International Report:
Neuromyths and Evidence-Based Practices in Higher Education

ONLINE LEARNING CONSORTIUM

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Neuromyths and Evidence-Based Practices in Higher Education

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Preface

Educators make countless decisions about their teaching and course design that are likely to impact on how well their students learn. At the heart of these decisions is a set of ideas about how learning proceeds, so it is self-evidently important that these ideas are valid and reflect our current scientific understanding. And yet, a growing body of research is revealing that many of the underlying beliefs of educators about learning are based on myth and misunderstanding – particularly in regard to the brain.

The data presented in this report make clear that higher education is not immune from these "neuromyths" about how learning proceeds. As the authors point out, misunderstandings are not restricted to any particular category of academic or their role within their institutions, but they are related to the extent to which educators engage with professional development and reading about the sciences of mind and brain.

With our increasing concern for the student learning experience, and our growing awareness of the dangers of online misinformation, the need for university and college institutions to ensure their practice is scientifically grounded and evidence-based has never been greater. I welcome this report as a source of much-needed insight into the diverse ideas held by higher education professionals about the role of the brain in learning, and the potential value of professional development in this area.

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Executive Summary

Neuromyths are false beliefs, often associated with education and learning, that stem from misconceptions or misunderstandings about brain function. Over the past decade, there has been an increasing amount of research worldwide on neuromyths in education. Belief in neuromyths has been found to be prevalent among K-12 teachers (Dekker, Lee, Howard-Jones, & Jolles, 2012; Garaizar, Vadillo, & Ferrero, 2016; Gleichgerrcht, Lira Luttges, Salvarezza, & Campos, 2015; Karakus, Howard-Jones, & Jay, 2015; Pickering & Howard-Jones, 2011; Sarrasin, Riopel, & Masson, 2019) as well as among pre-service K-12 teachers and undergraduate, graduate, and postgraduate students (Dündar & Gündüz, 2016; Papadatou-Pastou, Haliou, & Vlachos, 2016; Park & Shin, 2016). In 2017, a comparative study found that the general public endorsed significantly more neuromyths than educators and individuals with high neuroscience exposure (Macdonald, Germine, Anderson, Christodoulou, & McGrath, 2017).

The purpose of this international, non-experimental study was threefold. First, this study examined the awareness of neuromyths and general knowledge about the brain in higher education among instructors, instructional designers, and administrators who work with professional development (referred to as administrators) in two- and four-year institutions of higher education (IHE) across on-campus, blended/hybrid, and online programs. Second, this study examined the awareness of evidence-based practices from the learning sciences and Mind (psychology), Brain (neuroscience) and Education (pedagogy and didactics; MBE) science, among these different professional groups within higher education. Third, this study examined predictors of awareness of (a) neuromyths and general knowledge about the brain, and (b) evidence-based practices in higher education.

Respondents completed an online survey with three sections. The first section focused on neuromyths and general knowledge about the brain. The second section focused on evidence-based practices from the learning sciences and MBE science related to the brain, teaching practices, and learning processes. The third section focused on professional development and collected demographic data, including: primary role (instructor, instructional designer, administrator), educational modality (teaching or developing courses for on-campus, blended/hybrid, online), institution level (two-year, four-year), institution type (public, private, for-profit), instructor role (full-time, part-time), number of years teaching, number of years as an instructional designer, gender, age, time since highest degree completed, and level of highest degree completed (associate/bachelor's, master's, terminal, other).

The survey was sent by email to the Online Learning Consortium (OLC) listserv which included 65,780 emails across higher education institutions in the United States and worldwide. A total of 13,992 surveys were opened with 877 clicks on the survey link. Email recipients were asked to share the survey invitation with instructors, instructional designers, and professional development administrators who worked within their institutions or at other higher education institutions.

Frequencies and cross-tabulations were used to present descriptive data. The Kruskal-Wallis H test (i.e., one-way ANOVA by ranks) was used, due to unequal sample sizes and distributions between them, as a non-parametric method for reporting median percent correct responses to the statements which included neuromyths, general information about the brain, and evidence-based practices. Post-hoc analyses for the Kruskal-Wallis H tests included Bonferroni-corrected, Mann-Whitney U tests. Categorical linear regression analyses were used to determine predictors of awareness of (a) neuromyths and general knowledge about the brain, and (b) evidence-based practices in higher education.

