22.

Garrett, H. E., & Fisher, T. R. (1926). The prevalence of certain popular misconceptions. *Journal of Applied Psychology, 10,* 411-420. doi: 10.1037/n0074058

Geake, J. (2008). Neuromythologies in education. *Educational Research, 50,* 123-133. doi: 10.1080/00131880802082518

Glass, L, Bartels, J. M., Ryan, J. J., & Stark-Wroblewski, K. (2008). The effectiveness of psychology courses at disconfirming common psychological myths. *Individual Differences Research, 6,* 97-103.

Gleichgerrcht, E., Luttges, B. L., Salvarezza, F., & Campos, A. L. (2015). Educational neuromyths among teachers in Latin America. *Mind, Brain, and Education, 9*(3), 170-178. doi: 10.1111/mbe.12086

Goswami, U. (2004). Neuroscience and education. *British Journal of Educational Psychology, 74,* 1-14. doi: 10.1348/000709904322848798

Green, M., Piel, J. A., & Flowers, C. (2008). Reversing education majors' arithmetic misconceptions with short-term instruction using manipulatives. *Journal of Educational Research, 101*(4), 234-242.

Griggs, R. A., & Ransdell, S. E. (1987). Misconceptions tests or misconceived tests? *Teaching of Psychology, 14*(4), 210-214.

Hammer, D. (1996). Misconceptions or p-prims: How may alternative perspectives of cognitive structure influence instructional perceptions and intentions. *Journal of the Learning Sciences, 5*(2), 97-127. doi: 10.1207/s15327809jls0502_1

Hamza, K. M., & Wickman, P. (2008). Describing and analyzing learning in action: An empirical study of the importance of misconceptions in learning science. *Science Education, 92,* 141-164. doi: 10.1002sce.20233

Heddy, B. C., & Sinatra, G. M. (2013). Transforming misconceptions: Using transformative experience to promote positive affect and conceptual change in students learning about biological evolution. *Science Education, 97*(5), 723-744. doi: 10.1002/sce.21072

Herculano-Houzel, S. (2002). Do you know your brain? A survey on the public neuroscience literacy at the closing of the decade of the brain. *The Neuroscientist, 8*, 98-110. doi: 10.1177/107385840200800206

Higbee, K. L., & Clay, S. L. (1998). College students' beliefs in the ten-percent myth. *The Journal of Psychology, 132*, 469-476.

Hoffman, B., & McAfee, M. A. (2017). Transfer of knowledge: A modality, knowledge, and conceptual analysis. Accepted for presentation at the 2017 European Association for Research on Learning and Instruction (EARLI) Conference, Tampere, Finland, August 2017.

Holley, J. W., & Buxton, C. E. (1950). A factorial study of beliefs. *Educational and Psychological Measurement, 10*, 400-410.

Holmes, J. D. (2016). *Great myths of education and learning*. Chichester, West Sussex: John Wiley & Sons, Ltd. https://doi.org/10.1037/0022-0663.82.3.498

Hughes, S., Lyddy, F., & Kaplan, R. (2013a). The impact of language and response format on student endorsement of psychological misconceptions. *Teaching of Psychology, 40,* 31-37. doi: 10.1177/0098628312465861

Hughes, S., Lyddy, F., & Lambe, S. (2013b). Misconceptions about psychological science: A review. *Psychology Learning and Teaching, 12*(1), 20-31. doi: 10.2304/plat.2013.12.1.20

Hughes, S., Lyddy, F., Kaplan, R., Nichols, A. L., Miller, H., Saad, C. G., … Lynch, A-J. (2015). Highly prevalent but not always persistent: Undergraduate and graduate student's misconceptions about psychology. *Teaching of Psychology, 42,* 34-42. doi: 10.1177/0098628314562677

Hynd, C. R. (2001). Refutational texts and the change process. *International Journal of Educational Research*, 35(7), 699-714.

Im, S. H., Cho, J. Y., Dubinsky, J. M., & Varma, S. (2018). Taking an educational psychology course improves neuroscience literacy but does not reduce belief in neuromyths. *PloS One*, *13*(2), e0192163.

Johnson, M. L., & Sinatra, G. M. (2014). The influence of approach and avoidance goals on conceptual change. *Journal of Educational Research, 107,* 312-325. doi: 10.1080/00220671.2013.807492

Kendeou, P., & van den Broek, P. (2005). The effect of readers' misconceptions on comprehension of scientific text. *Journal of Educational Psychology, 97,* 235-245. doi: 10.1037/0022-0663.97.2.235

Kirschner, P. A., & van Merriënboer, J. J. G. (2013). Do learners really know best? Urban legends in education. *Educational Psychologist, 48*(3), 169-183. doi: 10.1080/00461520.2013.804395

Kowalski, P., & Taylor, A. K. (2004). Ability and critical thinking as predictors of change in students' psychological misconceptions. *Journal of Instructional Psychology, 31,* 297-303.

