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Learning Styles, Classroom Instruction, and Student Achievement

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Learning Styles, Classroom Instruction, and Student Achievement

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Chapter 1
Introduction

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This is the inaugural monograph in a series that critically examines current issues in the field of psychology in education. More specifically, this monograph series serves as a sort of watchdog designed to catch and report fake news and quackery. We have a plethora of new research that is produced every year. Much of this research in applied fields such as psychology and education examines new approaches to improving our lives. Such research efforts are responsible for some of the most important contributions in society. Unfortunately, however, many highly touted breakthroughs are not really breakthroughs at all. Instead, they are the equivalent of snake oil that is peddled by charlatans.

In the popular 1990s sitcom *Seinfeld*, the characters Jerry and George often had discussions about the legitimacy of something. George would often ask, "Is that a thing?" In other words, is it real? Is it actually something? We find ourselves asking the same questions frequently in our fields of psychology and education. For example, some recent buzzwords have emerged such as grit, mindfulness, and social-emotional intelligence. Should pre-service teachers, those who are in college studying to become K-12 teachers, learn these concepts as part of the curriculum? Should state licensing exams that certify persons to teach at the K-12 level include these concepts? Should K-12 schools and districts spend thousands of dollars on professional development so that teachers can implement such notions in their classrooms? Most importantly, will such implementation result in positive outcomes

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for students? The answers to the first three questions are obviously affirmative due to the fact that this is already happening. The answer to the last question is more difficult. Unfortunately, this question is by far the most important. And there is almost always a dearth of evidence to support it.

Such problems are not unique to education. In the fields of health and medicine, there are reputable schools where students can receive the best training. Such schools often include areas of study such as epidemiology, microbiology, neurology, and ophthalmology. Reputable schools of medicine do *not* include chiropractic, acupuncture, or homeopathic or naturopathic medicine in the curriculum. Such approaches to healing are considered pseudoscience. There is no evidence that such approaches actually heal. Using *Seinfeld* language, such things are not really a thing. Some people might think they are things. But, in reality, they are wastes of time and money.

In schools of business, you will find accounting, finance, and management but rarely sales or entrepreneurship. That seems peculiar if you think about it. After all, isn't sales the most important part of running a business? But sales is not something that is studied at the most reputable business schools. Of course, there are exceptions. Florida State University, for example, has the Jim Moran College of Entrepreneurship. It also has a sales institute within the College of Business. But again, the more reputable universities do not include these areas.

Similarly, in schools of education, you will find departments of teaching, curriculum, physical education, and administration. Including a department of leadership would be silly because, like sales and entrepreneurship, it cannot be scientifically studied and researched to determine best approaches, methods, etc. But wait, similar to Florida State University, there *are* several reputable schools of education that include departments of leadership. So, we must ask the question, "Is educational leadership really a thing?" Stay tuned as an upcoming monograph in this series will address that very same question.

This monograph concerns the question of whether learning styles (LS) is/are a thing. LS has been around for decades. As you will learn, LS receives overwhelming support from K-12 teachers and parents. But the scientific evidence to support LS is severely lacking. In the following chapters, we dive into this issue to determine whether LS should continue to be considered a thing or kicked to the curb.

Chapter 2 traces the history of LS, how it got started and its continued popularity. Chapters 3 and 4 continue this examination by specifically focusing on the widespread belief among educators and the general public and also possible reasons for such strong support of LS. Chapter 5 reviews the past decade of empirical research articles devoted to LS and concludes, surprisingly, that rather than experiencing a decline in supporting articles, LS appears to be gaining momentum, despite being repeatedly called out in scientific circles. Chapter 6 examines the consequences of supporting and implementing LS in the classroom. Finally, Chap. 7 concludes with a commentary on the previous chapters.

Chapter 2
What are Learning Styles and How did They Get Started?

Daniel H. Robinson

In 2018, US Secretary of Education Betsy DeVos announced her "Rethink School" tour: Our team is crossing the country this year to challenge local leaders, educators, and parents to rethink school. We know the current system is leaving too many students unprepared, so we must question everything about the way we do school in this country. There's no more time for tinkering around the edges. No more trying the same things and expecting different results. I'm excited to highlight pockets of innovation around the country that are truly challenging the status quo and working to ensure all children can have access to the education that fits their *learning style* (emphasis added) and prepares them for a successful future.

This notion that education should "fit" students' learning styles has been around for some time (Fig. 2.1).

How did This Get Started?

Learning styles have been around for several years, becoming most popular beginning in the 1970s. Rita and Kenneth Dunn began their work on learning styles in the 1960s mainly as a response to the New York State Education Department's concern for poorly achieving students. The Dunn and Dunn Learning Style model emphasized that instruction should match an individual's learning style to maximize motivation and learning. These styles involve environmental, emotional, sociological, physiological, and psychological influences. They have produced the following self-report instruments: the Dunn and Dunn Learning Styles Questionnaire (LSQ)

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Fig. 2.1 Cartoon by bill browning, from his webpage: http://www.mnispi.org/cartoon/2001/index.htm

(1979), the Dunn, Dunn and Price Learning Styles Inventory (LSI) (1992, 1996), and, yes, Our Wonderful Learning Styles (OWLS) (2002).

Later, Kolb's Learning Styles Inventory (KLSI) (Smith & Kolb, 1996) came up with nine different styles: initiating, experiencing, imagining, acting, balancing, reflecting, deciding, thinking, and analyzing. A bit more simplistic, Fleming's VARK model (Leite et al., 2010) posited four learning styles: visual, aural, read/write, and kinesthetic. The VARK website (vark-learn.com) has a "learning styles role playing" resource that can be used with teacher education students. Students need to "identify what VARK learning style each student represents/prefers and then discuss how you might focus your own teaching and curricula to accommodate these different learning preferences."

Finally, Felder's Index of Learning Styles (Felder & Silverman, 1988; Felder & Spurlin, 2005) posited four different learning dimensions: active vs. reflective, sensing vs. intuitive, visual vs. verbal, and sequential vs. global. In the USA, the Dunn, Dunn and Price LSI is still used in many elementary schools, whereas in the UK, both the KLSI and Honey and Mumford's (1992) Learning Styles Questionnaire (activist, theorist, pragmatist, and reflector) are widely known and used.

Based on a meta-analysis, Dunn et al. (1995) concluded that students whose learning styles were accommodated (instruction matched their style) typically score

0.75 standard deviations higher than those who are not accommodated. It is this idea of accommodating a learner's "style" that remains controversial.

Styles vs. Preferences

Dunn and Griggs (1988) argued that learning style is a "biologically and developmentally imposed set of characteristics that make the same teaching method wonderful for some and terrible for others" (p. 3). This notion of "style" reflects something that is not a choice and perhaps something we are stuck with. It is similar to a student who has vision or hearing impairments. Presenting instruction only visually to a student who is unable to see does not make sense. Rather, instruction should match the modality in which the student can sense the information. Thus, if there are truly biologically determined learning styles, then instruction should match those styles. Unfortunately, as previously mentioned, there is a dearth of evidence supporting such a notion.

What about preferences? Certainly, preferences seem less threatening than styles. In fact, in a recent defense of learning styles, Felder (2020) used the term *learning style preferences* and concluded that we should simply teach in a manner that balances student preferences. Felder (2010) argued that an "…awareness of learning style differences can help instructors teach in a manner that effectively reaches most students rather than putting a large subset of them at a disadvantage" (p. 1). Felder appears to identify "learning styles" instruction as simply varying modalities. That approach is much less controversial.

This notion that different people *prefer* to learn in different ways is quite different than assuming people are tied to biological learning styles. After all, people are also known to prefer to exercise in different ways, walk differently, talk differently, eat differently, etc. Preferences simply reflect a person's choices and not something beyond control. But, just like allowing people to eat and exercise in their preferred way may not be optimal, allowing student preferences to determine instruction does not always result in optimal learning.

Several years ago, one of my graduate students, Michael Mayrath, conducted experiments comparing different multimedia options in terms of student preference and, more importantly, learning. He found that students preferred watching a video that explained how brakes work that included both sound and closed captioning where the text is presented both aurally and visually. The condition under which students learned best, however, was simply a video with sound and no closed captioning. It turned out that the closed captioning competed for visual attention with the video and students did not see enough of the video to perform best. This is something known as the learner preference paradox. Similarly, Kornell and Bjork (2007) asked students which learning strategy would likely result in the most recall—studying or being tested. Most students chose studying, whereas testing was a superior strategy. Thus, instruction that is driven by student preferences risks non-optimal outcomes.

Does Higher Education Embrace Learning Styles?

Despite the lack of evidence for teaching that matches students' learning styles and the obvious risks of allowing students to choose how they wish to learn, support for these notions remains quite alive and well. Go to any university's website, locate the search engine, and type the following using quotations: "learning styles." You will find a TON of hits—most coming from either the library or the Center for Teaching and Learning or its equivalent. Learning styles as a concept and as an instructional tool is definitely far from dead and is a prime example of what Sinatra and Jacobson (2019) called a zombie concept.

The purpose here is not to single out and attempt to embarrass anyone. Thus, I searched using my own university's (The University of Texas at Arlington) website. The first thing that appeared was a book used to determine the university's core courses assessment concerning empirical and quantitative skills (Blair, 2006). One of the chapters is titled, "Student learning and the learning environment" and has a large section on learning styles. Think about this—the assessment of core knowledge at my university is based on the assumption of learning styles!

The next thing that appeared was a planning checklist from our Office of Institutional Planning and Reporting that includes "Students were prepared through EDUC 3333 and EDUC 4444 to be able to craft a teaching lesson while taking special note of diversity of learning styles and culturally responsive pedagogy." Yes, those are education courses—in the college where I work.

Next was a website for students who are majoring in music education. One course, MUSI 4216—Strategies and Assessment in Music Pedagogy, a senior-level course, mind you, includes such learning objectives as:

1. Define learning modalities, learning styles, and multiple intelligences.
2. Evaluation of his/her learning modalities and learning style.
3. Apply the various learning modalities and learning styles to musical instruction.

Yes, this course is for students who wish to become certified K-12 music teachers.

The fourth URL was a website for our recently created Division of Student Success. They offer struggling students a chance to meet with an "academic coach" where "students will examine their learning styles, habits of working, and current difficulties or barriers to success."

Finally, the fifth website was from our university's IDEAS Center that provides assistance to transfer students where "[t]utors and mentors are trained to provide these services to their peers who may have different learning styles (visual, aural, kinesthetic, etc.)."

Thus, as you can see, "learning styles" is very alive and well at the University of Texas at Arlington and other universities, including Harvard, Stanford, Vanderbilt, etc., despite all the publications in recent years calling for its discontinuation.

Why is Teaching Learning Styles So Popular?

When I took my first academic job at Mississippi State University, I skimmed through the recent dissertations in my department. I noticed that the majority included the term "Myers-Briggs" in the title. I knew from graduate school that the Myers-Briggs Type Indicator (MBTI) test was similar to a horoscope in terms of reliability and validity—extremely low. How was this quackery finding its way into dissertations? It turns out that a psychology professor, Thomas Carskadon, was serving as editor of the *Journal of Psychological Type*. Most of the educational psychology students were simply working with Dr. Carskadon.

Why was the MBTI so popular? Simple. Students liked it. You can spend a full class period administering, scoring, and discussing it. Students will typically react to their newly discovered "type" and say, "that is so me!" Of course, there is absolutely no empirical support for the MBTI. But it is a fun activity and appeals to many in the same way that palm-reading and tarot cards do. But in the absence of any empirical support, such pseudoscience should be labeled as "for entertainment purposes only."

What is the appeal of learning styles? Very similar to the MBTI, self-report tests that claim to assess one's learning style are simply entertaining for students. Results can "explain" why they have struggled in certain areas. "Oh, it's because my teachers have never fully taught in a way that matches my learning style! It's not my fault!" Gardner's (1983) Multiple Intelligences theory was embraced in the same way. "Oh, my intelligences are in *these* areas! The educational system simply has not allowed me to demonstrate my strengths and instead keeps making me take verbal tests over academic material."

Persons who resonate with these snake oil treatments are similar to those who watch late-night infomercials explaining to them that being overweight is not their fault. If they would simply spend money on this latest weight loss pill or exercise technique, they can be slim, healthy and more successful. Similarly, the reason why they are unsuccessful is not their fault. If they would simply call the psychic hotline, their lives could turn around for the better. The idea that education must fit a person's learning style will continue to stick around as long as there are gullible people. In the meantime, educational researchers should continue to call out its ridiculousness (Fig. 2.2).

Parents Of Nasal Learners Demand Odor-Based Curriculum
March 15, 2000 | Issue 36•09

COLUMBUS, OH–Backed by olfactory-education experts, parents of nasal learners are demanding that U.S. public schools provide odor-based curricula for their academically struggling children.

A nasal learner struggles with an odorless textbook.

… "My child is not stupid," Delia Weber, president of Parents Of Nasal Learners, said. "There simply is no way for him to thrive in a school that only caters to traditional students who absorb educational concepts by hearing, reading, seeing, discussing, drawing, building, or acting out."

Fig. 2.2 The Onion (2000)

References

Blair, R. (2006). *Beyond crossroads: Implementing mathematics standards in the first two years of college*. American Mathematical Association of Two-Year Colleges. Retrieved from https://www.uta.edu/ier/core-assessment/empirical-and-quantitative-studies/Beyond-Crossroads-Implementing-Mathematics-Standards-in-the-First-Two-Years-of-College.pdf

Dunn, R., & Griggs, S. A. (1988). *Learning styles: A quiet revolution in American secondary schools*. National Association of Secondary School Principals.

Dunn, R., Griggs, S. A., Olson, J., Beasley, M., & Gorman, B. S. (1995). A meta-analytic validation of the Dunn and Dunn Model of Learning-Style Preferences. *The Journal of Educational Research, 88*, 353–362.

Felder, R. M. (2010). Are learning styles invalid? (Hint: No!). On-Course Newsletter, September 27, 2010. Retrieved from https://www.engr.ncsu.edu/wp-content/uploads/drive/10S5mLk GElsN8NTsYgOe_f0taEdlSpbJD/2010-LS_Validity(On-Course).pdf

Felder, R. M. (2020, Spring). Opinion: Uses, misuses, and validity of learning styles. *Advances in Engineering Education*, 1–16. Retrieved from https://advances.asee.org/wp-content/uploads/vol08/issue01/Papers/AEE-Pathways-Felder.pdf

Felder, R. M., & Silverman, L. K. (1988). Learning styles and teaching styles in engineering education. *Engineering Education, 78*, 674–681.

Felder, R. M., & Spurlin, J. (2005). Applications, reliability, and validity of the Index of Learning Styles. *International Journal of Engineering Education, 21*, 103–112.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. Basic Books.

Honey, P., & Mumford, A. (1992). *The manual of learning styles* (3rd ed.). Maidenhead.

Kornell, N., & Bjork, R. A. (2007). The promise and perils of self-regulated study. *Psychonomic Bulletin & Review, 14*, 219–224.

Leite, W. L., Svinicki, M., & Shi, Y. (2010). Attempted validation of the scores of the VARK learning styles inventory with multitrait–multimethod confirmatory factor analysis models. *Educational and Psychological Measurement, 70*, 323–339.

Sinatra, G. M., & Jacobson, N. (2019). Zombie concepts in education: Why they won't die and why you can't kill them. In P. Kendeou, D. H. Robinson, & M. McCrudden (Eds.), *Misinformation and fake news in education*. Information Age Publishing.

Smith, D. M., & Kolb, D. A. (1996). *User's guide for the learning-style inventory: A manual for teachers and trainers*. McBer.

The Onion. (2000). Parents of nasal learners demand odor-based curriculum. The Onion. Retrieved from https://www.theonion.com/parents-of-nasal-learners-demand-odor-based-curriculum-1819565536

Chapter 3
The Widespread Belief in Learning Styles

Henrietta Den Dekker and Joseph A. Kim

Neuromyths in Education

John has not been performing well on his tests in high school and is earnestly trying to understand how to improve his grades. Searching for help online, he comes across learning styles theory, which has thousands of pages of hits. A quick online test reveals that he is a *kinaesthetic* learner. This revelation comes as both a relief and motivation for change. Looking back, John realizes that the course content at school is typically presented visually and suits only those with a *visual* learning style. Further reading confirms that learning styles is a widely accepted theory among students, teachers, school boards, and even many education researchers. John is convinced that if he were taught in a way that matched his learning style, improved academic performance will soon follow.

The belief that students learn best when they receive information in their preferred learning modality is an example of a neuromyth. The term *neuromyth,* as defined by the Organisation for Economic Co-operation and Development in 2002, refers to a misconception about the mind or brain (Organisation for Economic Cooperation, and Development, 2002). These neuromyths usually begin with "a misunderstanding, a mis-reading, and in some cases a deliberate warping of the scientifically established facts to make a relevant case for education or for other purposes" (Organisation for Economic Cooperation, and Development, 2002).

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One example of warped fact is "the cone of learning" derived from Dale's Cone of Experience (Subramony et al., 2014). The modern cone lists percentages to indicate how much people remember after learning material in different ways. These percentages were added to Dale's original cone, which was simply a visual to demonstrate how richer study experiences lead to better retention such as a field trip compared to an article reading. The percentages have no scientific basis, vary between different versions of the cone, and are neither reliable nor valid (Subramony et al., 2014). Modern versions and applications of the cone deviate from Dale's original intention and his warning against taking the cone too literally (Subramony et al., 2014).

Another popular neuromyth is the idea of critical periods during development when a child must be exposed to specific stimuli or risk never acquiring a trait (Organisation for Economic Cooperation, and Development, 2002; Strid, 2017). Other misconceptions include beliefs that humans only use 10% of their brain or that the brain shrinks with insufficient water intake (Dekker et al., 2012).

Several widespread neuromyths relate to education. Popular education neuromyths include beliefs that enriched environments increase learning, or that students are either left-brain or right-brain dominant and that this dominance influences their learning (Dekker et al., 2012). Sometimes these neuromyths form the basis for educational programs such as Brain Gym (Dekker et al., 2012). While education neuromyths may not directly harm learning, they can lead to a misallocation of limited resources from other learning practices that are demonstrably effective.

One of the most widespread educational neuromyths is learning styles theory, which is centered around student preferences to different modes of learning, typically either visual, auditory, or kinaesthetic and the belief that students should be taught in their preferred mode of learning. Within learning styles theory, researchers often use the *meshing hypothesis* to describe matching instructional approaches to a student's preferred learning style. For example, a teacher might teach a visual student with diagrams or other visual modes of communication. Unfortunately, there is virtually no evidence that matching instruction to a student's learning style improves learning (Pashler et al., 2008).

Learning style theories have gained considerable momentum over the past several decades among all key players in the education system including students, teachers, administrators, researchers, and the public. Support for learning styles has resulted in implementation at all levels, ranging from kindergarten classrooms, workplace training sessions, higher education, and teacher education. In an elementary classroom, the teacher might ask visual learners to highlight and color code their notes, auditory learners to recite the material to a rhythm or beat, and kinaesthetic learners to use different textured papers and different sized pencils (UMass Dartmouth Center for Access and Success, n.d.). In a workplace training session, the manager might have the employees each fill out a VARK questionnaire and separate the different groups to receive learning style-specific training. The countless resources directed towards implementation of learning style theories reinforce how deeply entrenched this neuromyth is.