A total of 1,290 surveys were completed, of which 929 met the criteria for inclusion, which is described in Section Five: Methodology. Respondents included full-time instructors (33%; n = 305), part-time instructors (13%; n = 122), instructional designers (26%; n = 239), and administrators involved in professional development (18%; n = 172). Ten percent (n = 91) selected “other” (see Section Six: Demographics for “other” responses; see Figure 1).

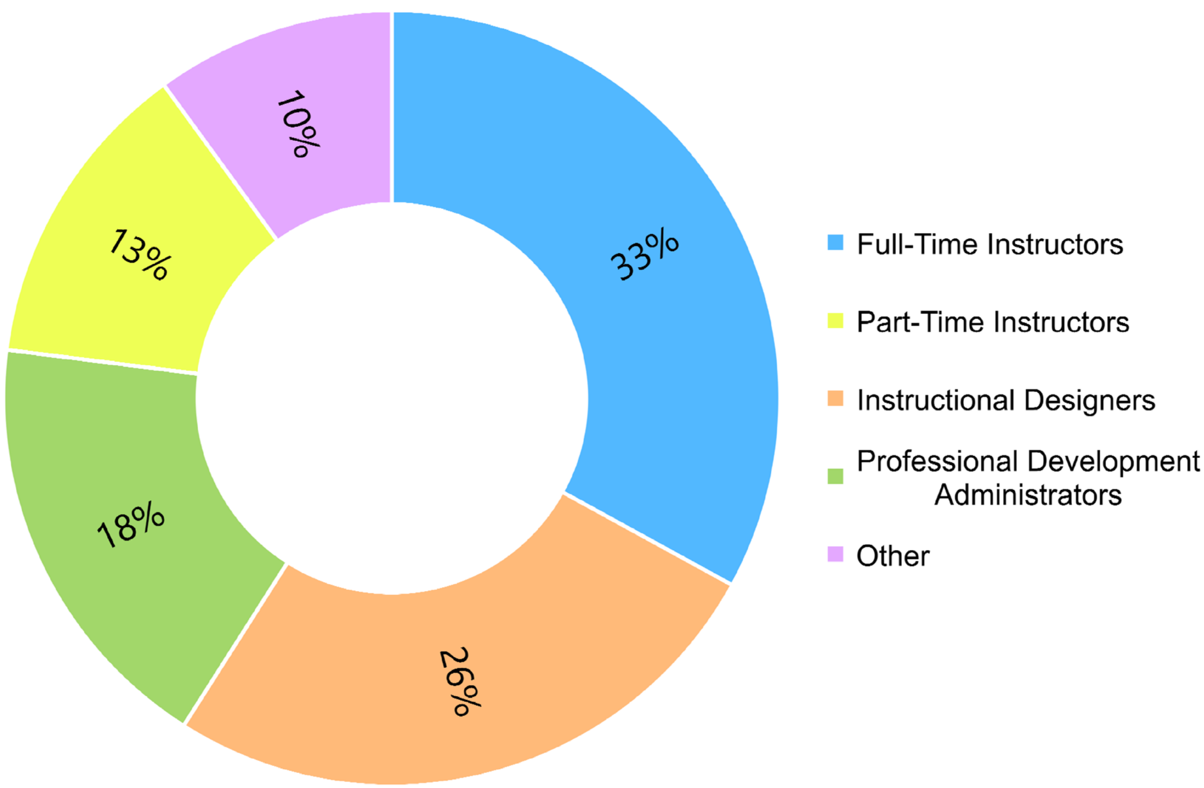

Figure 1. Breakdown of Respondents by Primary Role

Of the respondents, 68% (n = 619) worked at four-year institutions, 18% (n = 167) worked at two-year institutions. Fourteen percent (n = 125) worked at “other” types of institutions (see Section Six: Demographics for “other” responses; see Figure 2). Eighteen participants did not answer this question.