Kowalski, P., & Taylor, A. K. (2017). Reducing students' misconceptions with refutational teaching: For long-term retention, comprehension matters. *Scholarship of Teaching and Learning in Psychology*, *3*(2), 90-100.

Kowalski, P., & Taylor, A. K. (2019). How attempting to reduce misconceptions in Psychology reveals the challenges of change. In P. Kendeou, M. McCrudden, & D. Robinson (Eds.). *Misinformation and fake news in education* (pp. 259-278). Charlotte, NC: Information Age Publishing, Inc.

Krätzig, G. P, & Arbuthnott, K. D. (2006). Perceptual learning style and learning proficiency: A test of the hypothesis. *Journal of Educational Psychology, 98,* 238-246. doi: 10.1037/0022-0663.98.1.238

Kuhle, B. X., Barber, J. M., & Bristol, A. S. (2009). Predicting students' performance in introductory psychology from their psychology misconceptions. *Journal of Instructional Psychology, 36,* 119-124.

Kunda, Z. (1990). The case for motivated reasoning. *Psychological Bulletin, 108,* 480-498.

Lamal, P. A. (1979). College students' common beliefs about psychology. *Teaching of Psychology, 6,* 155-158. doi: 10.1207/s15328023top0603_8

Lamal, P. A. (1995). College students' misconceptions about behavior analysis. *Teaching of Psychology, 22,* 177-180. doi: 10.1207/s15328023top2203_3

Lee, C., & Sherman, S. (2008). Synaptic properties of thalamic and intracortical inputs to layer 4 of the first- and higher-order cortical areas in the auditory and somatosensory systems. *Journal of Neurophysiology, 100*(1), 317–326. doi: 10.1152/jn.90391.2008

Lilienfeld, S. O., Lynn, S. J., Namy, L., & Woolf, N. (2009). *Psychology: From inquiry to understanding*. Boston, MA: Allyn & Bacon

Lilienfeld, S. O., Lynn, S. J., Ruscio, J., & Beyerstein, B. L. (2010). *Fifty great myths of popular psychology: Shattering widespread misconceptions about human behavior.* Chichester, UK: Wiley-Blackwell.

Lindell, A. K., & Kidd, E. (2011). Why right-brain teaching is half-witted: A critique of the misapplication of neuroscience to education. *Mind, Brain, and Education, 5,* 121-127. doi: 10.1111/j.1751-228X.2011.01120.x

Lobato, E., Mendoz, J., Sims, V., & Chin, M. (2014) Examining the relationship between conspiracy theories, paranormal beliefs, and pseudoscience acceptance among a university population. *Applied Cognitive Psychology, 28*, 617-625. doi: 10.1002/acp.3042

Lombardi, D., & Sinatra, G. M. (2012). College students' perceptions about the plausibility of human-induced climate change. *Research in Science Education, 2*, 201-217.

Lombardi, D., Nussbaum, E. M., & Sinatra, G. M. (2016). Plausibility judgments in conceptual change and epistemic cognition. *Educational Psychologist, 51,* 35-56. doi: 10.1080/00461520.2015.1113134

Losh, S. C., & Nzekwe, B. (2011). The influence of education major: How diverse preservice teachers view pseudoscience topics. *Journal of Science Education and Technology, 20*, 579-591.

Lunn Brownlee, J., Ferguson, L.E., & Ryan, M. (2017). Changing teachers' epistemic cognition: A new conceptual framework for epistemic reflexivity. *Educational Psychologist*, *52*(4), 242-252, doi: 10.1080/00461520.2017.1333430

Lyddy, F., & Hughes, S. (2012). Attitudes toward psychology as a science and the persistence of psychological misconceptions in psychology undergraduates. In V. Karandashev & S. McCarthy (Eds.), *Teaching psychology around the world* (pp. 333-339). Newcastle upon Tyne, UK: Cambridge Scholars Publishing.

McAfee, M. A., & Hoffman, B. (2014) *Identifying the teaching, learning, and motivation misconceptions of graduate students in education*. Paper presented at the 2014 annual meeting of the Florida Educational Research Association, Cocoa Beach, FL, November 20, 2014.