The Belief in Learning Styles

Parents and Broader Society

The satirical news outlet *The Onion* published a story on parents of nasal learners demanding odor-based curricula for their children (The Onion, 2000). While the article was published in jest, it does capture the zeitgeist of societal beliefs in learning styles. Parents believe that everyone has a particular learning style and will learn best if they receive information in that specific modality. In one survey, 93% of respondents reported believing that individuals learn better when they receive information in their preferred learning style and 88% believed that children have learning styles that are dominated by particular senses (Macdonald et al., 2017). In another survey, close to 90% of respondents indicated that students should receive course information in their preferred learning style (Boser, 2017). Despite these and other erroneous beliefs, 75% of participants rated themselves as above average in their ability to evaluate instructional practice, likely drawing from personal educational experiences to create a sense of expertise (Boser, 2017). The website https://www.learning-styles-online.com/ boasts that over one million people have completed their particular online learning styles inventory. The myth is so prevalent that Nancekivell et al. (2020) noted "the learning style myth is thought to be one of the most pervasive misconceptions about cognition." In one study examining differences in learning styles beliefs, researchers only wanted survey respondents who endorsed learning styles. Out of 393 participants, only six had to be excluded who did not believe in learning styles and 24 who were not sure about learning styles (Nancekivell et al., 2020).

Parental beliefs in learning styles influence their children's beliefs, as well as interactions with teachers and school administration. For example, a parent who believes their child has a particular learning style might demand resources for teachers to support that learning style. Reflection on the overwhelming belief in learning styles among parents and broader society and the resulting influence on the education system highlights the importance of eliminating those beliefs.

Students

The widespread belief in learning styles holds true in students as well. Fifty-eight percent of students believe they have a specific learning style (Morehead et al., 2016) and 88% of students believe that teaching to a student's learning style enhances learning (Dandy & Bendersky, 2014).

Student beliefs influence their individual learning. If students believe they learn best visually, they might re-read their notes to prepare for a test or use another technique that does little to improve long-term learning. Similarly, students who believe they are a kinaesthetic learner might simply perform worse with a visual lesson due

to lower motivation or, conversely, students who receive instruction in their preferred learning style might be more motivated and confident, which could indirectly improve their performance. The improvements in learning would be a placebo effect, rather than a result of the matched learning styles.

Matching instructional style to a student's learning style is not always possible. Consider how different teaching styles fit with different subjects. Riener and Willingham (2010) highlight how silly it is to ask someone whether they would prefer to learn something visually or kinaesthetically without providing the context of what that person is trying to learn. For example, persons learning to drive a car must, at some point, kinaesthetically interact with the car, even if they prefer learning visually. A student learning to read sheet music must, at some point visually engage with the materials. Ultimately, a learning style mindset does not help the student. As Frank Coffield put it, "We do students a serious disservice by implying they have only one learning style, rather than a flexible repertoire from which to choose, depending on the context" (Henry, 2007).

Student beliefs also direct the feedback they give to educators. Riener and Willingham (2010) reported learning style beliefs surfacing in course evaluations, with statements such as "I am a visual learner, so the visual examples were good." When the Ontario Ministry of Education introduced an online educational platform for students, some complained it did not fit their learning style (Hristova, 2020). If students advocate for use of learning style theories in the classroom, teachers and policy makers might be inclined to cater to those students. With sufficient pressure from parents and students, education leaders might use resources integrating learning style theories into the program.

Finally, student beliefs influence instructor evaluations. In one popular college study skills textbook there is an activity (Activity 1.7, p. 16) where readers are encouraged to evaluate their instructor's teaching style in light of their preferred learning style (Van Blerkom, 2009). In the surrounding text, the reader finds more detail. If the instructor's teaching style matches the student's learning style that student will feel comfortable and in control. However, if the teaching style and learning styles do not match, then the student "may feel uncomfortable in class, have difficulty completing assignments and perform poorly on exams" (Van Blerkom, 2009 p. 17). Student evaluations of teaching can have large implications for educators, particularly those at the university level where teaching performance may influence tenure decisions.

K-12 Teacher Trainees

K-12 pre-service teachers represent a unique group of individuals who are university students, interested in education and learning, but who have not yet completed their formal training in education and learning. Their pedagogical approaches will likely inform their teaching throughout their career and influence the education of thousands of students. Unfortunately, many pre-service teachers remain largely

convinced of the learning styles myth (Dündar & Gündüz, 2016). In one survey of undergraduate pre-service teachers, 97% agreed with the statement "individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinaesthetic)" (Kim & Sankey, 2018). Those who agreed with the statement were also more confident in their answer than those who disagreed with the statement, indicating strong belief in learning styles (Kim & Sankey, 2018).

There is some evidence that pre-service science teachers are particularly susceptible to both educational and general neuromyths compared to pre-service teachers from other disciplines. This might be because teachers with a science background are more interested in neuroscience research and its possible applications to education. With limited training in neuroscience, they may inadvertently oversimplify and implement research without critical review (Dündar & Gündüz, 2016). Furthermore, most science students only take a general introductory-level neuroscience course, unless they choose to specialize in neuroscience. Weisberg et al. (2008) found that participants in introductory-level cognitive neuroscience courses were still as "seduced" by superfluous neuroscientific explanations as the general population.

Teachers

K-12 teachers constitute a significant part of the education system as the front-line decision-makers responsible for day-to-day instruction. Although differing by country, the typical process in the United States includes completion of a bachelor's degree from an accredited teacher preparation program and passing a state-specific certification test. Despite this extensive training, neuromyth prevalence among teachers remains high. In one influential study, researchers presented a survey to 242 teachers containing 15 neuromyths and 17 accurate statements about the brain and learning. The teachers indicated whether each statement was correct, incorrect, or if they did not know. Overall, teachers agreed with 49% of the neuromyths with the most common misconception regarding learning styles. 93% of UK teachers and 96% of Netherlands' teachers incorrectly believed that individuals learn better when they receive information in their preferred learning style (Dekker et al., 2012). In a survey regarding auditory and visual learning styles specifically, 85% of subjects believed that differences in learning preferences was supported by brain research (Tardif et al., 2015). Even sports coaches agree with learning styles, with a survey of British and Irish coaches revealing that 62% believed matching information to an individual's learning style would increase learning (Bailey et al., 2018).

The belief in learning styles among K-12 teachers persists globally. Independent surveys on K-12 teachers in the United Kingdom and Netherlands (Dekker et al., 2012), Greece (Deligiannidi & Howard-Jones, 2015; Papadatou-Pastou et al., 2017), Latin America (Gleichgerrcht et al., 2015), East China (Pei et al., 2015), Turkey (Karakus et al., 2015), and Spain (Ferrero et al., 2016) report between 91% and 97% belief in learning styles.

Endorsement of neuromyths is consistent among teachers from different disciplines, grades, and with different levels of expertise. Kindergarten teachers, for example, endorse the same neuromyths as high school teachers (Rato et al., 2013). Furthermore, a teacher's level of knowledge does not influence recognition and endorsement of neuromyths (Rato et al., 2013; Dekker et al., 2012). K-12 teachers with masters or PhD degrees endorse a similar number of neuromyths as their colleagues (Blanchette Sarrasin et al., 2019).

In addition to agreeing with learning styles in theory, upwards of 70% of teachers report applying learning style theories in their classrooms (Simmonds, 2014). In one survey of teachers and student teachers, 80% reported using or intending to use learning style preferences in their teaching while 87% believed that a pedagogical approach based on learning style differences would help learning (Tardif et al., 2015). In another study, 98% of teachers who agreed with learning styles implemented practices relating to learning styles, but preschool teachers reported using learning style theories more than primary or secondary teachers (Blanchette Sarrasin et al., 2019). Teacher beliefs about the brain inform their lesson planning, classroom practice, and provision for special needs predominantly (Simmonds, 2014). Sometimes the implementation is more dramatic, such as teachers labeling children with V, A, or K (Geake, 2008).

Teachers, as front-line decision-makers, are responsible for daily lessons, activities, and grading. Teachers have finite money and time. If teachers choose to expend time and energy evaluating students on their learning styles and creating personalized lessons to match each student's learning style, then they have fewer resources for interventions based on solid empirical research and ultimately, students will be disadvantaged.

Researchers

Most higher education faculty agree with and use learning style theories in their classrooms although they are more likely to just agree with the neuromyth rather than to actually implement it in their classrooms (Dandy & Bendersky, 2014). The practice of agreeing but failing to implement seems true of other theories and practices as well. In one study on instructor use of evidence-based instructional practices (EBIPs), respondents indicated awareness of a number of EBIPs, interest in only a subset, and implementation of only a selective few (Lund & Stains, 2015). Out of 146 instructors at an American university 91% of instructors believed students have different learning styles and 77% taught in a way that accommodated different learning styles (Morehead et al., 2016). In another survey of higher education faculty, 33% had given their students a version of a Learning Styles Questionnaire (Newton & Miah, 2017). In addition to individual beliefs, learning style theories are also endorsed at the institutional level, with 72% of 39 surveyed universities promoting such theories in faculty development (Meyer & Murrell, 2014).

Ministries

Countless ministries and regulatory organizations have published documents endorsing or supporting the learning styles myth. Learning style theories can be found in National Standards, State Teaching Standards, and State Teaching Exams.

Wininger et al. (2019) provided various examples of Learning Style Theories in National Standards. The 2016 document from the National Board for Professional Teaching Standards outlining the Five Core Propositions for teaching contains a section on altering classroom environments to fit different learning styles (NBPTS, 2016). In the core teaching standards document prepared by the Council of Chief State School Officers, the authors list differences in preferred learning modalities as an example of individual learning differences (Council of Chief State School Officers [CCSSO], 2013).

Many states include learning style theories in their official Teaching Standards. In the introductory section of the California Standards for the Teaching Profession is a section on creating classrooms that engage and challenge students with varying learning styles and other individual differences (Commission on Teacher Credentialing [CTC], 2009). In Standard 1 of the Ohio Standards for the Teaching Profession teachers are expected to "understand the processes and strategies students use to construct knowledge, and use this understanding to create learning activities appropriate for students' ages, abilities, and learning styles." To qualify as "distinguished" in this area, a teacher must implement strategies to assess individual learning styles. To meet Standard 3 teachers should "plan assessments and differentiate assessment choices to match the full range of student needs, abilities, and learning styles" (Educator Standards Board [ESB], 2005, p. 23).

Knowledge and use of learning style theories also appears in many state teacher certification exams. These tests, required in most states for teacher candidates to become certified, attempt to assess candidate knowledge in both teaching skills and their subject area, and, as it turns out, often assess knowledge on learning styles. In fact, the official study guides for 29 states and the District of Columbia all reference learning styles (Furey, 2020). In the New York State Teacher Certification Examinations preparation guide, for example, the explanation for a question referencing learning styles reads "Awareness of students' learning preferences can help the teacher determine how to provide learning opportunities that allow students to work and learn in their preferred modes and thus enhance learning" (New York State Teacher Certification Examinations [NYSTCE], 2006, p. 43).

The Praxis Test is one of several American teacher certification exams. In the official study companion for the Grade 7–12 certification exam is a list of test specifications, or the topics that the student should know for the test. One of the specifications is that the teacher candidate "identifies a number of variables that affect how students learn and perform." The first factor listed is learning style. Further in the guide teacher candidates are encouraged to give their own examples of the effects of learning styles and to reflect on how different instructional strategies fit with different learning styles (Educational Training Service [ETS], 2018).

The Kansas Performance Teaching Portfolio requires teacher candidates to demonstrate their use of learning style theories in the classroom (English, 2020). In the *Regulations and Standards for Kansas Educators (2017–2018)*, a document used for approving teacher training programs, there are multiple references to learning styles, and how teacher candidates should be using them in their practice. In one section, evaluators should ensure the candidate "selects and implements developmentally appropriate instruction that is sensitive to multiple needs, learning styles, and experience of learners" (p. 80).

Conclusion to Section

Belief in learning styles is rampant. Learning styles theories have infiltrated the education system, influencing all key players, including students, teachers, administrators, researchers, and the general public. This widespread belief begs the question of how. How does a theory, with no scientific merit, become commonly accepted knowledge? How are learning styles and other neuromyths propagated?

References

Bailey, R. P., Madigan, D. J., Cope, E., & Nicholls, A. R. (2018). The prevalence of pseudoscientific ideas and neuromyths among sports coaches. *Frontiers in Psychology, 9*(641), 1–11.

Blanchette Sarrasin, J., Riopel, M., & Masson, S. (2019). Neuromyths and their origin among teachers in Quebec. *Mind, Brain, and Education, 13*(2), 100–109.

Boser, U. (2017). What do people know about excellent teaching and learning? *Center for American Progress*. Retrieved from https://files.eric.ed.gov/fulltext/ED586242.pdf

Commission on Teacher Credentialing [CTC]. (2009). California standards for the teaching profession (CSTP). Retrieved from https://www.ctc.ca.gov/docs/default-source/educator-prep/standards/cstp-2009.pdf. Accessed 12 Apr 2021.

Council of Chief State School Officers [CCSSO]. (2013). InTASC model core teaching standards and learning progressions for teachers 1.0. Resource document. Retrieved from https://ccsso.org/sites/default/files/2017-12/2013_INTASC_Learning_Progressions_for_Teachers.pdf. Accessed 12 Apr 2021.

Dandy, K. L., & Bendersky, K. (2014). Student and faculty beliefs about learning in higher education: Implications for teaching. *International Journal of Teaching and Learning in Higher Education, 26*(3), 358–380.

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*, 429.

Deligiannidi, K., & Howard-Jones, P. A. (2015). The neuroscience literacy of teachers in Greece. *Procedia-Social and Behavioral Sciences, 174*, 3909–3915.

Dündar, S., & Gündüz, N. (2016). Misconceptions regarding the brain: The neuromyths of preservice teachers. *Mind, Brain, and Education, 10*(4), 212–232.

Educational Training Service [ETS]. (2018). Principles of learning and teaching: Grades 7–12. Retrieved from ets.org/s/praxis/pdf/5624.pdf. Accessed 12 Apr 2021.

Educator Standards Board [ESB]. (2005). Ohio Standards for the teaching profession. Resource document. Retrieved from http://education.ohio.gov/getattachment/Topics/Teaching/Educator-Equity/Ohio-s-Educator-Standards/TeachingProfessionStandards.pdf.aspx?lang=en-US. Accessed 12 Apr 2021.

English, A. (2020). Why Kansas can not get over the learning styles myth: A document analysis. *The Advocate, 25*(2), 3.

Ferrero, M., Garaizar, P., & Vadillo, M. A. (2016). Neuromyths in education: Prevalence among Spanish teachers and an exploration of cross-cultural variation. *Frontiers in Human Neuroscience, 10*, 496.

Furey, W. (2020, April 7). *The stubborn myth of "learning styles"*. Education Next. Retrieved from https://www.educationnext.org/stubborn-myth-learning-styles-state-teacher-license-prep-materials-debunked-theory/

Geake, J. (2008). Neuromythologies in education. *Educational Research, 50*(2), 123–133.

Gleichgerrcht, E., Lira Luttges, B., Salvarezza, F., & Campos, A. L. (2015). Educational neuromyths among teachers in Latin America. *Mind, Brain, and Education, 9*(3), 170–178.

Henry, J. (2007). "Professor pans 'learning style' teaching method." *The Telegraph*. 29 July 2007. Retrieved from https://www.telegraph.co.uk/news/uknews/1558822/Professor-pans-learning-style-teaching-method.html#:~:text=In%20effect%2C%20it%20dismisses%20so,kinaesthetic%22%20(Vak)%20teaching.

Hristova, B. (2020, March 27). *HWDSB to provide tablets to families in need amid COVID-19 school closures*. CBC News. Retrieved from https://www.cbc.ca/news/canada/hamilton/hwdsb-to-provide-tablets-to-families-in-need-amid-covid-19-school-closures-1.5512028.

Karakus, O., Howard-Jones, P. A., & Jay, T. (2015). Primary and secondary school teachers' knowledge and misconceptions about the brain in Turkey. *Procedia-Social and Behavioral Sciences, 174*, 1933–1940.

Kim, M., & Sankey, D. (2018). Philosophy, neuroscience and pre-service teachers' beliefs in neuromyths: A call for remedial action. *Educational Philosophy and Theory, 50*(13), 1214–1227.

Lund, T. J., & Stains, M. (2015). The importance of context: An exploration of factors influencing the adoption of student-centered teaching among chemistry, biology, and physics faculty. *International Journal of STEM Education, 2*(1), 1–21.

Macdonald, K., Germine, L., Anderson, A., Christodoulou, J., & McGrath, L. M. (2017). Dispelling the myth: Training in education or neuroscience decreases but does not eliminate beliefs in neuromyths. *Frontiers in Psychology, 8*, 1314.

Meyer, K. A., & Murrell, V. S. (2014). A national study of theories and their importance for faculty development for online teaching. *Online Journal of Distance Learning Administration, 17*(2), 1–15.

Morehead, K., Rhodes, M. G., & DeLozier, S. (2016). Instructor and student knowledge of study strategies. *Memory, 24*(2), 257–271.

Nancekivell, S. E., Shah, P., & Gelman, S. A. (2020). Maybe they're born with it, or maybe it's experience: Toward a deeper understanding of the learning style myth. *Journal of Educational Psychology, 112*(2), 221.

National Board for Professional Teaching Standards. (2016). What teachers should know and be able to do. resource document. Retrieved from http://accomplishedteacher.org/wp-content/uploads/2016/12/NBPTS-What-Teachers-Should-Know-and-Be-Able-to-Do-.pdf. Accessed 12 Apr 2021.

New York State Teacher Certification Examinations [NYSTCE]. (2006). Preparation guide elementary assessment of teaching skills-written. Resource document. Retrieved from https://www.nystce.nesinc.com/content/docs/NY_fld090_prepguide.pdf. Accessed 12 Apr 2021.

Newton, P. M., & Miah, M. (2017). Evidence-based higher education–is the learning styles 'myth'important? *Frontiers in Psychology, 8*, 444.

Organisation for Economic Cooperation, and Development. (2002). *Understanding the brain: Towards a new learning science*. OECD.

Papadatou-Pastou, M., Haliou, E., & Vlachos, F. (2017). Brain knowledge and the prevalence of neuromyths among prospective teachers in Greece. *Frontiers in Psychology, 8*, 804.

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

Pei, X., Howard-Jones, P. A., Zhang, S., Liu, X., & Jin, Y. (2015). Teachers' understanding about the brain in East China. *Procedia-Social and Behavioral Sciences, 174*, 3681–3688.

Rato, J. R., Abreu, A. M., & Castro-Caldas, A. (2013). Neuromyths in education: What is fact and what is fiction for Portuguese teachers? *Educational Research, 55*(4), 441–453.

Riener, C., & Willingham, D. (2010). The myth of learning styles. *Change: The magazine of higher learning, 42*(5), 32–35.

Simmonds, A. (2014). How neuroscience is affecting education: Report of teacher and parent surveys. Wellcome Trust.

Strid, J. E. (2017). The myth of the critical period. *TESOL Journal, 8*(3), 700–715.

Subramony, D. P., Molenda, M., Betrus, A. K., & Thalheimer, W. (2014). The mythical retention chart and the corruption of Dale's cone of experience. *Educational Technology*, 6–16.

Tardif, E., Doudin, P. A., & Meylan, N. (2015). Neuromyths among teachers and student teachers. *Mind, Brain, and Education, 9*(1), 50–59.

The Onion. (2000). Parents of nasal learners demand odor-based curriculum. Retrieved from https://www.theonion.com/parents-of-nasal-learners-demand-odor-based-curriculum-1819565536. Accessed 12 Apr 2021.

UMass Dartmouth Center for Access and Success. (n.d.). *How to accommodate different learning styles*. UMass Dartmouth. Retrieved from https://www.umassd.edu/dss/resources/faculty%2D%2Dstaff/how-to-teach-and-accommodate/how-to-accommodate-different-learning-styles/

Van Blerkom, D. (2009). *College study skills* (6th ed.). Wadsworth Cengage.

Weisberg, D. S., Keil, F. C., Goodstein, J., Rawson, E., & Gray, J. R. (2008). The seductive allure of neuroscience explanations. *Journal of Cognitive Neuroscience, 20*(3), 470–477.

Wininger, S. R., Redifer, J. L., Norman, A. D., & Ryle, M. K. (2019). Prevalence of learning styles in educational psychology and introduction to education textbooks: A content analysis. *Psychology Learning & Teaching, 18*(3), 221–243.