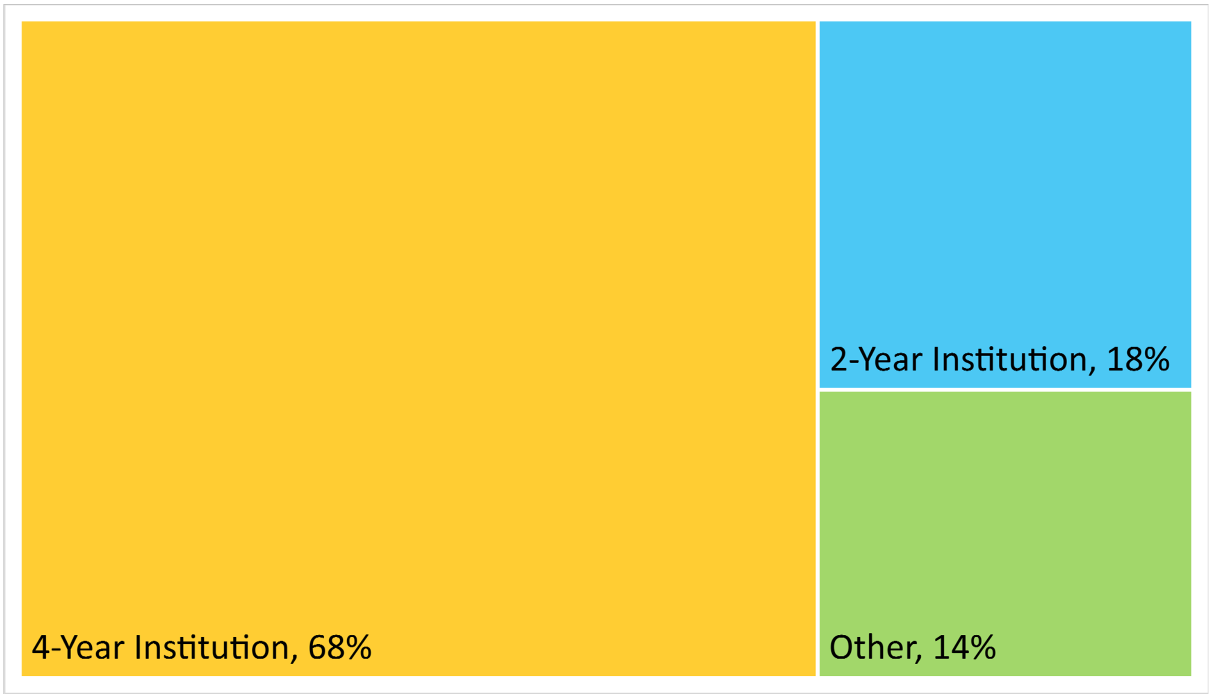

Figure 2. Breakdown of Respondents by Institutional Level

Over half of the respondents worked at public institutions (61%; n = 553) followed by private institutions (28%; n = 258), and for-profit institutions (7%; n = 62). Four percent (n = 39) chose "other" types of institutions (see Section Six: Demographics for "other" responses; see Figure 3). Seventeen participants did not answer this question.