McAfee, M. A., Xu, L., & Hoffman, B. (2015). *Identifying the educational psychology misconceptions among pre-service teachers*. Paper presented at the annual meeting of the American Psychological Association, Toronto, ON, August 8, 2015.

McAfee, M. A., Xu, L., & Hoffman, B. (2016a). *Development and validation of an educational psychology misconception scale for pre-service teachers*. Paper presented at the annual meeting of SoTL Commons Conference, Savannah, GA, March 30, 2016.

McAfee, M. A., Xu, L., & Hoffman, B. (2016b). *Measuring teaching and learning misconceptions among undergraduate teacher candidates*. Paper presented at the 2016 Convention of the American Psychological Association (APA), Denver, CO, August 6, 2016.

McCabe, D. P., & Castel, A. D. (2008). Seeing is believing: The effect of brain images on judgments of scientific reasoning. *Cognition, 107,* 343-352. doi: 10.1016/j.cognition.2007.07.017

McCutcheon, L. E. (1991). A new test of misconceptions about psychology. *Psychological Reports, 68,* 647-653. doi: 10.2466/PR0.68.2.647-653

McCutcheon, L. E., Apperson, J. M., Hanson, E., & Wynn, V. (1992). Relationships among critical thinking skills, academic achievement, and misconceptions about psychology. *Psychological Reports, 71,* 635-639. doi: 10.2466/PR0.1992.71.2.635

McCutcheon, L. E. Furnham, A., & Davis, G. (1993). A cross-national comparison of students' misconceptions about psychology. *Psychological Reports, 72,* 243-247. doi: 10.2466/PR0.1993.72.1.243

McKeachie, W. J. (1960). Changes in scores on the Northwestern Misconceptions Test in six elementary psychology courses. *Journal of Educational Psychology, 51*, 240-244. doi: 10.1037/h0048569

Muis, K. R., Etoubashi, N., & Denton, C. A. (2020). The catcher in the lie: The role of emotions and epistemic judgments in changing students' misconceptions and attitudes in a post-truth era. *Contemporary Educational Psychology*, *62*, 101898.

Muis, K. R., Sinatra, G. M., Pekrun, R., Winne, P. H., Trevors, G., Losenno, K. M., & Munzar, B. (2018). Main and moderator effects of refutation on task value, epistemic emotions, and learning strategies during conceptual change. *Contemporary Educational Psychology*, *55*, 155-165. doi: 10.1016/j.cedpsych.2018.10.001

Murphy, P. K., & Mason, L. (2006). Changing knowledge and beliefs. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology* (pp. 305–324) (2nd ed.). Mahwah, NJ: Erlbaum.

Organisation for Economic Cooperation, and Development. (2002). *Understanding the Brain: Towards a New Learning Science.* Paris: OECD.

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9*(3), 105-119.

Pasquinelli, E. (2012). Neuromyths: Why do they exist and persist? *Mind, Brain, and Education, 6,* 89-96. doi: 10.1111/j.1751-228X.2012.01141.x

Pew Forum on Religion and Public Life, (2009). *Many Americans mix multiple faiths: Eastern, new age beliefs widespread.* Washington, DC: Pew Research Center. Retrieved October 7, 2016 from http://www.pewforum.org/2009/12/09/many-americans-mix-multiple-faiths/

Pickering, S. J., & Howard-Jones, R. (2007). Educators' views on the role of neuroscience in education: Findings from a study of UK and international perspectives. *Mind, Brain, and Education, 1,* 109-113. doi: 10.1111/j.1751-228X.2007.00011.x

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63,* 167-199.

Posner, G. J., Strike, K. A., Hewson, P.W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66,* 211-227.

Purdy, N. (2008). Neuroscience and education: How best to filter out the neurononsense from our classrooms? *Irish Educational Studies, 27,* 197-208. doi: 10.1080/03323310802242120

Rad, M. S., Martingano, A. J., & Ginges, J. (2018). Toward a psychology of Homo sapiens: Making psychological science more representative of the human population. *Proceedings of the National Academy of Sciences*, *115*(45), 11401-11405.

Rauscher, F. H., & Hinton, S. C. (2006). The Mozart effect: Music listening is not music instruction. *Educational Psychologist, 41,* 233-238. doi: 10.1207/s15326985ep4104_3

Ruble, R. (1986). Ambiguous psychological misconceptions. *Teaching of Psychology, 13*(1), 34-37.