Chapter 4
Mechanisms of Propagation and Factors Contributing to Beliefs in Neuromyths

Henrietta Den Dekker and Joseph A. Kim

Mechanisms of Propagation

Consider newly certified teacher Cheyanne. When Cheyanne was in middle school, her teacher placed her in a group of *visual* learners. In high school, Cheyanne's teacher had all the students complete an online learning styles inventory. After high school, Cheyanne completed her teacher training program at a well-respected American college. In her first-year general education course, she learned that teachers should build inclusive classrooms by accommodating different learning styles. During her teaching placement, she designed hands-on activities for her kinaesthetic students, posters and pictures for her visual students, and various oral lessons for her auditory students to include in her mandatory final teaching portfolio. After completing the program, she takes the teaching certification exam and notes several questions on learning styles. Teacher Cheyanne is fully convinced of the merits of learning styles. She is excited to help her students find their preferred learning styles.

Cheyanne's story highlights the complex web of neuromyth transmission. Cheyanne heard about learning styles from a variety of sources because the learning styles theory has, in some sense become "common knowledge" (Riener & Willingham, 2010). The information presented in peer-reviewed literature is dispersed to teachers, teacher's colleges, the media, and regulatory bodies, but often misinterpreted in the process. Neuromyths are transmitted to teacher trainees and teachers via teacher's colleges, state teaching exams, and administration. Finally, teachers themselves further transmit neuromyths to other teachers and students.

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Transmission Via Peer-Reviewed Journals

Academic journals represent a source of new information. Kirschner (2017) describes it as such: "We are progenitors and gatekeepers of new knowledge. What we study and/or publish can and should make an impact on both the scientific world in which we travel and the world of education which we serve" (p. 170). Unfortunately, peer-reviewed research journals contribute to the spread of neuromyths by publishing articles where learning style theories provide the theoretical foundation or where the authors make concluding statements that cannot be justified by the research they completed. Newton (2015) paints a picture of what an academic searching for "learning styles" might find within peer-reviewed literature. He searched the ERIC and PubMed research databases for papers between July 23, 2013 and July 23, 2015 that referenced learning styles. Of the 109 papers, 94% began with a positive view of learning styles and 89% maintained a positive view of learning styles, either directly or indirectly endorsing their use.

Many of these published studies do not experimentally test the validity of learning styles (Pashler et al., 2008). An experiment must meet several criteria to be considered valid evidence for learning styles, including division of groups based on learning preferences, an identical final test for all participants, and a particular interaction effect in the results where instruction that matches a person's learning styles is shown to be better than instruction that does not match (Pashler et al., 2008).

Consider one peer-reviewed paper published late 2019. The first line of the abstract reads, "Individuals learn in different ways using several learning styles, but lecturers may not always share material and learning experiences that match students' learning preferences" (Chetty et al., 2019, p. 610). The last line of the abstract reads, "from this study we can conclude that teaching styles have significant impacts on students' learning styles and academic performances." The experimental design involved identifying students' preferred learning style and lecturers' teaching style and evaluating how many students failed the final exam. The experiment does not match the criteria proposed by Pashler et al. (2008). Yet, to any well-intentioned teacher, journalist, or education marketer, this could be viewed as valid support for learning styles.

In an article in the *International Journal of Technology and Design Education,* Emami et al. (2019) reported on a new course they developed for an undergraduate engineering program. After developing the course, the authors investigated how students with different characteristics, including learning styles, performed on different types of assessments within the course. They found that "students whose preferred learning styles align with the assessment themes showed better performance in the course" (p. 1). As with many other publications on learning styles, the research was correlational. While the authors did not intend to provide evidence for learning styles, the use of learning styles theory as a foundational point in the paper appears to lend support and contribute to further propagation.

Sometimes the push for learning styles is more subtle. In one peer-reviewed paper discussing a new activity to use in communication courses, the author explained how the activity is designed, among other things, "to leverage different

learning styles" (Riforgiate, 2019). Even though the paper is not specifically founded on learning styles theory, the message to teachers and other interested parties is that the learning styles theory is valid and worth mentioning.

Kirschner (2017) sends a message to all researchers. "I feel it necessary—and even our duty—as researchers and/or journal editors and reviewers not to propagate such myths. We must guard our credibility as researchers, as (the mouthpiece of) scientific communities and work to the benefit of those that we serve, namely the scientific community and the population at large, specifically educators and learners."

To avoid unfairly denouncing all learning styles research, it is important to make some key distinctions. Publishing research on learning styles is not a concern in and of itself. As referred to earlier, Pashler et al. (2008) provide excellent descriptions of what types of evidence are required to provide support for learning styles. The concern lies with the studies that do not specifically test learning style theories but still make broad claims in support of learning styles and with the studies that use learning style theories as the basis of their work, as if it were reliable knowledge. The evidence for learning styles is entirely insufficient to warrant using learning style theories as the theoretical framework for a study.

Analysis of recent publications reveals that the research on learning styles tends to appear in medical education, engineering education, and educational technology journals (Cuevas, 2015). Many of the authors are not specifically trained in psychology or education research but have designed such studies with connections to their fields. Much of the current research on learning styles originates from Turkey and Iran and appears more frequently in predatory journals that charge authors a fee to publish (Cuevas, 2015). A substantial portion of the research on learning styles is correlational, as evident in the examples above (Cuevas, 2015). Although correlational research has its merits, it does not provide sufficient evidence to justify spending limited time and resources testing and matching learning styles to instructional styles. Interestingly, there is almost no research on learning styles in reputable psychology journals or high-level education journals (Cuevas, 2015).

It should be a concern that peer-reviewed journals are propagating beliefs in learning styles. It is possible that the authors, publishing outside of their area of expertise, are entirely unaware of the lack of evidence for learning styles. Nonetheless, by publishing research with faulty foundations they are contributing to the spread of misinformation when they should be maintaining academic and scientific credibility. If neuromyths continue to propagate among trained scientists and within peer-reviewed journals the growing popularity among non-scientists should come as no surprise.

Media and Non-experts

In cases where published research findings are sound, they are often misconstrued and misinterpreted during dissemination by the media or non-experts. While the myths typically contain some scientific basis, the conclusion is exaggerated,

simplified, or applied to human subjects even though the research was completed on animal subjects (OECD, 2002). Although the distortion could be intentional, it more commonly stems from a well-intentioned desire and belief that the theory will "revolutionize science and society" (Beyerstein, 1999).

There are countless examples of publications published by non-experts or published without peer-review. A 2008 search of the ERIC database for "learning styles" revealed 1984 journal articles, 919 conference presentations, and 701 books or book chapters on learning styles (Lilienfeld et al., 2010). Coffield et al. (2004) compiled a database of work, both published and unpublished, that referenced learning styles. Much of this work was not published in peer-reviewed journals, indicating that teachers and instructors have resources available to them that have not been reviewed by experts in the field.

The misconstrued research is disseminated via news articles, publications, conferences, workshops, and educational materials (Busso & Pollack, 2015; Ferrero et al., 2016; Goswami, 2006). These resources have a far reach; survey findings show that teachers seek and obtain information from the media (Rato et al., 2013). While the media coverage and resource dissemination itself is not harmful, the misinformation associated with these resources often is harmful. For example, a survey of educators revealed that 26% heard about learning styles through educational media (Simmonds, 2014). Without any sources counteracting this misinformation, these teachers will likely implement harmful teaching practices. The misinformation then continues to spread to other teachers, students, parents, and broader society.

Imagine a teacher or parent who has recently heard the term "learning styles" and decides to do a quick web search. He will likely encounter website like teach.com and open the homepage to read statements like, "the notion of individualized learning styles has gained widespread recognition in education theory and classroom management strategy." He might read a little further and then discover that "many degree programs, specifically higher level ones like a doctorate of education, integrate different learning styles and educational obstacles directly into program curriculum." He finds a link to a website (https://www.learning-styles-online.com/) where he can complete a free learning styles inventory and have his students do it too.

Another teacher, interested in all things education, reads through the Education Dive blog. She finds an article, published in 2020, discussing how student learning styles impact the effectiveness of online learning (De La Rosa, 2020). The blog post references a paper from the University of Illinois Springfield and "a study by three university authors," which makes the argument even more compelling.

Further searching for a learning styles workshop reveals a resource for a free 50-min activity for teachers to complete with their students (Janecka, 2021). The goal of the workshop is to have students realize "their own individual learning preferences play a large part in their learning experiences" and then to help students identify "their individual preference for visual, auditory, or kinaesthetic learning." The resource is well written and contains easy step-by-step instructions, including discussion questions and suggested timelines for each step. The author provides positive anecdotes and "success stories." For example, one student discovered their preference for *kinaesthetic* learning and memorized literary terms walking from room to room. The

stories are compelling but entirely contradictory to the scientific process. Nonetheless, to a teacher with limited time and resources, this is a quick, free, easy-to-use resource, that, by all accounts, will make a great difference in their students' lives.

Teachers gravitate towards these materials because they are often free or low cost, while peer-reviewed research typically hides behind a paywall. Bozarth (2018) provides an illustration, "Consider, for example, a teacher in spring 2018, confronted with a pile of promotional materials countered only by the lone research piece by Husmann and O'Loughlin—available for a download fee charged by the publisher" (p. 20). Furthermore, these news articles and magazines are written in compelling, easy-to-read language compared to the peer-reviewed literature which is typically written in more technical language. In addition, educators often lack the technical training to decipher between fact and fiction (Busso & Pollack, 2015).

Now picture a parent or student, browsing through the news. They stumble across an article on e-learning in Covid-19 times. The article describes how e-learning makes it more difficult to address different learning styles (Sandle, 2020). Another article on e-learning reads, "It is a well-known fact that students have a dominant learning style" (Pinto, 2020). A search for the phrase "learning styles" in Google News reveals countless news articles mentioning learning styles, many of which were published within the past month. Each article references learning styles to varying degrees, but most portray learning styles positively. Some of the articles originate from reputable institutions. For example, the University of Buckingham released an article on June 4, 2019 about a new distant learning platform. The platform improves learning results for everyone, "whether the students are visual, logical, physical, or verbal learners" (University of Buckingham, 2019).

Parent surveys reveal that parents search for ways to improve their children's learning and often find resources online or through the media (Simmonds, 2014). Unfortunately, many of the resources directed towards parents contain misleading information about learning styles. The Scholastic Parents site published an article explaining how parents can understand their child's learning style. The authors recommend that parents teach their kinaesthetic child through movement games such as hopscotch and their musical child with beats and songs (Scholastic Parents, 2021). While the suggestions are creative and entertaining, there is no evidence that these approaches lead to better learning than other approaches.

Misconstrued research in news articles, publications, conferences, workshops, and other education materials is typically easy to access, compelling, and often free or low cost. It is perhaps not surprising that well-intentioned parents and teachers buy into various myths, despite the lack of valid scientific support.

Commercial Propagation

While some neuromyths are spread unintentionally, there are many instances where neuromyths are spread for commercial gain. The market for educational resources is significant, with schoolboards constituting a large portion of the consumer base.

In the United States alone, the 2017 education market was valued at approximately USD 1350 billion (Zion Market Research, 2018). Schools and universities spend millions of dollars each year on resources and testing related to learning styles (Cuevas, 2015). Outside of education, people are also interested in brain-based products, spending an estimated $1.9 billion on brain health and training apps in 2018 alone (Lam, 2019). Despite the market opportunity, much of the neuroscientific research completed in recent years cannot be generalized from the lab to the classroom, due to differences in level of analysis (Coch, 2018). The lack of relevant research causes education marketers, who lack neuroscientific training, to apply distantly related neuroscience to their products (Goswami, 2006; Lindell & Kidd, 2011). This results in a huge collection of resources available for purchase that are based on neuromyths.

Commercialized components include services (e.g., brain-training, learning style assessments), workshops and conferences, or materials such as books and teaching guides. In a survey of educators, 38% reported hearing about learning styles through an external training provider (Simmonds, 2014). In an open-ended discussion thread between parents about activities that improve learning 23% reported using commercial packages to help their child's learning (Simmonds, 2014). In one survey of parents, 27% reported using commercial products to boost academic performance in their children (Simmonds, 2014).

There are many different types of "brain-based" or "research-based" products available commercially. For example, the popular Brain Gym program has a website where educators can purchase books, posters, CDs and DVDs, and teaching aids (https://www.braingym.com/shop/). A quick Amazon search on Learning Styles reveals countless books available for purchase. The books have compelling subtitles such as "making a difference for diverse learners" or "here's the key to every child's learning success." Educators can also purchase numerous tests and inventories for their students to complete. Organizations such as the Academy of Learning Career College advertise that their "course materials and instructions provide an all-encompassing learning experience using multi-sensory learning styles and preferences" (https://www.academyoflearning.ab.ca/learning-styles/).

Learning style theories are also popular at conferences (Cuevas, 2015). Often, conferences include vendors who are selling various educational programs, some of which are based on neuromyths. Jane Bozarth (2018) published a quote from Clark Quinn, an outspoken critic of myths within education, that captures the issue with commercial interest in education. The story goes as follows: "Quinn shared this feedback from one participant" (who was also a vendor paying to exhibit at the event) who evaluated his session: "Not cool to debunk some tools that exhibitors pay a lot of money to sell at [conference name] only to hear from a presenter at the conference that in his opinion should be debunked. Why would I want to be an exhibitor at a conference that debunks my products?" (p. 20). The commercial potential of brain-based educational resources can discourage individuals from revealing the neuromyths behind the resources.

Workshops on learning styles attract hundreds of educators, who often pay hundreds of dollars to attend (Stahl, 1999). For example, The Institute for Learning

Styles Research offers a program for individuals to become a "certified multi-modal paired associates learning test practitioner" all for a cost of $1895 US (https://www.learningstyles.org/events/index.html). The VDC, a development center for people working with the vocational and education sector, offered a 3-h virtual workshop in July 2020 titled "Learning Styles in the VET Classroom" for $110 (VET Development Centre, 2020). What a bargain!

Unfortunately, the commercialization of education programs seems to correlate with increased belief in that program, whether accurate or not. Compared to other neuromyths, teachers are more likely to believe neuromyths related to commercialized educational programs (Dekker et al., 2012). For the typical teacher under time constraints and without sufficient background knowledge, the easiest route is to follow the marketing (Cuevas, 2015). Some also argue that the commercial benefits of evaluation instruments in education are so large that skepticism and critique is typically unwelcome (Bishka, 2010). Regardless of the specific mechanisms, commercialization plays a strong role in propagating learning styles and other neuromyths.

Academic Centers and University Libraries

Unfortunately, many neuromyths are also propagated by those people would typically trust on the subject matter such as university academic centers, libraries, and study skills websites. In a survey with 77 heads of academic support centers at varying higher education institutions, 9% listed learning styles as one of the top three strategies most frequently recommended to students (McCabe, 2018). Although this relatively low figure might not seem to be too large a concern, the 9% represents responses to a free-response question and some respondents might not have thought to mention learning styles. Furthermore, other respondents may have advocated for learning styles, just not as one of the top three strategies. Consider that some responses were quite broad, and the top response was "read course material," which some may argue is not a learning strategy but a requirement for learning in any course. Several examples below help illustrate this point. The University of Massachusetts Dartmouth Centre for Access and Success resource page lists tips for educators on accommodating different learning styles (UMass Dartmouth Center for Access and Success, 2021). The University of Illinois Springfield provides an online tutorial for incorporating learning styles into online learning. NC State University provides students with a free learning style assessment on their website. The examples listed above are but a few demonstrations of how the learning styles myth is propagated to both students and faculty via university academic center resource sites.

Dr. Paul Penn, author of *The Psychology of Effective Studying,* tweeted a series of examples of universities with a gold rating in the Teaching Excellence Framework who were actively promoting learning styles in their student support resources (Penn, 2020). The Teaching Excellence Framework is a UK initiative that rates the

quality of undergraduate teaching and a gold rating indicates outstanding performance. For example, the Staffordshire University Library and Learning Services website contains a page on learning styles. Following an explanation of different learning styles students are encouraged to discover their own learning style (Staffordshire University Library and Learning Services, 2020). Students can also access a "fact sheet" to learn more about learning styles. The University of Portsmouth website also includes a page on learning preferences. Students can take a quiz to discover their learning preference by choosing between scenarios, such as "I can discuss things with my classmates" or "I can do something practical or move around" (University of Portsmouth, 2021). Aberystwyth University contains a page on learning styles for their students as well. A student could read about the kinaesthetic learners who might learn better "fiddling with a pen, doodling or swinging on a chair" and then learn more by clicking on the various links provided underneath (AberSkills Team, 2021). As Dr. Penn points out, the examples listed above are only publicly available publications and do not include all the misinformation spread in informal contexts.

In addition to providing learning style resources on their websites, university student success centers also host in-person learning style workshops for their students. In their list of past workshops, Loyola University Chicago provides explanations of various learning style theories, tips for studying with a particular learning style, and a list of further resources (Loyola Libraries, 2021). Wilfred Laurier University has a series of slides available from a previous workshop on learning styles. The workshop provided techniques for students to optimize their learning styles, among other study tips (Wilfred Laurier University Study Skills & Supplemental Instruction Centre, 2021).

Teacher's Colleges

Even teacher's colleges endorse learning style theories in their coursework. In surveys analyzing teacher beliefs in neuromyths, over half of respondents reported receiving their brain-based or learning style ideas in their university training (Lethaby & Harries, 2016; Blanchette Sarrasin et al., 2019). Now, this is subjective as teachers may not be entirely accurate in their recollections of where they heard a specific idea. However, in an objective analysis of coursework from 48 teacher preparation programs in the United States, researchers found that 67% of programs teach student teachers to implement learning styles in their classrooms (Pomerance et al., 2016).

A search of the Ontario College of Teachers (OCT) Additional Qualification course guideline sheets revealed that several of the course guides still referred to learning styles and implementation in the classroom. Advancement Courses, a US company specializing in professional development, offer hundreds of courses for teacher recertification and advancement. In the syllabus for a course titled *Tech Tools for the Math Classroom* (advertised as a popular course), the description reads

"you'll examine important issues such as learning styles" (https://www.advance-mentcourses.com/courses/tech-tools-for-the-math-classroom/). The Advancement Courses website also contains a blog post explaining the four types of learners. The teacher or teacher trainee reading the post will discover that "learning styles are widely recognized in both classroom management theory and education theory in general" (Advancement Courses, 2017). Unfortunately, there is no source for the reader to verify the information. They will read through an explanation of the VARK model and, find a link to a featured course, *Differentiated Instruction.* According to the course description, the course is designed to teach educators that students have different learning styles, how educators can identify those learning styles, and, by the end, know how to teach every student with their unique learning style (https://www.advancementcourses.com/courses/differentiated-instruction/). Universal Class, an online continuing education portal, accredited by the International Association for Continuing Education and Training (IACET) offers a $75.00 7-h course on learning styles (https://www.universalclass.com/i/course/learning-styles.htm).

Teacher training programs are an important link in the transfer of information. Cuevas (2015) explains it like this, "what tens of thousands of pre-service teachers learn in certification program and subsequently take with them into the classroom can potentially impact the instruction of millions of k-12 students over the decades they teach."

Psychology and Education Textbooks

Learning style theories are endorsed within textbooks, including both study skill textbooks for the average student and psychology and education textbooks for teacher candidates. Dembo and Howard (2007) list several excerpts from study skills textbooks encouraging students to discover their learning style and use that information in their study. As just one example, the textbook titled *College Study Skills: Becoming a Strategic Learner (sixth edition)* contains an entire section on learning styles. The section begins with these words to students, "your learning style also affects your ability to succeed in college" (Van Blerkom, 2009, p. 9). The text contains a sample learning style inventory for students to complete and study techniques for different types of learners. The author lists a brief word of caution that the surveys included in the book have not been scientifically tested, but then proceeds with significantly longer section on "why your learning style is important" (p. 16).