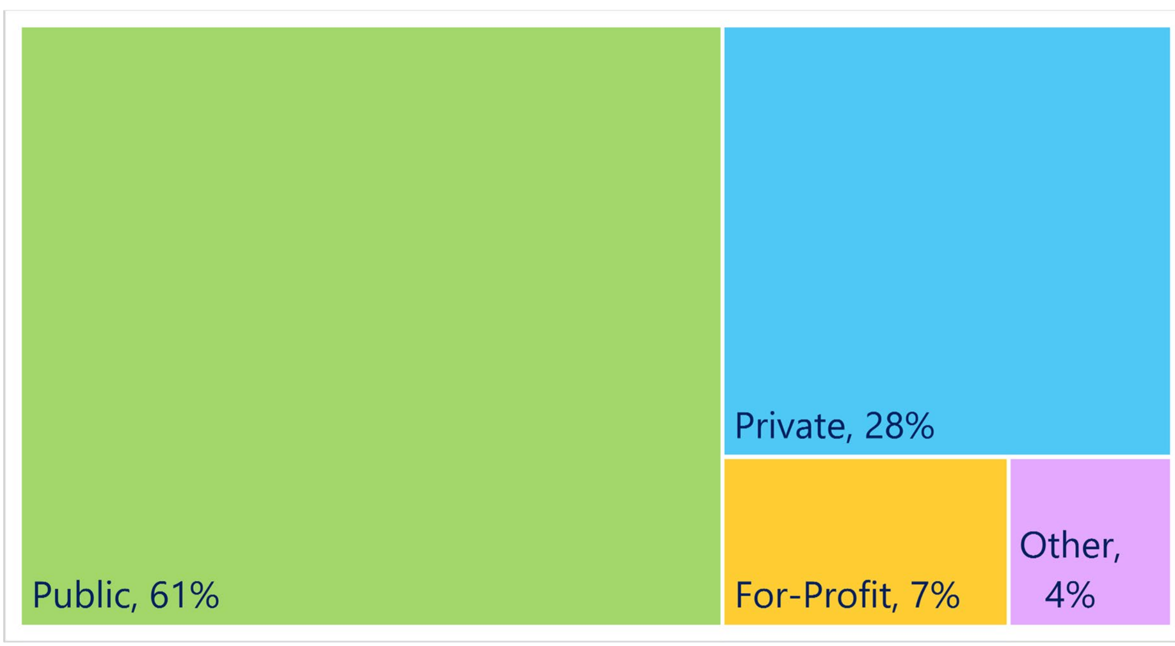

Figure 3. Breakdown of Respondents by Institutional Type

Of the respondents, 88% (n = 788) were from the United States while 12% (n = 112) were international. Respondents from the United States represented 48 of 50 states. A total of 45 countries were represented. Twenty-nine participants did not answer this question.

Key Findings

- The majority of respondents reported an interest in learning more about the brain and its influence on learning.

- Respondents indicated they found scientific knowledge about the brain and its influence on learning to be interesting and valuable to their teaching practice, course development, and professional development.

- Correct responses to the 23 statements, which included neuromyths and general information about the brain, ranged from 11% to 94% for instructors, instructional designers, and administrators.

- Neuromyths to which respondents were most susceptible included:
    - Listening to classical music increases reasoning ability.
    - A primary indicator of dyslexia is seeing letters backwards.
    - Individuals learn better when they receive information in their preferred learning styles (e.g., auditory, visual, kinesthetic).
    - Some of us are "left-brained" and some are "right-brained" due to hemispheric dominance, and this helps explain differences in how we learn.
    - We only use 10% of our brain.

- Correct responses to the 28 statements representing evidence-based practices from the learning sciences and MBE science ranged from 26% to 99% for instructors, instructional designers, and administrators.

- Evidence-based practices to which respondents had the greatest awareness included:
    - Emotions can affect human cognitive processes, including attention, learning and memory, reasoning, and problem-solving.
    - Explaining the purpose of a learning activity helps engage students in that activity.
    - Maintaining a positive atmosphere in the classroom helps promote learning.
    - Stress can impair the ability of the brain to encode and recall memories.
    - Meaningful feedback accelerates learning.

- Instructional designers had greater awareness of neuromyths, knowledge about the brain, and evidence-based practices than instructors and administrators.

- There were no significant differences in (a) awareness of neuromyths and knowledge about the brain, or (b) evidence-based practices and demographic categories including: educational modality (i.e., teaching or developing courses for on-campus, blended/hybrid, online), institution level (two-year, four-year), institution type (public, private, for-profit), instructor role (full-time, part-time), number of years teaching, number of years as an instructional designer, gender, age, or time since highest degree completed.

- Reading journals related to neuroscience, psychology, and MBE science increased awareness of (a) neuromyths and general information about the brain, and (b) evidence-based practices.

- Professional development is a predictor of awareness of (a) neuromyths and general knowledge about the brain, and (b) evidence-based practices among higher education instructors, instructional designers, and administrators.

Definitions

For the purpose of this study, vocabulary from the OLC (Mayadas, Miller & Sener, 2015) was used to assure shared and consistent definitions for three commonly used terms:

- **Classroom Course:** “Course activity is organized around scheduled class meetings held onsite at an institution or another location” (para. 8).
- **Blended/Hybrid Course:** “Online activity is mixed with classroom meetings, replacing a significant percentage, but not all required face-to-face instructional activities” (para. 11).
- **Online Course:** “All course activity is done online; no requirements for on-campus activity” (para. 13).

Introduction

Economic and demographic shifts are transforming the higher education landscape (Carlson, 2018; Cohn & Caumont, 2016; Fong, Halfond, & Schroeder, 2017). To meet the needs of an increasingly diverse student population, and to provide expanded course offerings, institutions of higher education (IHE) now provide different delivery modalities for learning, including on-campus, blended/hybrid, and online courses and programs. Instructors today, therefore, need diverse skills to teach effectively across these multiple modalities. More than ever, instructional designers who support online and blended/hybrid modalities need to develop courses that maximize engagement, support academic performance, and meet intended outcomes while applying evidence-based pedagogical and didactic practices. Furthermore, administrators involved in professional development need to provide instructors and instructional designers with training to support the highest quality of teaching and learning across multiple educational modalities.