Ryan, J., & McCrae, B. (2005). Subject matter knowledge: Mathematical errors and misconceptions of beginning teachers. In P. Clarkson, A. Downtown, D. Gronn, M. Horne, A. McDonough, R. Pierce, & A. Roche (Eds), Building Connections: Research, Theory and Practice: Proceedings of the 28th Annual Conference of the Mathematics Education Research Group of Australasia, (Vol. 2, pp. 641-648). Melbourne, Australia: Deakin University.

Sadler, P. M., & Sonnert, G. (2016). Understanding misconceptions: Teaching and learning in middle school physical science. *American Educator, 40*(1), 26-32.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology*, *82*, 498-504.

Shaw, J., & Woodworth, M. (2013). Are the misinformed more punitive? Beliefs and misconceptions in forensic psychology. *Psychology, Crime, & Law, 19,* 687-706. doi: 10.1080/1068316X.2013.793335

Sinatra, G. M., & Broughton, S. H. (2011). Bridging reading comprehension and conceptual change in science education: The promise of refutational text. *Reading Research Quarterly, 46,* 374-393. doi: 10.1002/RRQ.005

Sinatra, G. M., & Lombardi, D. (2020). Evaluating sources of scientific evidence and claims in the post-truth era may require reappraising plausibility judgments. *Educational Psychologist*, 1-12.

Sinatra, G. M., Kienhues, D., & Hofer, B. K. (2014). Addressing challenges to public understanding of science: Epistemic cognition, motivated reasoning, and conceptual change. *Educational Psychologist, 49*(2), 123-138. doi: 10.1080/00461520.2014.916216

Sinatra, G. M., Southerland, S. A., McConaughy, F., & Demastes, J. W. (2003). Intentions and beliefs in students' understanding and acceptance of biological evolution. *Journal of Research in Science Teaching, 40*, 510-528. doi: 10.1002/tea.10087

Smolleck, L., & Hershberger, V. (2011). Playing with science: An investigation of young children's science conceptions and misconceptions. *Current Issues in Education, 14*(1), 1-31.

Standing, L. G., & Huber, H. (2003). Do psychology courses reduce belief in psychological myths? *Social Behavior and Personality, 31,* 585-592. doi: 10.2224/sbp.2003.31.6.585

Sylvan, L. J., & Christodoulou, J. A. (2010). Understanding the role of neuroscience in brain based products: A guide for educators and consumers. *Mind, Brain, and Education, 4,* 1-7. doi: 10.1111/j.1751-228X.2009.01077.x

Tardif, E., Doudin, P-A, & Meylan, N. (2015). Neuromyths among teachers and student teachers. *Mind, Brain, and Education, 9,* 50-59. doi: 10.1111/mbe.12070

Taylor, A. K., & Kowalski, P. (2012). Students' misconceptions in psychology: How you ask matters…sometimes. *Journal of the Scholarship of Teaching and Learning, 12*(3), 62-77.

Thompson, R., & Zamboanga, B. (2004). Academic aptitude and prior knowledge as predictors of student achievement in introduction to psychology. *Journal of Educational Psychology, 96,* 778-784. doi: 10.1037/0022-0663.96.4.718

Tippett, C. D. (2010). Refutation text in science education: A review of two decades of research. *International Journal of Science and Mathematics Education, 8,* 951-970.

Trani, R. (2004). I won't teach evolution; it's against my religion. And now for the rest of the story… *The American Biology Teacher, 66*(6), 419-427.

Vaughan, E. D. (1977). Misconceptions about psychology among introductory psychology students. *Teaching of Psychology, 4*(3), 138-141.

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou. E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction*, 11(4), 381-419.

Waterhouse, L. (2006a). Multiple Intelligences, the Mozart Effect, and Emotional Intelligence: A critical review. *Educational Psychologist, 41*, 207-225. doi: 10.1207/ s15326985ep4104_1

Waterhouse, L. (2006b). Inadequate evidence for Multiple Intelligences, Mozart Effect, and Emotional Intelligence theories. *Educational Psychologist, 41*, 247-255. doi: 10.1207/ s15326985ep4104_5

Willingham, D. T., Hughes, E. M., & Dobolyi, D. G. (2015). The scientific status of learning styles theories. *Teaching of Psychology, 42,* 266-271. doi: 10.1177/0098628315589505

Woolfolk Hoy, A., Davis, H., & Pape, S. J. (2006). Teacher knowledge and beliefs. In P.A. Alexander & P. H. Winne (Eds.), *Handbook of Educational Psychology* (pp. 715-738). Mahwah, NJ: L. Erlbaum Associates.