Analysis of commonly used education textbooks also reveals endorsement of learning style theories. In one peer-reviewed textbook for clinical teachers in health professionals, the authors recommend allowing students to take a learning styles inventory, ideally at the beginning of the course, and then acting on those learning styles throughout the course. While we provide this one example to illustrate our point, similar sentiments appear in many education textbooks. In an analysis of 20

introduction to education and educational psychology texts, 80% of the texts included references to learning styles. Half of the texts referred to learning styles as a learner preference and half referred to learning styles as a way that an individual processes new information. Most of the references were positive (Wininger et al., 2019). A separate analysis of 48 education educational psychology, general methods, and secondary subject-specific methods courses revealed that 59% endorsed incorporation of learning styles into instruction (Pomerance et al., 2016). Another survey of general teacher education textbooks revealed that most texts included sections on learning styles and were heavily focused on practical applications of learning style theories (Cuevas, 2015). Most of the texts did not contain references to peer-reviewed literature (Cuevas, 2015). When reporting on the source of their belief in learning styles 28% of teachers report books and textbooks as their source (Blanchette Sarrasin et al., 2019). Clearly textbooks play a large role in propagating neuromyths.

Administration to Teachers

Learning styles and other education neuromyths are also transferred from administrative to lower levels. When asked about learning styles, only 46% of instructional designers and 35% of administrators correctly labelled the statement as a myth (Betts et al., 2019). Those beliefs then transfer to the teachers and other individuals who work with the students. Surveys on faculty development for online teaching reveals that 72% of institutions used learning style theories in their development of faculty materials. This transmission is supported by educator reports of hearing of learning styles through their institution (Simmonds, 2014).

Teachers to Students

Teachers transmit ideas to their students both directly and indirectly. Consider Elise, who completed learning style inventories in multiple courses. The fact that the teacher took time to integrate it into the course leaves Elise with the impression that learning styles are important for learning. In most of the correlational research appearing in journals, the researchers report giving the VARK questionnaires to their students. For example, the instructor in one undergraduate engineering design course had all the students complete MBTI and VARK questionnaires at the beginning of the term since 2011 (Emami et al., 2019). Even without endorsing something directly, implementing it in the lesson communicates to the students that the idea has merit. This is also true when teachers, even without administrating a questionnaire, uses learning style practices in their classroom. This appears to be a prevalent practice. Reports of teachers show that 65% of teachers regularly use learning style practices and 33% of teachers sometimes using learning style practices

(Blanchette Sarrasin et al., 2019). Considering that very few students from a typical high school class will continue on to become education researchers, those neuromyths will likely remain with those students for life.

In one survey of undergraduate pre-service teachers, 48% reported that their belief in learning styles came from their school teachers (Kim & Sankey, 2018). In a written component of the survey, respondents reported incidences where their teachers assigned learning style quizzes and introduced study techniques for different learning styles (Kim & Sankey, 2018).

Conclusion

The web of transmission is complex, with misinformation being propagated back and forth between countless individuals, organizations, and institutions. The rapid and pervasive transmission highlights the eagerness of individuals to transmit information without adequate knowledge of scientific fact, a trend that has become abundantly clear during the Covid-19 pandemic. Neuromyths are prevalent and the web of transmission is complex. The remaining question is why individuals so readily believe neuromyths despite extensive rebuttal from the scientific community.

Factors Contributing to Beliefs in Neuromyths

Enthusiasm for Neuroscience Combined with Lack of Neuroscientific Knowledge

The decade from 1990–1999 has been termed "The Decade of the Brain" because of the great enthusiasm for neuroscience research. In conjunction with the broader enthusiasm for neuroscience is a more specific excitement towards the applications of neuroscience in education, termed "neuroeducation" (Ansari et al., 2012). This enthusiasm becomes evident when we consider the various initiatives, including programs and journals, dedicated to the field of Mind, Brain, and Education (Ansari et al., 2012).

The enthusiasm towards neuroeducation also holds true among educators. In a survey of 929 instructors, instructional designers, and administrators, 89% reported finding knowledge on the brain and learning interesting. The respondents also found that scientific knowledge valuable for teaching, course development, and professional development (Betts et al., 2019). Many teachers report reading popular science magazines or reading neuroscience research with goals of implementing that research in their classrooms.

While enthusiasm for neuroscience in education is positive in and of itself, most teachers lack sufficient neuroscientific knowledge to interpret and understand the

research. Most teacher training programs do not include neuroscience and the graduating teachers therefore cannot critically evaluate educational programs that claim to have a neuroscientific basis (Howard-Jones, 2014). Some researchers recommend training educators in neuroscience and research methods to overcome this issue (Devonshire & Dommett, 2010).

Inaccessible Peer-Reviewed Research

Connected with teacher's lack of neuroscientific knowledge is an inaccessibility to peer-reviewed literature. Those with access to peer-reviewed literature endorse fewer neuromyths than those without access (Macdonald et al., 2017). In one survey, respondents who read journals related to neuroscience, Mind, Brain, and Education (MBE) science, and psychology had a greater awareness of neuromyths and general information about the brain than those who did not read journals related to neuroscience, MBE science, and psychology (Betts et al., 2019). The inaccessibility to peer-reviewed literature often "protects the myth from scrutiny" (Howard-Jones, 2014) because educators and other non-specialists cannot critique the information being presented to them (Howard-Jones, 2014).

Barriers Between Researchers and Practitioners

Various barriers between researchers and educators also contribute to the formation and propagation of neuromyths. While neuroscientists have in-depth knowledge of the brain, they often lack knowledge of educational research methods or current pedagogical approaches in schools. Conversely, educational researchers lack knowledge of the brain and neuroscience research practices. This lack of understanding causes miscommunications which can lead to widespread neuromyths such as learning styles (Ansari et al., 2012).

Devonshire and Dommett (2010) discussed various barriers to neuroeducation. One issue is that education and neuroscience research is very different in theories, goals, and methodologies. Much of the neuroscience research to date has very little practical applications for education. To create and evaluate applications of neuroscience to education, there needs to be a middle field, a collaboration between researchers and educators where both approaches are considered.

Another barrier is the use of different terminology between researchers and educators. These vocabulary differences make direct communication difficult (Devonshire & Dommett, 2010) and can lead to errors in translation of ideas (Howard-Jones, 2014). In addition, many of the same words have different connotations or definitions in the different fields (Howard-Jones, 2014). This problem worsens if teacher trainees receive none or very little neuroscience training in their programs.

Cognitive and Emotional Biases

In addition to lack of knowledge and practical barriers, the human brain is subject to cognitive biases that can serve to distort the truth. There are several cognitive biases that contribute to the formation and propagation of neuromyths.

Confirmation Bias

One factor contributing to the prevalence of neuromyths is the confirmation bias. The confirmation bias refers to a tendency to seek out information that supports a prior theory or belief. Imagine a teacher who designs their lessons to match different learning styles. They will likely only pay attention to success for the matched learning styles. The examples of the few students who did improve are far more salient than the majority of students who showed no improvement. Self-fulfilling prophecy might also play a role, where teacher expectations influence student performance. Pasquinelli (2012) describes this as selective perception and memory. This bias likely accounts for a large percentage of the 62% of teachers who said they found evidence for learning styles in their practice (Blanchette Sarrasin et al., 2019).

Bias Towards Scientific Explanations

It turns out humans are particularly prone to neuroscience myths. References to neuroscientific content increases belief in a product, even if the neuroscience is logically irrelevant (Weisberg et al., 2008). In a study involving a hypothetical education program, participants who viewed an advertisement with a brain image rated the program more positively than participants who viewed the advertisement without a brain image (Lindell & Kidd, 2013). Unfortunately, many current "brain-based" educational programs have little or no empirical support (Tardif et al., 2015). Whether this bias is towards neuroscientific content specifically or towards scientific content more generally remains in debate (Busso & Pollack, 2015), but either way, this bias contributes to the spread of education-related neuromyths.

Furthermore, educators are often positive towards brain-based products (Ritchie et al., 2012). Education marketers certainly take advantage of this bias towards scientific products. Take, for example, this excerpt from https://www.learning-styles-online.com/. "Research shows us that each learning style uses different parts of the brain. By involving more of the brain during learning, we remember more of what we learn. Researchers using brain-imaging technologies have been able to find out the key areas of the brain responsible for each learning style." Note the references to "research," "brain," and "brain-imaging technologies." There are no sources for the reader to link to and verify the information, but it sounds "science-y."

Egalitarianism

Learning style theories appeal to people because of the underlying assumption that all children can succeed, if only taught in their preferred learning style (Pashler et al., 2008; Bozarth, 2018). Pashler et al. (2008) refer to the concern parents have about their children being taught as unique individuals. There is some speculation the appeal of learning styles may correlate with the influential self-esteem movement that began in the 1970s (Twenge, 2006; Pashler et al., 2008).

If learners perform badly, they can transfer responsibility to either the teacher who did not teach in the student's preferred learning style or to the test itself, which was not presented in the student's preferred modality (Pashler et al., 2008). Again, the satirical story published in The Onion captures the sentiment in an exaggerated and humorous manner. The story included a mock interview with a parent of a nasal learner who was struggling in school. "My child is not stupid," Weber said. "There simply was no way for him to thrive in a school that only caters to traditional students who absorb educational concepts by hearing, reading, seeing, discussing, drawing, building, or acting out" (The Onion, 2000). Another parent in the article realized his daughter's failures were caused by mismatched learning styles, "Now I realize that all those Ds and Fs did not represent any failure on my daughter's part, but rather her school's failure to provide an appropriate nasal-based curriculum" (The Onion, 2000). In one article on a parent blog site, the author provides an example of a student who was described as a "slow learner" and "lazy" for years. After recording his multiplication facts into a song and memorizing the song he now knows every multiplication fact without error (Chuni, 2021). Learning styles provide a way for individuals to feel good about themselves and it only makes sense to believe in and transmit information about something that provides a good feeling.

Categorization

Finally, learning style inventories categorize learners into different types. Discovering and identifying with one's type provides "eternal and deep appeal" (Pashler et al., 2008). This appeal holds because categories help "order the social environment and offer quick ways of understanding each other" (Chick, 2016).

Conclusion

The belief in learning styles and other neuromyths begins to make more sense when considering some of the factors contributing to beliefs in neuromyths. More importantly, understanding why neuromyths are so appealing can provide ammunition for battle. For example, knowing that research paywalls contribute to the spread of

neuromyths might provide an incentive to remove some of those paywalls. Understanding the barriers between researchers and educators can spark the building of a bridge. Together the education community can make room for evidence-based practice in classrooms across the globe.

References

AberSkills Team. (2021) Learning strategies. Retrieved from https://www.aber.ac.uk/en/aberskills/learning/#learning-styles-and-learning-strategies. Accessed 13 Apr 2021.

Advancement Courses. (2017). 4 Types of Learners in Education. Retrieved from https://blog.advancementcourses.com/articles/4-types-of-learners-in-education/. Accessed 22 May 2021.

Ansari, D., De Smedt, B., & Grabner, R. H. (2012). Neuroeducation–a critical overview of an emerging field. *Neuroethics, 5*(2), 105–117.

Betts, K., Miller, M., Tokuhama-Espinosa, T., Shewokis, P. A., Anderson, A., Borja, C., Galoyan, T., Delaney, B., Eigenauer, J. D., & Dekker, S. (2019). International report: Neuromyths and evidence-based practices in higher education. *Online Learning Consortium.*

Beyerstein, B. (1999). Pseudoscience and the brain: Tuners and tonics for aspiring Superhumans. In S. Della Sala (Ed.), *Mind myths: Exploring everyday mysteries of the mind and brain* (pp. 59–82). John Wiley and Sons.

Bishka, A. (2010). Learning styles fray: Brilliant or batty? *Performance Improvement, 49*(10), 9–13.

Blanchette Sarrasin, J., Riopel, M., & Masson, S. (2019). Neuromyths and their origin among teachers in Quebec. *Mind, Brain, and Education, 13*(2), 100–109.

Bozarth, J. (2018). *The truth about teaching to learning styles, and what to do instead*. The Learning Guild.

Busso, D. S., & Pollack, C. (2015). No brain left behind: Consequences of neuroscience discourse for education. *Learning, Media and Technology, 40*(2), 168–186.

Chetty, N. D. S., Handayani, L., Sahabudin, N. A., Ali, Z., Hamzah, N., Rahman, N. S. A., & Kasim, S. (2019). Learning styles and teaching styles determine students' academic performances. *International Journal of Evaluation and Research in Education, 8*(4), 610–615.

Chick, N. (2016). *Learning styles*. Vanderbilt Center for Teaching.

Chuni, S. (2021). Children and learning styles: All you need to know. ParentCircle. Retrieved from https://www.parentcircle.com/article/children-and-learning-styles-all-you-need-to-know/

Coch, D. (2018). Reflections on neuroscience in teacher education. *Peabody Journal of Education, 93*(3), 309–319.

Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004). *Learning styles and pedagogy in post-16 learning: A systematic and critical review*. Learning and Skills Research Centre.

Cuevas, J. (2015). Is learning styles-based instruction effective? A comprehensive analysis of recent research on learning styles. *Theory and Research in Education, 13*(3), 308–333.

De La Rosa, S. (2020). Educators can adjust online classes to fit learning styles. Retrieved from https://www.k12dive.com/news/educators-can-adjust-online-classes-to-fit-learning-styles/576054/. Accessed 12 Apr 2021.

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*, 429.

Dembo, M. H., & Howard, K. (2007). Advice about the use of learning styles: A major myth in education. *Journal of college reading and learning, 37*(2), 101–109.

Devonshire, I. M., & Dommett, E. J. (2010). Neuroscience: Viable applications in education? *The Neuroscientist, 16*(4), 349–356.

Emami, M. R., Bazzocchi, M. C., & Hakima, H. (2019). Engineering design pedagogy: A performance analysis. *International Journal of Technology and Design Education*, 1–33.

Ferrero, M., Garaizar, P., & Vadillo, M. A. (2016). Neuromyths in education: Prevalence among Spanish teachers and an exploration of cross-cultural variation. *Frontiers in Human Neuroscience, 10*, 496.

Goswami, U. (2006). Neuroscience and education: From research to practice? *Nature Reviews Neuroscience, 7*(5), 406–413.

Howard-Jones, P. A. (2014). Neuroscience and education: Myths and messages. *Nature Reviews Neuroscience, 15*(12), 817–824.

Janecka, G. (2021). Learning styles. Retrieved from https://oncourseworkshop.com/life-long-learning/learning-styles/. Accessed 12 Apr 2021.

Kim, M., & Sankey, D. (2018). Philosophy, neuroscience and pre-service teachers' beliefs in neuromyths: A call for remedial action. *Educational Philosophy and Theory, 50*(13), 1214–1227.

Kirschner, P. A. (2017). Stop propagating the learning styles myth. *Computers & Education, 106*, 166–171.

Lam, K. (2019). People spent $1.9B on brain training apps in 2018, data shows. Retrieved from https://www.foxbusiness.com/technology/1-9-billion-brain-training-apps-2018-data. Accessed 13 Apr 2021.

Lethaby, C., & Harries, P. (2016). Learning styles and teacher training: Are we perpetuating neuromyths? *ELT Journal, 70*(1), 16–27.

Lilienfeld, S. O., Lynn, S. J., Ruscio, J., & Beyerstein, B. L. (2010). Busting big myths in popular psychology. *Scientific American Mind, 21*(1), 42–49.

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*(3), 121–127.

Lindell, A. K., & Kidd, E. (2013). Consumers favor "right brain" training: the dangerous lure of neuromarketing. *Mind, Brain, and Education, 7*(1), 35–39.

Loyola Libraries. (2021). Library workshops: Learning styles and developing good work habits for first-year students. Retrieved from https://libguides.luc.edu/workshops/workhabits. Accessed 13 Apr 2021.

Macdonald, K., Germine, L., Anderson, A., Christodoulou, J., & McGrath, L. M. (2017). Dispelling the myth: Training in education or neuroscience decreases but does not eliminate beliefs in neuromyths. *Frontiers in Psychology, 8*, 1314.

McCabe, J. A. (2018). What learning strategies do academic support centers recommend to undergraduates? *Journal of Applied Research in Memory and Cognition, 7*(1), 143–153.

Newton, P. M. (2015). The learning styles myth is thriving in higher education. *Frontiers in Psychology, 6*, 1908.

Organisation for Economic Cooperation, and Development. (2002). *Understanding the brain: Towards a new learning science*. 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*(2), 89–96.

Penn, P. [@Dr_Paul_Penn]. (2020). 1. Attention Edu-Twitter. If you're wondering why the myth of learning styles is so persistent, the answer is really very simple. [Tweet]. Twitter. Retrieved from https://twitter.com/Dr_Paul_Penn/status/1283387585902120961?s=20

Pinto. (2020). E-learning: The advantages and challenges. Retrieved from https://www.entrepreneur.com/article/351860. Accessed 12 Apr 2021

Pomerance, L., Greenberg, J., & Walsh, K. (2016). Learning about learning: What every new teacher needs to know. National Council on Teacher Quality. Retrieved May 4, 2020, from https://www.nctq.org/dmsView/Learning_About_Learning_Report

Rato, J. R., Abreu, A. M., & Castro-Caldas, A. (2013). Neuromyths in education: What is fact and what is fiction for Portuguese teachers? *Educational Research, 55*(4), 441–453.

Riener, C., & Willingham, D. (2010). The myth of learning styles. *Change: The Magazine of Higher Learning, 42*(5), 32–35.

Riforgiate, S. E. (2019). Puzzled by communication? Playing with puzzle pieces to promote teamwork and theory understanding. *Communication Teacher, 33*(4), 281–285.

Ritchie, S. J., Chudler, E. H., & Della Sala, S. (2012). Don't try this at school: The attraction of 'alternative'educational techniques. *Neuroscience in education: The good, the bad, and the ugly*, 244—265.

Sandle. (2020). How COVID-19 has upturned the e-learning market. Retrieved from http://www.digitaljournal.com/tech-and-science/technology/how-covid-19-has-upturned-the-e-learning-market/article/573300. Accessed 12 Apr 2021.

Scholastic Parents. (2021). The different ways your child learns. Retrieved from https://www.scholastic.com/parents/family-life/creativity-and-critical-thinking/learning-skills-for-kids/how-your-child-smart.html. Accessed 13 Apr 2021.

Simmonds, A. (2014). *How neuroscience is affecting education: Report of teacher and parent surveys*. Wellcome Trust.

Staffordshire University Library and Learning Services. (2020). Learning styles: Things you need to know. Retrieved from https://libguides.staffs.ac.uk/studying_at_uni/learning_styles. Accessed 13 Apr 2021

Stahl, S. A. (1999). Different strokes for different folks? A critique of learning styles. *American Educator, 23*(3), 27–31.

Tardif, E., Doudin, P. A., & Meylan, N. (2015). Neuromyths among teachers and student teachers. *Mind, Brain, and Education, 9*(1), 50–59.

The Onion. (2000). Parents of nasal learners demand odor-based curriculum. Retrieved from https://www.theonion.com/parents-of-nasal-learners-demand-odor-based-curriculum-1819565536. Accessed 12 Apr 2021

Twenge, J. (2006). *Generation me: Why today's young Americans are more confident, assertive, entitled—and more miserable—Than ever before*. Free Press.

UMass Dartmouth Center for Access and Success. (2021). How to accommodate different learning styles. UMass Dartmouth. Retrieved from https://www.umassd.edu/dss/resources/faculty%2D%2Dstaff/how-to-teach-and-accommodate/how-to-accommodate-different-learning-styles/

University of Buckingham. (2019). The first MBA to use AI to adapt content to each student's individual learning style launches with the University of Buckingham. Retrieved from https://www.buckingham.ac.uk/news/the-first-mba-to-use-ai-to-adapt-content-to-each-students-individual-learning-style-launches-with-the-university-of-buckingham/. Accessed 12 Apr 2021.