Since 1987, tuition has risen 213% at four-year public institutions, and 129% at private four-year institutions (Martin, 2017) while student debt has climbed to $1.53 trillion (Singeltary, 2018). During this time, IHEs have come under increased scrutiny from students, as well as from society as a whole, about the cost-benefit ratio of the higher education experience (Abel & Deitz, 2014; Mulhern, Spies, & Wu, 2015). The convergence of shifting enrollments and rising costs with a sharper focus on students' expectations now places more stringent demands on higher education, particularly with respect to instruction and instructional design. Thus, the base of what was previously considered "general pedagogical knowledge" (Schulman, 1986) should be expanded to include new information grounded in the learning sciences. Researchers in the learning sciences are working collaboratively to document ways in which the brain learns best, and to design environments and teaching interventions that improve the likelihood of learning for a wide range of learners. However, not all instructors, instructional designers, or administrators in higher education are aware of key scientific findings about the brain, mind, and learning that are relevant to course development and teaching.

Research shows a relationship between an instructor's beliefs about learning and her/his instructional practices (Brownlee, Ferguson & Ryan, 2017; Knapp, 2013; OECD, 2009; Nie, Tan, Liau, Lau, & Chua, 2013; Stein & Wang, 1988), which, in turn, can influence learners' epistemological beliefs (Brownlee et al., 2017; Johnston, Woodside-Jiron, & Day, 2001). This connection has been established mainly with regard to teachers' self-efficacy in K-12 education and primarily in traditional teaching in face-to-face, onsite environments.

This international study was designed as the first to examine "beliefs" from the lens of awareness and predictors of (a) neuromyths and general knowledge about the brain, and (b) evidence-based practices from the learning sciences and MBE science among instructors, instructional designers, and administrators in two- and four-year IHEs across on-campus, blended/hybrid, and online programs.

The seven sections within this report present the key findings, with an emphasis on implications for instruction, instructional design, and the role of professional development.

Section One focuses on awareness of neuromyths and general knowledge about the brain. *What are neuromyths? Who is more likely to be aware of neuromyths and general information about the brain?*

Section Two explores the types of evidence-based practices related to the learning science and MBE science that might serve as protective factors against susceptibility to neuromyths. *What type of new pedagogical content knowledge base should higher education instructors, instructional designers, and administrators be aware of?*

Section Three examines professional development as a predictor for awareness of (a) neuromyths and general knowledge about the brain, and (b) evidence-based practices. This section also examines perceived value and interest of scientific knowledge about the brain and its influence on learning to teaching practice, course development, and professional development. *How and to what extent does professional development that integrates the learning sciences and MBE science predict awareness of neuromyths and general knowledge about the brain*, *or evidence-based practices? What is the level of interest about the brain and its influence on learning among instructors, instructional designers, and administrators?*

Section Four provides conclusions and recommendations guided by the research questions and based on the findings. *Given the findings of this report, how and to what extent should IHEs consider reviewing professional development provided for instructors, instructional designers, and administrators across all educational modalities? How can future research on neuromyths and evidence-based practices add to the literature in the learning sciences and MBE science?*

Section Five provides an overview of the methodology for this study including the purpose, significance, research questions, measures, and methods.

Section Six provides a breakdown of the demographics of the respondents in this study, including primary role, institution level, institutional type, primary location of employment, instructional format, course development format, highest degree completed, number of years teaching, number of years as an instructional designer, gender, age, time since highest degree completed, and level of highest degree completed (associate/bachelor’s, master’s, terminal, other).

Section Seven provides research-based explanations for each of the 23 neuromyths and statements about the brain, and 28 evidence-based practice statements from the learning sciences and MBE science.

The report concludes with the Appendices. Appendix A provides the survey. Appendix B provides tables for the full sets of answers (e.g., Correct, Incorrect, and I Don't Know) from the respondents for the statements which included (a) neuromyths, and information about the brain, and (b) evidence-based practices by primary role. Appendix C provides resources that may be of interest following the review of this report.

Section One: Awareness of Neuromyths and General Knowledge about the Brain in Higher Education

Neuromyths have been described as misconceptions that arise from misunderstanding, misquoting, misinterpretations, or the misreading of information about the brain (Geake & Cooper, 2003; Goswami, 2006; OCED, 2002). Examples of neuromyths include the belief that people use only 10% of their brains; teaching according to visual, auditory or kinesthetic learning styles increases academic performance; individuals are right-brained or left-brained; and there are critical periods in human development after which certain skills can no longer be learned (Betts & Parr, 2017; OECD, 2007; Tokuhama-Espinosa, 2018; Weale, 2017). Reasons for widespread neuromyth belief have been associated with "bandwagonism, popular press, commercial benefits, scientific literacy, and [because] humans want simplicity" (Tokuhama-Espinosa, 2018, p. 176; see Figure 4).