University of Portsmouth. (2021). Learning preferences. Retrieved from https://www.port.ac.uk/student-life/help-and-advice/study-skills/learning-preferences. Accessed 13 Apr 2021.

Van Blerkom, D. (2009). *College study skills* (6th ed.). Wadsworth Cengage.

VET Development Centre. (2020). Professional learning semester 2 | Jul-Dec 2020 program. Resource Document. Retrieved from https://vdc.edu.au/wp-content/uploads/2020/07/Flyer-VDC-PL-Program-Semester-2-2020-with-linksV2.pdf. Accessed 22 May 2021.

Weisberg, D. S., Keil, F. C., Goodstein, J., Rawson, E., & Gray, J. R. (2008). The seductive allure of neuroscience explanations. *Journal of Cognitive Neuroscience, 20*(3), 470–477.

Wilfred Laurier University Study Skills & Supplemental Instruction Centre. (2021). Understanding your learning style. Resource document. Retrieved from https://downloads.wlu.ca/downloads/academics/support-and-advising/documents/ssc-workshop-learning-styles.pdf. Accessed 13 Apr 2021.

Wininger, S. R., Redifer, J. L., Norman, A. D., & Ryle, M. K. (2019). Prevalence of learning styles in educational psychology and introduction to education textbooks: A content analysis. *Psychology Learning & Teaching, 18*(3), 221–243.

Zion Market Research. (2018). U.S. education market by type; by content; by smart learning mode; by component; by end user) - industry analysis, size, share, growth, trends, and forecast, 2018 – 2026. Market Report. Retrieved from https://www.researchandmarkets.com/research/mwp7hm/2_trillion_u_s?w=4#. Accessed 13 Apr 2021

Chapter 5
Myth Busted or Zombie Concept? A Systematic Review of Articles Referencing "Learning Styles" from 2009 to 2019

Amanda A. Olsen, John Elwood Romig, Ambra L. Green, Candace Joswick, and Vandana Nandakumar

Coffield et al. (2004) identified 71 distinct models of learning styles. These learning style models represent an educational concept that proliferated the research literature, guided kindergarten to high school classroom instruction, permeated teacher training and professional development, and was stalwart in educational textbooks and assessments. Although the underlying perspectives of these 71 models vary, the message is the same: "individuals differ in regard to what mode of instruction or study is most effective for them" (Pashler et al., 2009, p. 105). If the notion of learning styles is legitimate, then individuals can and *should* identify their best modes of learning so responsive instruction can match their most effective mode of learning.

According to Landrum and McDuffie (2010), the notion that people have unique learning needs has tremendous intuitive appeal. Matching learners' styles with instructional modality was touted to result in increased teaching and learning effectiveness, which helped learning styles quickly pervade the field of K-12 education (see Dunn & Griggs, 1998). However, Pashler et al. (2009) cast doubt on the validity and efficacy of the learning styles theory. Nonetheless, the promotion of learning styles in research literature, classroom practices, teacher training, and commercial products still exists. Since 2009, other reviews have found no evidence to support the idea that matching instruction to students' learning styles improved learning (Aslaksen & Lorås, 2018; Cuevas, 2015), and no empirical studies have satisfactorily refuted the conclusions of Pashler and colleagues. In this respect, learning styles can be considered a busted myth. However, references to learning styles theory continue to appear in journal articles, textbooks, and other publications, making learning styles a zombie idea in education (Goodwin, 2021)—a dead idea continually brought back to life with each publication. Given the lack of evidence for

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learning styles theory, the number of articles referencing learning styles theory is concerning. Therefore, our goal in the present chapter was to examine the dissemination of articles referencing learning styles in peer-reviewed educational research beginning in 2009.

The Structure and Purpose of Dissemination in the Field of Education

Dissemination, the process of distributing or broadcasting to wider audiences, is an essential process for sharing educational theory, research, and practice. Dissemination is part of a complex, iterative process of knowledge creation and can be generally thought of as a means of knowledge transfer. That is, as new knowledge is developed, it is transferred to others through the dissemination process. In many scholarly fields, including K-12 teaching and learning, journal publications are the primary dissemination method. For instance, through journal article publications, K-12 education discoveries are communicated to specific audiences, like other researchers and policymakers. These discoveries are then translated into practitioner-friendly formats (e.g., textbooks, professional development workshops, etc.). In the following paragraphs, we briefly describe the journal publication process and the role this process plays in screening articles for theories that lack evidence.

First, the onus for publication preparation (e.g., the research and the writing of the manuscript) is on authors. Many journals explicitly state research and publication ethics in addition to the standards they expect authors who submit manuscripts to follow. For instance, the American Educational Research Association (2006), a premier education research organization, states in their Standards for Reporting on Empirical Social Science Research in AERA Publications:

> Reporting should include a review of the relevant scholarship that bears directly on the topic of the report. It should include a clear statement of the criteria used to identify and select the relevant scholarship in which the study is grounded. A review should make clear how the study contributes to, challenges, and/or extends theory, practice, methodology, research results, knowledge (p. 34).

Authors carefully select journals to submit their work for consideration. Factors for selection include the journal's country of origin (e.g., USA), their education subfield (or specific discipline or content, e.g., early childhood education), intended distribution (e.g., domestic, published and distributed in the USA), metrics (like Scimago Journal & Country Rank), and others. These factors can help determine the fit of authors' work to a relevant journal. For instance, Scimago Journal & Country Rank (SJR) scores are a particular metric that indicates the average number of weighted citations per document published and can indicate the relative impact of articles in the journal. The AERA publication, *American Educational Research Journal*, had an SJR score of 3.223 in 2019, ranking among the most prestigious education-focused journals (ranked tenth). After author submission to a selected journal, the journal editor or editorial board can accept the manuscript for review.

Review processes vary, but generally, journal editors solicit and select highly qualified reviewers in the field(s) of the manuscript to provide detailed reviews of the work. These reviewers provide feedback to the authors and editors on the merit of the work. Although journals vary by country of origin, education subfield, intended distribution, prestige and impact metrics, and other characteristics, peer and editorial review serve the same function—*ceteris paribus*, the review provides an additional check on the ethics and standards of the knowledge contribution pre-publication. Iterations of reviews, feedback to the authors, and re-submissions of revised manuscripts are common before final acceptance for publication. This review process is intended to result in published articles that have gone through a rigorous review process to meet the ethics and standards presented by the publishing journal.

Dissemination is intended to and typically creates increased awareness of new knowledge generation. Thus, it can be used to maximize the impact of shared ideas and findings and bridge the "research to practice" gap, that is, the disconnect between research-based practices and their implementation in K-12 environments. Indeed, much of US-based educational research is intended to improve teaching, learning, and knowledge sharing to promote positive reform. For example, U.S.-based assessment, instruction, and cognitive research have impacted learning standards, increased the training of and knowledge expected for teachers, provided rationale for better services for exceptional student education, and even charted waters for expanding free pre-kindergarten programs for young children across the country.

Theory Talk Continuum and Theory Support Continuum Scale

In addition to understanding the journals that are publishing learning styles articles, it is also important to understand what message is being disseminated. Articles that reference learning styles could use the theory in myriad ways. One method to discern differences between levels of theory use is the Theory Talk Continuum developed by Kumasi et al. (2013). Within this framework, there are three categories: minimal theory talk, moderate theory talk, and major theory talk. Minimal theory talk includes theory dropping (i.e., discussion of the theory after the literature review) and theory positioning (i.e., introducing a theory at the beginning or end of a paper). Moderate theory talk includes theory diversification (i.e., multiple theories are introduced, but relevance is unclear) and theory conversation (i.e., the theory is discussed in a scholarly way), and major theory talk includes theory application (i.e., theory informs the research design and data analysis), theory generation (i.e., creating a new theory based on an old theory), and theory testing (i.e., validating an existing theory; Kumasi et al., 2013).

Further, in addition to understanding the role of learning styles in an article (i.e., level of theory talk), it is also important to understand to what extent the article supports learning styles theory. Therefore, a Theory Support Continuum Scale was developed by the researchers for this review to gauge whether learning styles were being questioned (i.e., the article acknowledges the ongoing debate about learning styles and/or is looking to test the learning styles theory to determine whether it is effective or not), opposed (i.e., the article clearly states that learning styles is a framework that should not be used), or promoted (i.e., the article uses the learning styles framework without negative commentary and/or uses language that supports learning styles).

Study Purpose

Although there is broad evidence questioning the practice of implementing learning styles in K-12 classrooms, researchers continue to apply learning styles and disseminate studies referencing this theory. The primary goal of this exploratory study was to document learning styles scholarly articles using Pashler et al.'s (2009) critical review of learning styles as a starting point. The secondary goals were to extend the literature base by (1) discovering how learning styles are being used in articles through applying an adapted version of Kusmasi et al.'s (2013) Theory Talk Continuum, (2) determining whether articles referencing learning styles were questioning, opposing, or promoting the theory (i.e., Theory Support Continuum Scale), and (3) examining the specific characteristics of the journals publishing articles referencing learning styles. One may hypothesize that after Pashler et al.'s (2009) publication, and perhaps after articles in queue for publication were released, the prevalence of learning styles-related literature would wane, moderate to major theory talk of learning styles might ensue or learning styles would fall on the "opposed" Theory Support Continuum Scale. The current study addresses the following research questions:

1. How many peer-reviewed, K-12 education-based empirical research articles referencing "learning styles" in the title, abstract, or keywords have been published beginning in 2009?
2. How are learning styles being referenced throughout academic papers using an adapted version of the Theory Talk Continuum developed by Kumasi et al. (2013)?
3. Are articles referencing learning styles questioning, opposing, or promoting the theory?
4. What are the characteristics, specifically country of origin, education subfield, intended distribution, and Scimago Journal Rank, of the disparate journals in which learning styles-related articles have been published beginning in 2009?

Methods

Four general phases were used for this systematic review. Phase 1 was the collection, review, and final selection of published journal articles. In Phase 2, journals and characteristics of the publishing journals of the selected articles were determined. During Phase 3, all data were extracted from the review software, and an audit for agreement or interrater reliability was performed. Phase 4 included descriptive analyses of the included articles.

Phase 1: Article Collection, Review, and Final Selection

Inclusion Criteria

To be selected for this review, studies must (1) have been published in a peer-reviewed journal, (2) explicitly use the term "learning style(s)" in the article title, abstract, or keywords, (3) used "learning style(s)" in empirical work, and (4) took place within a K-12 education setting. In addition, studies must have been published from 2009 to 2019. Studies that were not written in English, solely reviewed the literature (e.g., meta-analyses, systematic reviews, and literature reviews), were not peer-reviewed (e.g., commentaries, white papers, and dissertations), or were designed to exclusively validate a measure or instrument were not included.

Databases and Search Terms

The databases that were selected for this study included PsychINFO, ERIC, Academic Search Premier, and SCOPUS. ERIC was selected since it is the largest education database in the world, PsychINFO was selected to capture interdisciplinary research in education and the social sciences, and Academic Search Premier and SCOPUS were used to identify education research published in non-education specific databases. The search terms selected for this review were "learning style*" AND "student," as well as "learning style*" AND "teacher." These search terms were selected to provide the most comprehensive and robust selection of articles published on learning styles in education. The search was completed in September 2019.

Article Review

Journal articles were uploaded into Covidence, a software used for article screening, data abstraction, and quality assessment. Duplicates were removed at this time. The remaining articles were then reviewed for adherence to the inclusion criteria.

Specifically, an abstract review, followed by a full-text review, was conducted by two independent reviewers (Authors 1 and 2), and conflicts were resolved by a third independent reviewer (Author 3). The final selection of articles for this review was then established.

Phase 2: Journal and Article Characteristic Determination, Data Extraction

Journals, and Article Characteristics

From the articles selected in Phase 1, the specific publishing journals were recorded. Recall, article characteristics included the Theory Support Continuum Scale and the adapted Theory Talk Continuum Level (Kumasi et al., 2013), and journal characteristics included country of origin, education subfield or specific discipline or content, intended distribution, and Scimago Journal Rank (SJR score). In Phase 2, we determined these characteristics, as outlined below, for each article and journal from Phase 1.

Theory Talk Continuum

An adapted version of the Theory Talk Continuum was used to determine whether articles used minimal or major theory talk. This adaption was made to better suit the objectives of this review. For example, we removed the moderate theory category that included theory diversification (i.e., multiple theories are introduced, but relevance is unclear) and theory conversation (i.e., the theory is discussed in a scholarly way), as we were only focused on one theory, learning styles, and all included papers were journal articles, suggesting scholarly language would be used. After this adaptation, the minimal theory talk category was divided into theory dropping (i.e., learning styles is discussed/mentioned in the introduction or methods section and not revisited later) and theory relating (i.e., learning styles is referred to in the discussion to make meaning of the original research results, but the learning styles did not inform the study design or analysis). The major theory talk was also divided into two categories, theory application (i.e., employs learning styles throughout, typically to inform the research design and data analysis) and theory generation (i.e., building, revising, or expanding on the learning styles theory to create a new theory).

Theory Support Continuum Scale

This scale has three levels. The first level is questioning, where the article acknowledges the ongoing debate about learning styles and/or is looking to test the learning styles theory to determine whether it is effective or not. The second level is opposing, meaning the article clearly states that learning styles is a framework that should not be

used, and the final level is promoting, where the article uses the learning styles framework without negative commentary and/or uses language that supports learning styles.

Country of Origin

Journals were categorized by country of origin, determined through a review of the publisher's website of each journal, done in 2020.

Education Subfield

The journals were organized into nine categories: early childhood; exceptional children; general; general education; language learning and literacy; leadership and policy; social science; science, technology, engineering, and mathematics (STEM) and STEM education; and teaching and teacher education. Specifically, early childhood was defined as any journal specifically focused on children/early childhood or Pre-K through sixth grade (e.g., *Early Child Development and Care*). Journals including behavioral disorders or gifted/talented and were categorized as exceptional children (e.g., *Learning and Individual Differences*). General journals included those that published on any topic or any topic on a specific theme such as creativity or diversity (e.g., *Sage Open*). This category also included journals that published on two topic areas (e.g., social science and education), excluding multiple STEM subfields. Journals with a language learning and literacy focus included topics such as teaching a second language (e.g., *Journal of Language, Identity, and Education*). Leadership and policy journals emphasized educational leadership and policy (e.g., *KEDI Journal of Educational Policy*), and social science journals included areas such as psychology, political science, economics, etc. (e.g., *Journal of Environmental Science*). STEM or STEM education journals emphasized any or multiple aspects of science, technology, engineering, or mathematics (e.g*., Educational Technology Research and Development*), and finally, teacher education journals focused on the training of future educators (e.g., *Teaching and Teacher Education*).

These categories were established by Authors 1 and 4. Categories were first determined from those that journals used for classification themselves, found on the publisher's website. Operational descriptions of each (above) were written, and all other journals were explored (e.g., publisher descriptions) to determine categorization. All journals were found to fit in a single category.

Intended Distribution

Journals were categorized into "international" or "domestic" intended distribution. Journals that identified themselves as international, either in title or description, were categorized as such (e.g., *International Journal of Leadership in Education*)

regardless of country of origin. Journals published outside of the USA were also categorized as having an "international" intended audience. Domestic journals were those that originate from and were intended for U.S. readership (e.g., *Educational Technology Research and Development*). Intended distribution was determined through a review of the publisher's website of each journal, completed in 2020. All journals intended distribution could be determined.

SJR Score

Journal impact was also determined using the SJR score metric, found for most journals from the Scimago Journal & Country Rank website (https://www.scima-gojr.com/). Note, each SJR score from the website was calculated for the year 2019. When not available from the Scimago Journal & Country Rank website, SJR scores were determined from the publisher's website, if available. Compared to other prestige and impact metrics, like cite scores, SJR scores were available for a larger majority of journals of interest and thus were chosen as the impact metric for this review.

Phase 3: Data Extraction and Audit

Data Extraction

After identifying articles to be included in this study (Phase 1) and the journal characteristics (Phase 2), Author 1 extracted these data from Covidence.

Audit

Agreement or interrater reliability between the researchers on the extracted data was confirmed through an audit. For the audit, 10% of the articles were randomly selected and reviewed by Author 4, with more than 95% agreement across the variables of interest. The data set (articles, journals, and journal characteristics) was then finalized.

Phase 4: Descriptive Analysis

Using the final data set produced in Phase 3, descriptive statistics were represented in data displays (see Miles et al., 2014) and described. The results are presented as frequency (percent) for categorical data and mean (standard deviation (SD) for
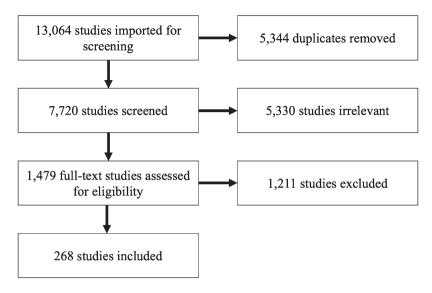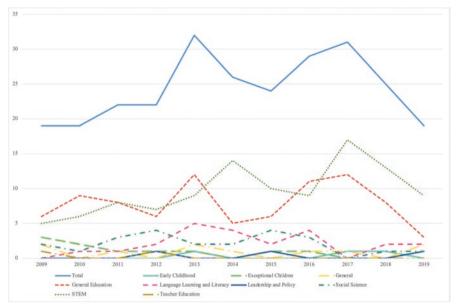
Fig. 5.1 PRISMA diagram

continuous data. Additionally, the journal country of origin is represented using Tableau software and a world map.

Results

As seen in Fig. 5.1 (PRISMA Diagram), in Phase 1, 13,064 articles were imported for screening, and 7,720 abstracts were reviewed after removing duplicates, leaving 1,479 articles for the full-text screening. Of these, 268 articles met the inclusion criteria.

Articles by Year

As seen in Fig. 5.2, since 2009 and Pashler et al.'s publication (December 2009), articles using learning styles have generally increased year-over-year. In 2009 ($N = 19$), in 2010 ($N = 19$), in 2011 ($N = 22$), in 2012 ($N = 22$), in 2013 ($N = 32$), in 2014 ($N = 26$), in 2015 ($N = 24$), in 2016 ($N = 29$), in 2017 ($N = 31$), in 2018 ($N = 25$), and in 2019 through October (N = 19). Notably, between the years of 2009 ($N = 19$) and the last full year of data in our review, 2018, ($N = 25$), there was 31.58% increase. When comparing 2009, as a "baseline," against the average number of articles published between the years of 2010 and 2018 ($M = 25.56$) there was a 34.53% increase.

Note: Article totals may not be representative of the entire year in 2019, since data was pulled in September 2019.

Fig. 5.2 Number of learning styles articles by year
Note: Article totals may not be representative of the entire year in 2019, since data was pulled in September 2019

Article Characteristics

Theory Talk Continuum

There were 15 (5.60%) articles that engaged in theory dropping, 22 (8.32%) that engaged in theory relating, and 231 (86.19%) articles that engaged in theory application, with no articles providing theory generation. Therefore, 37 (13.81%) articles used minimal theory talk, and 231 (86.19%) articles used major theory talk (see Table 5.1).

Theory Support Continuum Scale

There were 10 (3.72%) articles that questioned learning styles, 0 (0%) articles that opposed learning styles, and 258 (96.27%) articles that promoted learning styles (see Table 5.2).

Journal Characteristics

The 268 articles included in our review were published in 170 unique journals (see Table 5.3).

Table 5.1 Theory talk continuum (*N* = 268)

Continuum level	Category	Description	Articles *N* (%)
Minimal	Theory dropping	A theory is discussed/mentioned (with or without citation) in the *introduction or methods* section and not revisited later	15 (5.60%)
	Theory relating	Theory is referred to in the *discussion* (with or without citation) to make meaning of the original research results, but the theory did not inform study design or analysis	22 (8.21%)
Major	Theory application	Employs theory *throughout*, typically to inform the research design and data analysis.	231 (86.19%)
	Theory generation	*Building, revising, or expanding* on the learning styles theory to create a new theory	0 (0.00%)

Adapted from Kumasi et al. (2013)

Table 5.2 Theory support continuum scale (*N* = 268)

Continuum level	Description	Articles *N* (%)
Questioning	Acknowledges the ongoing debate about learning styles and/or is looking to test the learning styles theory to determine whether it is effective or not	10 (3.73%)
Opposing	Clearly states that learning styles is a framework that should not be used	0 (0.00%)
Promoting	Uses the learning styles framework without negative commentary and/or uses language that clearly supports learning styles	258 (96.27%)

Country of Origin

Over half of the articles were published in journals based in the United Kingdom (*n* = 72; 26.87%) or the USA (*n* = 59; 20.15%). The next most common country of origin was Turkey (*n* = 25; 9.33%). In total, articles about learning styles were published in 30 unique countries. Note that 10 (5.88%) of 170 journals, accounting for 14 (5.22%) of 268 articles, did not identify a country of origin. These data are displayed in Fig. 5.3, a world map, where light gray represents a low number of articles published about learning styles, and dark gray represents a high number of articles published about learning styles.
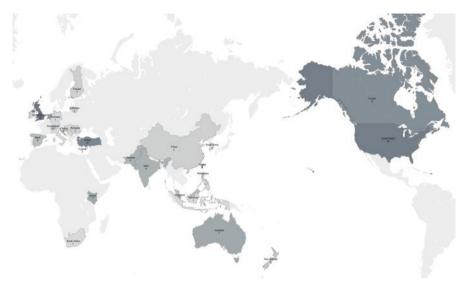
Education Subfield

When classifying the 268 articles in this review by the nine journal categories, 107 (39.93%) were published in science, technology, engineering, and mathematics, 86 (32.09) in general education journals, 23 (8.58%) in language learning and literacy journals, 23 (8.58%) in social science journals, and STEM education journals, 11 (4.10%) in exceptional children journals, 10 (3.73%) in general journals, 3 (1.12%) were published in early childhood journals, 3 (1.12%) in leadership and policy journals, and 2 (0.75%) in teaching and teacher education journals.

Table 5.3 Descriptive statistics by article and journal characteristics

Journal category	Operational definitions	Articles N (%)	Journals N (%)	Journal origin[a] N (%)	SJR score[b] M (SD)
Early childhood	Any journal specifically focused on children/ early childhood (K through sixth grade)	3 (1.12%)	3 (1.76%)	I: 3 (100%) D: 0 (0.00%)	0.38 (0.40)
Exceptional children	Any journal pertaining to special education, including behavioral disorders, or gifted and/or talented	11 (4.10%)	7 (4.12%)	I: 5 (71.43%) D: 2 (28.57%)	0.55 (0.49)
General	Any journal that can publish on any topics. Can include themed journals (e.g., creativity, diversity, etc.)	10 (3.73%)	9 (5.29%)	I: 8 (88.89%) D: 1 (11.11%)	0.23 (0.33)
General education	Any journal that can publish on any educational topic. May include journals that cover two categories (i.e., social science and education), excluding STEM subfields	86 (32.09%)	52 (30.59%)	I: 41 (78.85%) D: 11 (21.15%)	0.35 (0.38)
Language learning and literacy	Any journal with an emphasis on language, language learning, teaching a second language, or literacy	23 (8.58%)	19 (11.18%)	I: 16 (84.21%) D: 3 (15.79%)	0.35 (0.38)

Leadership and policy	Any journal with an emphasis on leadership and policy studies	3 (1.12%)	3 (1.76%)	I: 3 (100%) D: 0 (0.00%)	0.30 (0.39)
Social science	Any journal that covers one or multiple social science disciplines including but not limited to anthropology, psychology, political science, economics, etc.	23 (8.58%)	17 (10.00%)	I: 14 (82.35%) D: 3 (17.65%)	0.35 (0.59)
Science, Technology, Engineering, and Mathematics (STEM), and STEM education	Any journal with an emphasis on any or multiple aspects of science, technology, engineering or mathematics, and STEM education	107 (39.93%)	58 (34.12%)	I: 46 (79.31%) D: 12 (20.69%)	0.60 (0.61)
Teaching and teacher education	Any journal specifically focused on teacher education and the training of teachers	2 (0.75%)	2 (1.18%)	I: 1 (50.00%) D: 1 (50.00%)	0.90 (1.27)
Totals		268	170	I: 137 (80.59%) D: 33 (19.41%)	0.45 (0.54)

[a] Denominator in the percentage calculation was the total number of domestic and international journals, respectively, for that specific journal topic

[b] 36 (17%) of journals were missing SJR scores. N = number, $\%$ = percent, M = mean, SD = standard deviation, I = journal identifies as an international journal, D = journal does not identify as an international journal and journal origin is in the United States, and SJR Score = Scimago Journal Rank

Note: This map projection was automatically generated using the Tableau software and was not chosen by the authors.

Fig. 5.3 Map of countries that have published learning styles articles
Note: This map projection was automatically generated using the Tableau software and was not chosen by the authors.

With regard to the categorization of journals, 58 (34.12%) were categorized as STEM or STEM education journals, 52 (30.59%) were general education journals, 19 (11.18%) journals were about language learning and literacy, 17 (10.00%) journals were social science-themed, 9 (5.29%) journals were identified as general, 7 (4.12%) were categorized as exceptional children journals, 3 (1.76%) journals were categorized as early childhood journals, 3 (1.76%) journals emphasized leadership and policy, and 2 (1.18%) journals were on teaching and teacher education. These data are explicated in Table 5.3.

Intended Distribution

As seen in Table 5.3, for STEM and STEM education, 46 (79.31%) were international, and 12 (20.69%) were domestic; for general education journals, 41 (78.85%) were international and 11 (21.15%) were domestic; for language learning and literacy journals, 16 (84.21%) were international and 3 (15.79%) were domestic; for social science, 14 (82.35%) were international and 3 (17.65%) were domestic; for general themed journals, 8 (88.89%) were international and 1 (11.11%) was domestic; for exceptional children journals, 5 (71.43%) were classified as international and 2 (28.57%) were domestic; for the early childhood journals all 3 (100%) were international; for leadership and policy all 3 (100%) were international; with 1 (50.00%) international and 1 (50.00%) domestic for teacher education journals. Overall, 137 (80.59%) journals were classified as international, and 33 (19.41%) journals were classified as domestic.

SJR Score

Journal impact or influence was measured using SJR score by the nine journal categories, specifically STEM and STEM education ($M = 0.60$, SD = 0.61), general education ($M = 0.35$, SD = 0.38), language learning and literacy ($M = 0.35$, SD = 0.38), social science ($M = 0.35$, SD = 0.59), general ($M = 0.23$, SD = 0.33), exceptional children ($M = 0.55$, SD = 0.49), early childhood ($M = 0.38$, SD = 0.40), leadership and policy ($M = 0.30$, SD = 0.39), and teaching and teacher education ($M = 0.90$, SD = 1.27). The overall SJR average for all journals was 0.45 (SD = 0.54). The highest SJR score for all journals was 3.05 and the lowest was 0. Note that 33 (19.41%) of the 170 journals were missing SJR scores and were therefore coded as a 0. SJR score by the nine journal categories are also displayed in Table 5.3.

Discussion

A systematic review of peer-reviewed, K-12 education-based empirical research articles referencing "learning styles" in the title, abstract, or keywords, published beginning in 2009, was conducted. The year 2009 was chosen because it marks a benchmark year for data comparison and was the year of publication of Pashler et al.'s (2009) critical review of learning styles. Two hundred and sixty-eight articles were found, published between January 2009 and September 2019, that met the study's inclusion criteria. These articles were published in 170 disparate journals. We hypothesized that the quantity of these types of publications may wane over time after the appearance of Pashler et al.'s (2009) publication, but this hypothesis was rejected. In fact, although just 19 articles were published in 2009, the trend in recent years has been higher (29 in 2016, 31 in 2017, and 25 in 2018). Despite a long history and continued appearance in the literature, there remain conflicting reviews of the validity, reliability, and implementation of learning styles (Landrum & McDuffie, 2010; Pashler et al., 2009).

This review adds to the learning styles literature base by providing an overview of where recent learning styles articles are being disseminated, as well as the publishing journal characteristics, and article characteristics (Newton & Salvi, 2020). Recall, article characteristics included the Theory Talk Continuum (Kumasi et al., 2013) and the Theory Support Continuum Scale, and journal characteristics included country of origin, education subfield, intended distribution, and Scimago Journal Rank. Note, Pashler et al.'s (2009) article appeared in *Psychological Science in the Public Interest*, a journal we would categorize as originating from the USA, social science-themed, intended for an international audience, and an SJR score (2019) of 6.73 (note, the social science category SJR score average was 0.35). This particular article was excluded from the systematic review because it did not meet the empirical study criteria for inclusion.

In general, findings from the study yielded variability in the publication of research related to learning styles across the country of origin, education subfield,

intended distribution, and Scimago Journal Rank, and several articles published. Most articles were published in general education and STEM and STEM education journals, specifically in international journals. However, although general education and STEM and STEM education saw research published in the greatest number of journals, the teaching and teacher education and leadership and policy categories had journals with the highest average SJR scores (0.80 and 0.88, respectively), possibly suggesting higher impact or even greater dissemination. In terms of article characteristics, most articles employed major theory talk through theory application and were promoting the learning styles theory. The wide dissemination of these articles is cause for concern given that most articles promote the theory with little evidence to support it.

Implications for Research

It is troubling that most studies included in this review were using the learning styles theory to justify or inform their research design and analysis. This demonstrates that learning styles, a theory under much scrutiny, discredited by Pashler et al. (2009), is still being proliferated and applied to support this myth. In addition, we note that most studies were promoting the use of learning styles, with less than 4% of studies questioning the theory, and zero studies opposing it. This finding demonstrates that the learning styles theory is still considered by many researchers, who likely disseminate this practice to practitioners, to be a legitimate and valid theory, which is alarming.

To move the field forward in providing empirical explanations regarding the validity, reliability, and implementation of learning styles, research studies that systematically assess the relationship between the use of learning styles are desperately needed, although we do note there are studies that have begun questioning and opposing this theory (Husmann & O'Loughlin, 2018; Klitmøller, 2015; Pershan & Riley, 2017; Rogowsky et al., 2015; Weale, 2017; Wiliam, 2016). In particular, the fields in which most of the journal articles were collected, STEM and STEM education and general education, should assess the relationship between teachers' use of learning styles during academic instruction and students' academic achievement. Likewise, due to the reciprocal relationship between academics and behavior, the same such studies should focus on students' behavioral outcomes related to the use of learning styles. That is to ask, to what extent does teachers' use, or non-use of students' individual learning styles affect their academic and behavioral outcomes?

Further, with a more detailed review of the literature, we would be able to determine the message of the articles included in our systematic review. That is, with the present study, we cannot determine how many of the articles did or did not consider Pashler et al.'s (2009) publication, especially the call for more empirical work to prove the efficacy of learning styles. Although we believe it inconceivable, all 268 articles, or at least many of those after December 2009 (and the publications already queued for release at that time), may have been in direct response to Pashler et al.

(2009). Assessing the particular studies and findings of these publications (planned for a future study) would allow for a richer understanding of how Pashler et al.'s (2009) article possibly changed the K-12 field of education. Future research should include expanding the depth of this systematic review and completing a meta-analysis on research that studies particular learning style schemes (e.g., VARK, Fleming & Mills, 1992). We also suggest future studies capture the continued dissemination of learning styles beyond research literature (e.g., teacher professional development, textbook and assessment publication) and scope beyond the K-12 scholarly field.

Implications for Dissemination

Many of the articles were found in international journals with high impact factors. Notably, these articles were research articles in the fields of STEM and STEM education. Given the mixed findings regarding the validity and reliability of learning styles, future efforts toward dissemination should be critical in the screening and reviewing of such articles. For example, standards for assessing research designs for rigor, such as the What Works Clearinghouse (WWC) Research Design Standards (U.S. Department of Education, 2020) or the Standards for Excellence in Education Research Principles (Institute of Education Sciences, 2020), should be consulted. Additionally, reviewers should have a sufficient depth of knowledge related to the issues surrounding learning styles.

   The learning styles studies in this review were published in a variety of journals ranging from general education to STEM to the social sciences. Understanding where learning styles research is being published is important, as journals target specific audiences and may engage the audience with discipline-specific lenses. Further, educators and researchers may not realize that learning styles research is being published in a wide variety of journals. Since learning styles research is being published through so many different journals, it is reaching a wide audience, which may make it more difficult to contain the proliferation of this myth.

Limitations

Limitations must be considered when evaluating the findings of this study. First, this study was exploratory and therefore causality or generalizations related to the use of the articles in their respective fields cannot be surmised. Second, this review did not assess the rigor of individual studies, as only the potential rigor of the journal these articles were published in was noted via their SJR score. Third, although the databases and journals included in our search were comprehensive, there is still potential that the review missed relevant articles. Fourth, our categorizations for the intended journal audience were U.S.-centric. Fifth, the SJR scores identified were

the most recently published by the Scimago Journal & Country Rank and the publishing journal (typically from 2019) and may not represent the journal's SJR score when the article was published. The popularity of journals may have changed between publication and retrieval of the current SJR score. Further, other prestige and impact metrics are available and were not considered (due to a lack of availability for all journals). Sixth, this review was focused on learning styles as defined by Pashler et al. (2009) and articles were only included if they contained the phrase "learning styles" in the title, abstract, or article keywords. This approach may have excluded articles that referenced learning styles by another name (e.g., cognitive styles) or articles that referenced learning styles in places other than the title, abstract, or article keywords.

Conclusion

Learning styles theory suggests that individuals have a specific learning style that can be identified and used to match instruction. This match between instruction and learning style is theorized to lead to improved outcomes for students. However, this theory lacks compelling, rigorous empirical support. As evident throughout this chapter, many researchers have identified conceptual and empirical flaws in the learning styles literature. However, our review found that the learning styles myth is still quite prevalent, and increasingly so, in education journals. This trend is concerning given the lack of empirical support for learning styles theory. Peer reviewers and editors should be aware of the empirical support for learning styles theories and provide feedback to authors in light of this research base.

References

American Educational Research Association. (2006). Standards for reporting on empirical social science research in AERA publications. *Educational Researcher, 35*(6), 33–40. https://doi.org/10.3102/0013189X035006033

Aslaksen, K., & Lorås, H. (2018). The modality-specific learning style hypothesis: A mini-review. *Frontiers in Psychology, 9*(1538). https://doi.org/10.3389/fpsyg.2018.01538

Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004). *Learning styles and pedagogy in post-16 learning: a systematic and critical review. LSRC reference*. Learning & Skills Research Centre.

Cuevas, J. (2015). Is learning styles-based instruction effective? A comprehensive analysis of recent research on learning styles. *Theory and Research in Education, 13*(3), 308–333. https://doi.org/10.1177/1477878515606621

Dunn, R., & Griggs, S. A. (Eds.). (1998). *Learning styles and the nursing profession*. National League for Nursing Press.

Fleming, N. D., & Mills, C. (1992). Not another inventory, rather a catalyst for reflection. *To Improve the Academy, 11*, 137–155.

Goodwin, B. (2021). Zombie ideas in education. *Educational Leadership, 78*(8), 44–49.

Husmann, P. R., & O'Loughlin, V. D. (2018). Another nail in the coffin for learning styles? Disparities among undergraduate anatomy students' study strategies, class performance, and reported VARK learning styles. *Anatomical Sciences Education, 12*(1), 6–19. https://doi.org/10.1002/ase.1777

Institute of Education Sciences. (2020, March 16). *Standards for excellence in education research.* Retrieved December 31, 2020, from https://ies.ed.gov/seer/index.asp

Klitmøller, J. (2015). Review of the methods and findings in the Dunn and Dunn Learning Styles Model research on perceptual preferences. *Nordic Psychology, 67*(1), 2–26. https://doi.org/10.1080/19012276.2014.997783

Kumasi, K. D., Charbonneau, D. H., & Walster, D. (2013). Theory talk in the library science scholarly literature: An exploratory analysis. *Library & Information Science Research, 35*, 175–180. https://doi.org/10.1016/j.lisr.2013.02.004

Landrum, T. J., & McDuffie, K. A. (2010). Learning styles in the age of differentiated instruction. *Exceptionality, 18*, 6–17. https://doi.org/10.1080/09362830903462441

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). SAGE Publications.

Newton, P. M., & Salvi, A. (2020). How common is belief in the learning styles neuromyth, and does it matter? A pragmatic systematic review. In *Frontiers in Education* (Vol. 14, p. 270). Frontiers. https://doi.org/10.3389/feduc.2020.602451

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2009). Learning styles: Concepts and evidence. Psychological Science in the Public Interest, 9(3), 105–119. doi: https://doi.org/10.1111/j.2Fj.1539-6053.2009.01038.x.

Pershan, M. & Riley, B. (2017, June 29). Why mythbusting fails*: A guide to influencing. Education with science.* Deans for Impact. Retrieved from https://deansforimpact.org/why-mythbusting-fails-a-guide-to-influencing-education-with-science/

Rogowsky, B. A., Calhoun, B. M., & Tallal, P. (2015). Matching learning style to instructional method: Effects on comprehension. *Journal of Educational Psychology, 107*(1), 64–78. https://doi.org/10.1037/a0037478

U.S. Department of Education, What Works Clearing House. (2020, October). *Standards handbook (Version 4.1).* Retrieved from https://ies.ed.gov/ncee/wwc/Docs/referenceresources/WWC-Standards-Handbook-v4-1-508.pdf.

Weale, S. (2017, March 12). Teachers must ditch 'neuromyth' of learning styles, says scientists*. The Guardian*. Retrieved from https://www.theguardian.com/education/2017/mar/13/teachers-neuromyth-learning-styles-scientists-neuroscience-education?CMP=share_btn_tw.

Wiliam, D. (2016, April 28). *Learning styles: What does the research say*? Deans for Impact. Retrieved from https://deansforimpact.org/learning-styles-what-does-the-research-say/.

Chapter 6
Consequences of Endorsing the Individual Learning Styles Myth: Helpful, Harmful, or Harmless?

Veronica X. Yan and Connie M. Fralick

The belief in "individual learning styles" is widespread across all levels of education, all educational stakeholders (from students to parents to educators), and around the world (Dekker et al., 2012; Newton, 2015; see also Chap. 3 of this monograph). And yet, there is surprisingly little consensus about what constitutes a learning style. Coffield et al. (2004a), for example, identified 71 different models of learning styles that warranted consideration. But regardless of the specific framework of styles one examines, they are all underpinned by the idea that learners each have different preferences for how they process information, and that learners will learn better when instruction matches the preference (the "meshing hypothesis"; Pashler et al., 2008).

The argument that learning styles proponents make is that instructional or study methods should be tailored to learners based on these style differences. For some proponents, tailoring might mean teaching in a way that specifically matches the learners' strengths (i.e., visually to a visual learning style; kinesthetically to a kinesthetic learning style). For other proponents, however, tailoring might mean "teaching around the cycle"—spending some time teaching in ways that match a learner's strengths, but also spending other time teaching in ways that encourages them to strengthen an area in which they are weak (Felder, 2010, 2020; Fleming & Mills, 1992; Kolb, 1984). Note, however, that this latter perspective still relies on a basic assumption of the meshing hypothesis: It assumes there are certain styles that are matched to a learner's strengths and certain styles that are matched to a learner's weaknesses and that there is some empirical, real alignment between learning style preference and actual learning efficacy. So, we cannot rule out the importance of understanding whether learning style preference is related to learning consequences.

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However, there is little empirical evidence that the tailoring—regardless of the direction—matters for learning (Allcock & Hulme, 2010; Aslaksen & Lorås, 2019; Husmann & O'Loughlin, 2018; Knoll et al., 2016; Krätzig & Arbuthnott, 2006; Massa & Mayer, 2006; Rogowsky et al., 2015, 2020).

If there are no direct *learning* consequences of tailoring instruction in a way that "matches" or "mismatches" the learners' preferences, what are the other possible consequences of endorsing the belief in individual learning styles? In other words, is this myth harmful, harmless, or possibly even helpful? In this chapter, we review the different arguments for how a belief in individual learning styles might impact students' and teachers' implicit beliefs about learning potential, metacognition, learning, and instructional practices.

Variability in Individual Learning Styles Beliefs

The notion of individual learning styles is widespread. But even among those who endorse the idea, there is wide variability in what people think it means, and the way in which learning styles is conceptualized may have different consequences. One of the most vociferous defenders of learning styles research, Richard Felder, defined learning styles as common patterns of student preferences that are associated with certain attributes—"behavior, attitudes, strengths, and weaknesses." (Felder, 2020, p. 3). However, this does not constitute a prevailing consensus so much as one definition among many. There is actually a great deal of conceptual confusion even in differentiating between terms such as "learning styles," "cognitive styles," "learning strategies," and so forth (Cassidy, 2004). For example, Riding and Cheema (1991) distinguish between cognitive style and learning style by arguing that cognitive styles are generally a bipolar dimension while learning styles are not. However, they also discuss how cognitive style might be a subset of learning styles. They then go on to refer to the two as a single entity and assert that this entity itself has been interpreted in a variety of ways: as a structure (stable), a process (changeable), or even partially personality or aptitude-based.

Perhaps then, we should examine what the users—teachers and learners—mean when they talk about learning styles. Papadatou-Pastou et al. (2020) administered a survey consisting of both closed- and open-ended questions to 123 education professionals. They found that most participants' responses aligned with the VAK/VARK model (visual, auditory, reading, kinesthetic; Barbe et al., 1979; Fleming & Baume, 2006; Fleming & Mills, 1992). In most of the empirical literature examining the nature of belief in learning styles, researchers too have tended to use this VAK/VARK type of classification (e.g., Dekker et al., 2012; Nancekivell et al., 2020; Newton & Miah, 2017). However, Papadatou-Pastou and colleagues also found that responses from education professionals sometimes conflated learning styles with Gardner's multiple intelligences theory (Gardner himself wrote in *The Washington Post* about how his multiple intelligence theory has been misinterpreted as support for learning styles, Strauss & Gardner, 2013), and with other learning

theories (e.g., behaviorism, teacher-centered instruction, modeling, collaborative learning). In other words, despite over 70 different models of individual learning styles, it seems that most teachers and learners use the phrase "individual learning styles" to refer specifically to the VAK model, while also conflating the notion with a grab-bag of other constructs.

Does the Model of Learning Styles Matter?

There are many different learning styles models, although the psychometric validity of many of them are questionable. Coffield et al. (2004b), for example, reviewed 13 popular learning styles models, finding that most of them had insufficient test-retest reliability and internal consistency. In general, they criticized the learning styles field for "theoretical incoherence and conceptual confusion" (Coffield et al., 2004a, p. 135; see also Duff & Duffy, 2002; Martin, 2010).

Even the learning styles proponents themselves are not always clear on the model. Sometimes they support multiple models, sometimes they remain neutral on which model to pick, or other times, simply state that instructors should pick whatever model best suits their context. For example, Rosenfeld and Rosenfeld (2004) conducted a 60-h, year-long professional development course that taught nine different types of learning styles models. Felder (1996) described four different models (Myer-Briggs Type Inventory, Kolb's Learning Style Model, Herrmann Brain Dominance Instrument, Felder-Silverman Learning Style Model), but then concluded that "which model educators choose is almost immaterial, since the instructional approaches that teach around the cycle for each of the models are essentially identical." (p. 22). This perspective seems to imply that the theoretical basis is less important than the practical application; and as long as a teacher is teaching "to everyone," it does not matter how one defines each individual learning style. Interestingly, this perspective turns the individual learning styles concept into something decidedly un-individual.

Can Learning Styles Change?

Nancekivell et al. (2020) conducted an examination of what it means to endorse the general myth of individual learning styles. Specifically, they were interested in whether people held "essentialist" beliefs that one's learning style is biologically based (hardwired into the brain, genetic), and identified two clusters of learning styles adherents that they labeled essentializers and non-essentializers. The essentializers comprised about two-thirds of their first sample ($N = 331$) and about half of their second sample ($N = 337$). Nancekivell and colleagues argued that "essentialist" beliefs reflect the conviction that there are biological determinants that predict behavior and ability—in this case, that we can clearly categorize people into

different "learning styles," and that one's style is biologically rooted, immutable, and predicts learning outcomes. This kind of restrictive, deterministic thinking gives rise to another concern: the possibility of self-handicapping and pigeon-holing based on one's supposed style. We will address this idea in our section on the consequences for beliefs about learning potential.

In contrast, non-essentialist learning styles beliefs refer to beliefs that learning styles are non-discrete, overlapping, or that one's learning style can change with experience or across contexts. The implication from this view is learning styles should not be considered rigid categories but rather should be considered a set of strengths and weaknesses, where one can focus on developing one's weaknesses in addition to playing to one's strengths. This non-essentialist view of learning styles is also most likely to be the one endorsed by learning styles proponents, with some going so far as to suggest that a person's learning style profile of strengths and weaknesses can change depending on the subject, the teacher, and even the student's mood (Felder, 2020). However, this philosophy is not well captured by learning styles inventories (which pose general questions that imply invariance across contexts; we have yet to find a learning styles inventory where the questions try to account for contextual features or mood), and even those who were categorized as non-essentializers by Nancekivell et al. (2020) tended to endorse some "essentialist" type thinking. For example, the non-essentialists highly endorsed the idea that one's learning style is detectable as a child. This illustrates both variability in learning style interpretation across learning styles proponents and a lack of internal consistency within the individual. It seems many hold at least some measure of essentialist beliefs, regardless of how their learning style beliefs were categorized, the vast majority of participants believed that one's learning style is predictive of life outcomes: the kinds of school settings from which one learns best (92–93%), the kinds of teachers from whom one learns best (90–93%), and to a lesser extent, the kinds of career at which one would excel (68–75%). We will explore how this more varied view of learning styles might have consequences for metacognition and instructional approaches (potential benefits and harms), as well as the possibility that despite the widespread endorsement, learning styles beliefs might not actually have any effect on teacher and student behaviors.

Consequences for Beliefs About Learning Potential

The belief that a person's learning style can limit their potential may influence learners to engage in self-handicapping behaviors. This has been the speculation in many papers about the myth of individual learning styles. Researchers have argued that students labeled (either by a teacher or by themselves) as having a particular dominant learning style may choose to avoid subjects that are perceived to be predominated by a different learning style (Furey, 2020; Newton, 2015). The "visual learner" may avoid music; the "auditory learner" may avoid engineering. Others

have suggested that learners might use a "mismatch of learning style" to a subject or to a teacher's method of teaching as an excuse for poor classroom performance (Willingham et al., 2015). Such a convenient excuse allows learners to make stable (e.g., *I'm never going to be able to do well in this subject; this subject will always mismatch my learning style*), external (e.g., *it's the teacher's teaching style*), and uncontrollable (e.g., *I can't change my style or what the teacher is doing)* attributions for their failures (and perhaps also their successes). However, such attributions are detrimental to motivating learners to feel empowered in taking control of their own learning (Weiner, 1985): *If it will never change and it's not in my control, then there's no point trying to do anything about it.*

Belief in learning styles may not only affect how learners see themselves, but may also impact how teachers interact and provide feedback to their students. Scott (2010), for example, speculated that endorsement of learning styles may result in harmful teaching practices that label learners as being limited by their style (rather than focusing on evidence-based practices of what does actually promote learning) and perpetuate a cultural tendency to rely upon stereotypes to explain behavior and attainment. Although Nancekivell et al. (2020) did not directly examine it, those who hold essentialist beliefs of learning styles (i.e., who believe that learning styles cannot change) might be especially likely to fall back on these self-handicapping and pigeon-holing behaviors (i.e., making excuses, avoidance behaviors). However, it is also important to note that these have been speculations of the negative consequences of belief in individual learning styles, and we are not aware of empirical evidence that speaks to the extent to which these fears are borne out.

To begin to examine this question, we conducted a survey (Yan & Fralick, unpublished data) asking undergraduate students at a large public American university for their beliefs about individual learning styles and naive theories of intelligence, ease, and difficulty (Dweck, 2006; Fisher & Oyserman, 2017). In this dataset, we found that the more a student endorses the individual learning styles myth, the more likely they are to hold the belief that intelligence cannot be changed (*fixed mindset;* Dweck et al., 1995), $r(188) = 0.25$, $p < 0.001$, and the more likely they are to think that when a task feels easy, it means that it is possible (*ease-as-possibility;* Fisher & Oyserman, 2017), $r(188) = 0.23$, $p < 0.01$. Essentialist beliefs about learning styles were even more strongly related to the fixed mindset, $r(188) = 0.45$, $p < 0.001$, as well as being related to the belief that if a task feels difficult, it is likely impossible (*difficulty-as-impossibility;* Fisher & Oyserman, 2017), $r(188) = 0.31$, $p < 0.001$, and the belief that if a task feels easy, it is likely trivial (*ease-as-triviality;* Fisher & Oyserman, 2017), $r(188) = 0.36$, $p < 0.001$. This latter combination of endorsing both difficulty-as-impossibility and ease-as-triviality is particularly interesting; it suggests that those who hold essentialist beliefs about learning styles may be more likely to think that regardless of ease or difficulty, studying is simply not worth engaging in, which may be related to self-handicapping. Of course, these data are merely correlational—we do not know whether learning styles beliefs themselves cause the related beliefs about intelligence potential, ease, and difficulty.

Consequences for Metacognition

Metacognition, or thinking about one's thinking, encompasses many processes, including monitoring one's own learning progress and the efficacy of one's learning strategies, and various study decisions (what to study, when to move onto something else, how to study; Nelson & Narens, 1990); metacognitive processes are particularly important for self-regulated learning (Zimmerman, 2002). What are potential metacognitive consequences of endorsing individual learning styles? Learning styles proponents might argue that the different models of individual learning styles can serve as useful tools for self-reflection; critics, however, may question the utility of these reflective practices if the basic assumptions are not empirically supported.

Promoting Dialogues and Self-Reflection

Many learning styles proponents argue that a person's learning style should not be treated as a steadfast categorization. Instead, they focus on using learning styles as a framework for thinking about learners' profiles of strengths and weaknesses. Arising from the non-essentialist perspective that learning styles are changeable, learning styles proponents argue that learning styles are useful for fostering self-reflection and starting conversations about one's strengths and weaknesses (Felder, 2010, 2020; Syofyan & Siwi, 2018). Instructions provided after taking the VARK learning styles questionnaire also explicitly states: "The VARK results indicate a *'rule of thumb'* and should not be rigidly applied. The questionnaire is not intended to '*box*' you into a mindset that you have been '*diagnosed*'. Rather, it is designed to initiate discussion about, and reflection upon, your learning style—***metacognition.***" (VARK Learn, n.d.). That is, instead of focusing on tailoring learning to fit only a learner's strengths, learning styles proponents argue that understanding one's learning style "profile" can help focus learners on developing their perceived weaknesses. In fact, learning style proponents sometimes even argue that teachers should deliberately *mis*match student learning style and teaching methods, which could "help them learn in new ways and to bring into play ways of thinking and aspects of the self not previously developed" (Zhou, 2011, p. 76). The self-reflection can occur at the level of the individual learner, or it can take place as teacher-led or teacher-mediated discussions in the classroom. The goal is to force students to "stretch and grow, building important skills that they might never develop if their preferences were exclusively catered to" (Felder, 2020, p. 9).

Hindering Accurate Metacognition

There is little systematic evidence, however, to examine (a) whether or how often metacognitive discussion occurs, and (b) if it does happen, whether it is actually beneficial for learners. In fact, the information provided after taking learning style quizzes undermines the argument that one should focus on both strengths and weaknesses. For example, despite language on the VARK encouraging people to explore multiple styles, the VARK website also directs users to "helpsheets" with strategies that are suited to just one modality once they receive their questionnaire results. The implication to the user is that if you are a "visual learner," then you should refer to the visual learner helpsheet to read about all the visual strategies that you should be using; if you are an "auditory learner," then you should refer to the auditory learner helpsheet to read about all the auditory strategies that you should be using, and so on.

Rosenfeld and Rosenfeld (2004) examined whether receiving training on learning styles influenced teacher–student dialogues. They conducted a 60-h professional development course in which 14 English-as-a-foreign-language (EFL) teachers learned about research into different learning styles models and took a battery of learning style inventories. They reported that having the language to talk about learning styles led teachers to feeling more empowered to open up a teacher–student dialogue. However, it is unclear what teachers were talking to students about and whether there were any positive outcomes on student learning. Moreover, if there were positive benefits, it is unclear whether these benefits are linked specifically to learning styles. There are likely general benefits that result from fostering stronger teacher–student relationships (Niemiec & Ryan, 2009), and this general effect does not require that teachers talk to their students about learning styles; any other number of approaches or topics can help foster positive relationships too (e.g., learning about students' hobbies, families, histories, and so on). Even if teachers talked with their students about learning styles and students engaged in self-reflections, there is no evidence intentional shifts in learning styles will do anything to improve student outcomes. Trying out new strategies that are aligned or misaligned with one's "learning style" is a waste of time and energy if they have no bearing on actual learning. Though a student might benefit from closer interaction with their teacher, why use individual learning styles as the basis for discourse, instead of more empirically supported strategies?

Moreover, self-reflection in and of itself is not enough; self-reflection should be *accurate*. Consider for example the learner who engages in frequent metacognitive monitoring. This learner might regularly pause to check in on their learning progress (and hence whether they should terminate study and move on to something else) and reflect on whether the strategies they are employing are working for them (and hence whether they should change strategies). But if they inaccurately monitor their learning, they may end up making poor decisions—terminating study too soon, studying one thing for too long, switching to less effective strategies, or persisting with an ineffective strategy (Son & Schwartz, 2002).

Here are ways in which belief in individual learning styles might hinder accurate metacognition. For example, when learners perceive a topic to play to their learning style "strengths," this can lead to false confidence or illusions of learning. There is some empirical evidence for this negative potential outcome. Knoll et al. (2016) asked participants to take the Verbalizer-Visualizer questionnaire to find out their preferred learning style and then had participants engage in a learning task where they studied and were tested on lists of word pairs and picture pairs. Participants were also asked to predict how well they had learned the word and picture pairs. They found that participants' visualizer score was positively correlated with their picture-pair predictions and that their verbalizer score was positively correlated with their word-pair predictions. However, *neither* score was correlated with actual recall performance. Scaled up to educational settings, this false sense of confidence could mean that learners end up overestimating their learning gains and investing less effort than they should when they perceive a subject to play to their "dominant style." Learners might also underestimate their learning gains when engaging in a subject that does not align with their perceived strengths, with the consequence of either over-investing effort (that could be better spent elsewhere) or disengagement. In either case, poor metacognitive judgment can have negative consequences.

Consequences for Teaching and Learning Practices

Among those who endorse the idea of individual learning styles, there is a significant lack of clarity regarding beliefs about how changeable learning styles are and what pedagogical action should be taken once learners' learning styles are determined. Some people take the idea of individual learning styles to mean that learners should always study in a way that matches their strengths. This view is especially likely to be adopted by those in the general public. In a systematic review of studies that examined learning styles beliefs among educators and trainee educators, Newton and Salvi (2020) found that 89.1% of educators believe instruction should be matched to the learner's style and 79.7% said that they used or intended to use the matching of instruction to learning styles.

Others, however, argue that the goal should be to focus on both one's strengths and weaknesses. Learning style inventory creators have tended to highlight "teaching around the cycle"—that rather than trying to match students' strengths, learning styles frameworks should be used as a guide for hitting an optimal balance. What the optimal balance looks like may depend on the students, the teacher, the subject, and so on, but they argue that having some sort of balance undergirded by some idea of individual learning styles is better than not having a balance. In fact, Felder (2010, 2020) has argued that the learning styles critics who hinge their criticism on the meshing hypothesis miss the point. He argues that the meshing hypothesis is irrelevant to the notion of learning styles entirely because "it's impossible to match teaching to the learning styles of all students in a class simultaneously." (Felder,

2020, p. 9). This focus on "balanced teaching" is also the reason why he is agnostic as to which learning styles model an educator might choose—if you teach in every way, it no longer matters how you choose to categorize the options.

But this argument misunderstands what the meshing hypothesis represents. The meshing hypothesis represents the underlying process by which individual learning styles are presumed to work; Felder confuses this underlying process with the practical recommendation of what a teacher should do. In fact, his very argument hinges on the meshing hypothesis: He argues that the optimal teaching style should achieve a balance so that it "effectively reaches most students rather than putting a large subset of them at a disadvantage" (Felder, 2010, p. 1). But by claiming that students have learning style-aligned strengths and weaknesses, and that teaching in one style puts a subset of students at a "disadvantage" presupposes that learning styles and the meshing hypothesis (that one's preference is indeed one's learning strength) are true in the first place.

Moreover, the claim that the meshing hypothesis is irrelevant because teachers always have many different styles in their classrooms assumes a very narrow idea of what teaching and learning can look like. It assumes that individual learning styles models are used only by teachers in one-teacher-many-students (i.e., classroom) settings. However, teaching and learning go far beyond classroom environments. Tutors often teach just one student at a time and computer-delivered educational technology is increasingly focused on tailoring instruction to the individual learner (a trend that was greatly accelerated in 2020 by the COVID-19 pandemic). Oftentimes, learning takes place without a teacher at all (i.e., self-regulated study). Learners can choose for themselves how they approach their own study. In these many different learning scenarios, people who strongly endorse the idea of individual learning styles are likely to try to match strategies to "strengths." These learning-style aligned strategies may not be optimal, and rather, may direct attention away from more effective strategies.

A Distraction from Effective Practices or a Disguise for Effective Practices?

One of the primary concerns about the widespread educational focus on learning styles is that it is taking time, effort, resources, and investment away from other, more scientifically supported learning techniques and strategies (Scott, 2010). Despite its widespread endorsement, there is little empirical evidence to support enthusiasm for individual learning styles. Meanwhile, there is rich, robust evidence to support the effectiveness of other, often less well-known learning strategies. In direct contrast to individual learning styles, there is a large body of research emphasizing the importance of dual-coding and multimedia learning (Butcher, 2014; Cuevas & Dawson, 2017; Mayer, 2002; Paivio, 2014). Rather than arguing that some people are stronger visual or verbal learners, there is evidence that everyone

learns best when they encode information multimodally (i.e., both visually *and* verbally, and integrating the multiple representations). There are many evidence-supported domain-general strategies that encourage deep and active information processing and promote long-term learning, such as distributing study (Carpenter, 2017), interleaving (Brunmair & Richter, 2019), generative activities (Fiorella & Mayer, 2016), and retrieval practice (Yang et al., 2021). There are also many discipline-specific strategies for learning specific concepts in specific domains (e.g., teaching understanding of the equal sign to improve middle school algebra, McNeil et al., 2006). Yet these empirically supported learning strategies are far less well-known and appreciated by the general public than the flawed and controversial learning styles meshing hypothesis. To some researchers and learning styles critics, the intense focus on individual learning styles in education may divert time and resources away from learning strategies proven to be effective.

Ironically, the instructional design recommendations made by learning styles proponents are often well aligned with empirically supported recommendations, though not for the reasons that they think. By aiming to "teach around the cycle," recommendations end up aligning with multimedia learning and dual-coding principles, and with student-centered, generative, active, and collaborative learning principles. For example, Felder (2010) lists that teachers should not just lecture, but rather should provide opportunities in class for both active practice of methods (for the active learners) and reflection on the outcomes (for the reflective learners); that basic principles and theories should be taught (for the intuitive learners) but only in the context of real-world applications and many concrete examples (for the sensing learners); that information should be presented both verbally and visually rather than only verbally; that material should be taught in a logical and systematic way (for the thinkers and sequential learners) but also connect it to students' prior knowledge and experience and to real-world issues (for feelers and global learners). Burke and Dunn (2002) described how training a cohort of teachers on learning styles and encouraging them to implement new instructional strategies in their classrooms was impactful:

> *As teachers introduced small-groups strategies such as team learning, circle of knowledge, brain-storming, and case studies (*Dunn & Dunn, 1992, 1993*), students began to learn by participating rather than merely listening. When teachers added floor games, children who previously had seemed hyperactive and attentive learned through active-but-disciplined-mobility rather than passivity. As electroboards, flip chutes, and pic-a-holes (*Dunn & Dunn, 1992, 1993*) were introduced, students began learning through self-teaching manipulatives rather than playing with objects and frequently being told, 'Keep your hands to yourself!' (*p. 105).

However, there is little to suggest that these positive impacts are a result of *individual* learning styles; there is plenty of evidence to suggest that these strategies are useful for engaging the type of processes that are likely to benefit *all* learners, regardless of their preferred style.

Charitably, one might argue that the idea of individual learning styles can act as a disguise for effective practices: it is the sugar that helps the medicine go down. Even though the basis of the individual learning styles theory is not solid, it is

appealing to educators (the sugar) and the practical impact is positive: it can introduce metacognitive discussions that foster student–teacher relationships and increase the diversity of instructional strategies available to teachers (the medicine). Less charitably, one could argue that it is never good practice to let faulty premises guide actions. Although the idea of individual learning styles could have some inadvertent benefits, it is also likely to lead to misconceptions and detrimental practices too. Rather, it is better to teach teachers about the fundamental cognitive processes that lead to better long-term learning.

A Harmless Myth?

Another possibility is that the belief in learning styles does not take away from more effective practices, nor does it meaningfully bring in discussion of other effective practices. Instead, it is possible that learning styles is merely a harmless myth—that although the learning styles myth is available in long-term memory stores (and people endorse it when asked about it), it may not actually be brought to bear upon educational scenarios. For example, people understand that information is forgotten over time and that learning occurs with more study. However, lab experiments have shown that when asked during study, people often act in ways that do not reflect their general knowledge. Koriat et al. (2004) presented participants with a list of words and asked them to make predictions about recall. Some were asked to predict how much they would remember if tested immediately; others were asked to predict how much they would remember if tested a week later. Participants gave roughly the same estimate, regardless of condition; their knowledge about forgetting over time did not affect their judgments. In another study, people gave similar recall predictions for items that they knew they were not going to study again as they did for items they knew that they would study three additional times; their knowledge about learning through more study did not affect their judgments (Kornell & Bjork, 2009). Individual learning styles might be another case where people's theoretical beliefs do not affect practical actions. This discrepancy is made even more likely by the fact that when asked about the nature of their individual learning styles beliefs, participants appear to have internal logical inconsistencies. Whether classified as essentializers or as non-essentializers, people generally believed that a person's learning style is detectable at childhood, but also generally believed that a person can have multiple learning styles and have a different learning style for different academic subjects (Nancekivell et al., 2020). In other words, people's beliefs are not coherent.

In a survey of 426 undergraduate anatomy students, Husmann and O'Loughlin (2018) asked students to complete a study strategies questionnaire and the VARK questionnaire. They found that students' reported use of study strategies was not correlated with their learning style preferences from the VARK. In our own data (Yan & Fralick, unpublished data), we found that despite high levels of individual learning styles endorsement (mean endorsement = 5.04, SD = 0.70, where 1 = no endorsement, and 6 = strong endorsement of learning styles), participants' efficacy

ratings of strategies were not grouped by modality. We presented 199 participants (129 females, 67 male, and 3 other or decline to disclose, mean age = 21.17, age range 18–30) with a list of 21 strategies that aligned with each of the three "styles" (e.g., use concept maps, convert visual illustrations and diagrams into words, act out the information I am learning) from the VAK helpsheets. We asked each participant to rate how effective they thought each strategy was for them in their own learning. We then conducted a confirmatory factor analysis (with oblique factor rotation to allow for correlated factors) to test whether the strategies fell into three modality-aligned factors. They did not, $CFI = 0.685$, $TLI = 0.644$. Even though people endorse learning styles, they did not treat the strategies as if they were related to modalities. Thus, learning styles beliefs might not affect how students think about the learning strategies that are available to them.

Conclusion

In general, the literature on individual learning styles has tended to fall in one of two camps. In one camp are a substantial set of psychology and cognitive science researchers (usually also educators, but tend to primarily identify as researchers), who argue that there is no empirical evidence to support the notion that learners' style preferences are mapped onto their actual strengths and weaknesses in learning. These researchers do not doubt that individual differences are important, but are simply arguing that learning styles are not the important individual difference variable. This researcher camp has tended to make general statements about potential harms of perpetuating the idea of learning styles (categorizing and pigeon-holing students, distraction from effective teaching and learning strategies), but has not often directly collected evidence on these potential harms.

In the other camp are a number of educators (who might also be researchers, but primarily identify as educators) who argue that the meshing hypothesis is irrelevant (e.g., Felder, 2010, 2020), and focus instead on pedagogical implications: that a learning styles framework can be useful to help facilitate teacher–student conversations that make individual students feel valued, and to diversify instructional approaches. Understood in this way, it can be easy to see why people in this camp would be so convinced that the idea of individual learning styles is useful in education—it feels consistent with a focus on equity, diversity, and recognizing students as individuals. Although the theoretical basis of these practices might be empirically tenuous, the outcomes can be positive (e.g., the instructional recommendations by learning styles proponents are helpful for moving teachers away from lecture-only teaching). Largely, these differences in focus also might explain why the two camps have continued to talk past each other for so many decades. However, there is also little direct evidence that using a learning styles framework actually has these positive benefits on teacher–student relationships and teaching practices (especially given survey evidence that most teachers interpret learning styles to mean that styles should be "matched" to the learner, Newton & Salvi, 2020).

In other words, there is neither great evidence of the potential harms that critics warn about, nor of the potential benefits that the proponents espouse. But rather than weighing the two sides of the argument equally, it is important to note that the potential positive outcomes do not rely on a learning styles framework. Teachers can employ non-learning styles-related language to foster relationships with their students. Most student-centered learning approaches have nothing to do with learning styles. Teachers can also draw upon empirically supported learning theories to improve and diversify their instructional approaches. There is now a large body of work describing how active learning approaches can improve student achievement—again, these make no reference to individual learning styles, but rather are focused on the types of engagement and cognitive processing that benefits all learners, and which also contribute to promoting equity (Benassi et al., 2014; Lombardi et al., 2021; Theobald et al., 2020). In fact, one of the dangerous aspects of relying on a learning styles framework is that the frameworks themselves are often so conceptually unclear that they can become a "grab bag" of ideas. As many have shown, endorsing the idea of individual learning styles can mean so many different things (Cassidy, 2004; Coffield et al., 2004a, 2004b; Nancekivell et al., 2020; Papadatou-Pastou et al., 2020; Sharp et al., 2008) that it ends up running the risk of becoming "just-so" stories that we tell ourselves to justify our own pre-existing intuitions, biases, and beliefs. Instead, time, effort, and money are better directed toward promoting strategies for student learning, metacognition, and motivation that are better supported by empirical evidence.

References

Allcock, S. J., & Hulme, J. A. (2010). Learning styles in the classroom: Educational benefit or planning exercise? *Psychology Teaching Review, 16*(2), 67–77.

Aslaksen, K., & Lorås, H. (2019). Matching instruction with modality-specific learning style: Effects on immediate recall and working memory performance. *Education Sciences, 9*, Article 32. https://doi.org/10.3390/educsci9010032

Barbe, W., Swassing, R., & Milone, M. (1979). *Teaching through modality strengths: Concepts and practices*. Zaner-Bloser.

Benassi, V. A., Overson, C. E., & Hakala, C. M. (2014). *Applying science of learning in education: Infusing psychological science into the curriculum*. Society for the Teaching of Psychology. http://teachpsych.org/ebooks/asle2014/index.php

Brunmair, M., & Richter, T. (2019). Similarity matters: A meta-analysis of interleaved learning and its moderators. *Psychological Bulletin, 145*(11), 1029–1052. https://doi.org/10.1037/bul0000209

Burke, K., & Dunn, R. (2002). Learning style-based teaching to raise minority student test scores there's no debate! *The Clearing House: A Journal of Educational Strategies, Issues, and Ideas, 76*(2), 103–106. https://doi.org/10.1080/00098650209604959

Butcher, K. R. (2014). The multimedia principle. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 174–205). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.010

Carpenter, S. K. (2017). Spacing effects on learning and memory. In J. H. Byrne (Ed.), *Learning and memory: A comprehensive reference* (pp. 465–485). Elsevier. https://doi.org/10.1016/b978-0-12-809324-5.21054-7

Cassidy, S. (2004). Learning styles: An overview of theories, models, and measures. *Educational Psychology, 24*(4), 419–444. https://doi.org/10.1080/0144341042000228834

Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004a). *Learning styles and pedagogy in post-16 learning: A systematic and critical review*. Learning and Skills Research Centre.

Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004b). *Should we be using learning styles? What research has to say to practice*. Learning and Skills Research Centre.

Cuevas, J., & Dawson, B. L. (2017). A test of two alternative cognitive processing models: Learning styles and dual coding. *Theory and Research in Education, 16*(1), 40–64. https://doi.org/10.1177/1477878517731450

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*, Article 429. https://doi.org/10.3389/fpsyg.2012.00429

Duff, A., & Duffy, T. (2002). Psychometric properties of Honey & Mumford's learning styles questionnaire (LSQ). *Personality and Individual Differences, 33*(1), 147–163. https://doi.org/10.1016/s0191-8869(01)00141-6

Dunn, R., & Dunn, K. (1992). *Teaching elementary students through their individual learning styles: Practical approach for grades 3–6*. Allyn and Bacon.

Dunn, R., & Dunn, K. (1993). *Teaching secondary students through their individual learning styles: Practical approach for grades 7–12*. Allyn and Bacon.

Dweck, C. S. (2006). *Mindset: The new psychology of success*. Random House.

Dweck, C. S., Chiu, C.-Y., & Hong, Y.-Y. (1995). Implicit theories and their role in judgments and reactions: A word from two perspectives. *Psychological Inquiry, 6*(4), 267–285. https://doi.org/10.1207/s15327965pli0604_1

Felder, R. (1996). Matters of style. *ASEE Prism, 6*(4), 18–23. https://www.jstor.org/stable/24155919

Felder, R. M. (2010). Are learning styles invalid? (Hint: No!). *On-Course Newsletter, 27*, 1–7. https://doi.org/10.13140/RG.2.1.3417.7041

Felder, R. M. (2020). Opinion: Uses, misuses, and validity of learning styles. *Advances in Engineering Education, 8*(1), 1–16. Retrieved from https://advances.asee.org/wp-content/uploads/vol08/issue01/Papers/AEE-Pathways-Felder.pdf

Fiorella, L., & Mayer, R. E. (2016). Eight ways to promote generative learning. *Educational Psychology Review, 28*(4), 717–741. https://doi.org/10.1007/s10648-015-9348-9

Fisher, O., & Oyserman, D. (2017). Assessing interpretations of experienced ease and difficulty as motivational constructs. *Motivation Science, 3*(2), 133–163. https://doi.org/10.1037/mot0000055

Fleming, N., & Baume, D. (2006). Learning styles again: VARKing up the right tree! *Educational Developments, 7*(4), 4–7.

Fleming, N. D., & Mills, C. (1992). Not another inventory, rather a catalyst for reflection. *To Improve the Academy: A Journal of Educational Development, 11*(1), 137–155. https://doi.org/10.1002/j.2334-4822.1992.tb00213.x

Furey, W. M. (2020). The stubborn myth of learning styles: How teacher certification exam prep materials peddle a debunked theory. *Education Next, 20*(3), 8–12.

Husmann, P. R., & O'Loughlin, V. D. (2018). Another nail in the coffin for learning styles? Disparities among undergraduate anatomy students' study strategies, class performance, and reported VARK learning styles. *Anatomical Sciences Education, 12*(1), 6–19. https://doi.org/10.1002/ase.1777

Knoll, A. R., Otani, H., Skeel, R. L., & Van Horn, K. R. (2016). Learning style, judgements of learning, and learning of verbal and visual information. *British Journal of Psychology, 108*(3), 544–563. https://doi.org/10.1111/bjop.12214

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice Hall.

Koriat, A., Bjork, R. A., Sheffer, L., & Bar, S. K. (2004). Predicting one's own forgetting: The role of experience-based and theory-based processes. *Journal of Experimental Psychology: General, 133*(4), 643–656. https://doi.org/10.1037/0096-3445.133.4.643

Kornell, N., & Bjork, R. A. (2009). A stability bias in human memory: Overestimating remembering and underestimating learning. *Journal of Experimental Psychology: General, 138*(4), 449–468. https://doi.org/10.1037/a0017350

Krätzig, G. P., & Arbuthnott, K. D. (2006). Perceptual learning style and learning proficiency: A test of the hypothesis. *Journal of Educational Psychology, 98*(1), 238–246. https://doi.org/10.1037/0022-0663.98.1.238

Lombardi, D., Shipley, T. F., Bailey, J. M., Bretones, P. S., Prather, E. E., Ballen, C. J., Knight, J. K., Smith, M. K., Stowe, R. L., Cooper, M. M., Prince, M., Atit, K., Uttal, D. H., LaDue, N. D., McNeal, P. M., Ryker, K., St. John, K., van der Hoeven Kraft, K. J., & Docktor, J. L. (2021). The curious construct of active learning. *Psychological Science in the Public Interest, 22*(1), 8–43. https://doi.org/10.1177/1529100620973974

Martin, S. (2010). Teachers using learning styles: Torn between research and accountability? *Teaching and Teacher Education, 26*(8), 1583–1591.

Massa, L. J., & Mayer, R. E. (2006). Testing the ATI hypothesis: Should multimedia instruction accommodate verbalizer-visualizer cognitive style? *Learning and Individual Differences, 16*(4), 321–335. https://doi.org/10.1016/j.lindif.2006.10.001

Mayer, R. E. (2002). Multimedia learning. In B. H. Ross (Ed.), *Psychology of learning and motivation* (Vol. 41, pp. 85–139). Elsevier. https://doi.org/10.1016/s0079-7421(02)80005-6

McNeil, N. M., Grandau, L., Knuth, E. J., Alibali, M. W., Stephens, A. C., Hattikudur, S., & Krill, D. E. (2006). Middle-school students' understanding of the equal sign: The books they read can't help. *Cognition and Instruction, 24*(3), 367–385. https://doi.org/10.1207/s1532690xci2403_3

Nancekivell, S. E., Shah, P., & Gelman, S. A. (2020). Maybe they're born with it, or maybe it's experience: Toward a deeper understanding of the learning style myth. *Journal of Educational Psychology, 112*(2), 221–235. https://doi.org/10.1037/edu0000366

Nelson, T. O., & Narens, L. (1990). Metamemory: A theoretical framework and new findings. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 26, pp. 125–173). Academic Press.

Newton, P. M. (2015). The learning styles myth is thriving in higher education. *Frontiers in Psychology, 6*, Article 1908. https://doi.org/10.3389/fpsyg.2015.01908

Newton, P. M., & Miah, M. (2017). Evidence-based higher education – Is the learning styles 'myth' important? *Frontiers in Psychology, 8*, Article 444. https://doi.org/10.3389/fpsyg.2017.00444

Newton, P. M., & Salvi, A. (2020). How common is belief in the learning styles neuromyth, and does it matter? A pragmatic systematic review. *Frontiers in Education, 5*, Article 602451. https://doi.org/10.3389/feduc.2020.602451

Niemiec, C. P., & Ryan, R. M. (2009). Autonomy, competence, and relatedness in the classroom: Applying self-determination theory to educational practice. *Theory and Research in Education*, *7*(2), 133–144.

Paivio, A. (2014). Intelligence, dual coding theory, and the brain. *Intelligence, 47*, 141–158. https://doi.org/10.1016/j.intell.2014.09.002

Papadatou-Pastou, M., Touloumakos, A. K., Koutouveli, C., & Barrable, A. (2020). The learning styles neuromyth: When the same term means different things to different teachers. *European Journal of Psychology of Education, 36*(2), 511–531. https://doi.org/10.1007/s10212-020-00485-2

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9*(3), 105–119. https://doi.org/10.1111/j.1539-6053.2009.01038.x

Riding, R., & Cheema, I. (1991). Cognitive styles—An overview and integration. *Educational Psychology, 11*(3–4), 193–215. https://doi.org/10.1080/0144341910110301

Rogowsky, B. A., Calhoun, B. M., & Tallal, P. (2015). Matching learning style to instructional method: Effects on comprehension. *Journal of Educational Psychology, 107*(1), 64–78. https://doi.org/10.1037/a0037478

Rogowsky, B. A., Calhoun, B. M., & Tallal, P. (2020). Providing instruction based on students' learning style preferences does not improve learning. *Frontiers in Psychology, 11*, Article 164. https://doi.org/10.3389/fpsyg.2020.00164

Rosenfeld, M., & Rosenfeld, S. (2004). Developing teacher sensitivity to individual learning differences. *Educational Psychology, 24*(4), 465–486. https://doi.org/10.1080/0144341042000228852

Scott, C. (2010). The enduring appeal of 'learning styles.' Australian Journal of Education, 54(1), 5–17. doi: https://doi.org/10.1177/000494411005400102

Sharp, J. G., Bowker, R., & Byrne, J. (2008). VAK or VAK-uous? Towards the trivialisation of learning and the death of scholarship. *Research Papers in Education, 23*(3), 293–314. https://doi.org/10.1080/02671520701755416

Son, L. K., & Schwartz, B. L. (2002). The relation between metacognitive monitoring and control. In T. J. Perfect & B. L. Schwartz (Eds.), *Applied Metacognition* (pp. 15–38). Cambridge University Press. https://doi.org/10.1017/CBO9780511489976.003

Strauss, V. & Gardner, H. (2013, October 16). Howard Gardner: 'Multiple intelligences' are not 'learning styles.' *The* Washington Post. Retrieved from https://www.washingtonpost.com/news/answer-sheet/wp/2013/10/16/howard-gardner-multiple-intelligences-are-not-learning-styles/

Syofyan, R., & Siwi, M. K. (2018). The impact of visual, auditory, and kinesthetic learning styles on economics education teaching. *Proceedings of the First Padang International Conference On Economics Education, Economics, Business and Management, Accounting and Entrepreneurship (PICEEBA 2018)*. doi: https://doi.org/10.2991/piceeba-18.2018.17

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., II, Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E., … Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences, 117*(12), 6476–6483. https://doi.org/10.1073/pnas.1916903117

VARK Learn (n.d.) Understanding the results. Retrieved from https://vark-learn.com/introduction-to-vark/understanding-the-results. Accessed Retrieved 25 June 2021.

Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological Review, 92*(4), 548–573. https://doi.org/10.1037/0033-295X.92.4.548

Willingham, D. T., Hughes, E. M., & Dobolyi, D. G. (2015). The scientific status of learning styles theories. *Teaching of Psychology, 42*(3), 266–271. https://doi.org/10.1177/0098628315589505

Yan, V. X., & Fralick, C. M. (unpublished data). *Correlates and consequences of endorsing individual learning styles*.

Yang, C., Luo, L., Vadillo, M. A., Yu, R., & Shanks, D. R. (2021). Testing (quizzing) boosts classroom learning: A systematic and meta-analytic review. *Psychological Bulletin, 147*(4), 399–435. https://doi.org/10.1037/bul0000309

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory Into Practice, 41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2

Zhou, M. (2011). Learning styles and teaching styles in college English teaching. *International Education Studies, 4*(1), 73–77. https://doi.org/10.5539/ies.v4n1p73

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