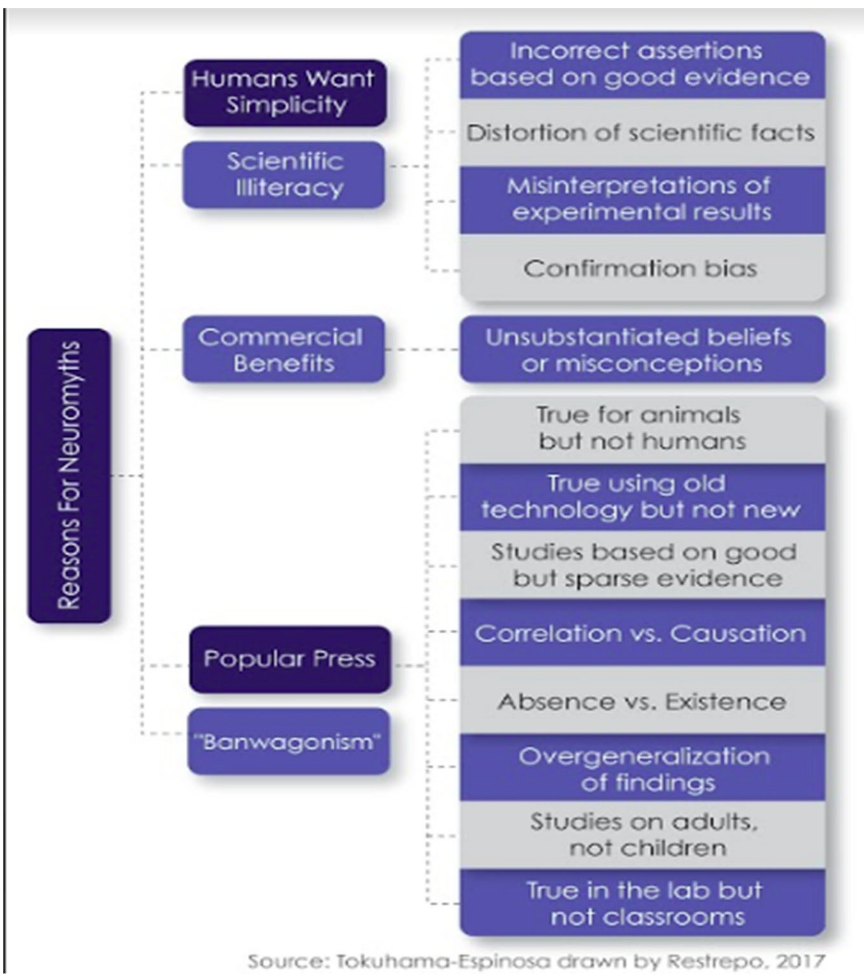

Figure 4. Reasons for Neuromyths. Source: Tokuhama-Espinosa, 2018, W.W. Norton. Reprinted with permission of the author.

Over the past decade, there has been tremendous growth in publications on the human brain both in academia and the popular media. However, educational approaches that claim to be “brain-based” often lack empirical support (Tardif, Doudin, & Meylan, 2015). Therefore, it is necessary to critically evaluate relevant sources. It is also important to understand the pedagogical beliefs of instructors, instructional designers, and administrators, and their awareness of neuromyths and general knowledge about the brain to better inform professional development that builds upon the literature and advancements in the learning sciences and MBE science.

Neuromyth Studies in K-12 Education

The extent to which neuromyths exist in education has been the focus of studies worldwide. Studies have shown belief in neuromyths to be high not only among preservice K-12 teachers in Greece (Deligiannidi & Howard-Jones, 2015), Turkey (Dündar & Gündüz, 2016), and the United States (Van Dijk & Lane, 2018) but also among K-12 teachers in Portugal (Rato, Abreu, & Castro-Caldas, 2011), the United Kingdom (Simmonds, 2014), the Netherlands (Dekker, Lee, Howard-Jones, & Jolles, 2012), China (Pei, Howard-Jones, Zhang, Liu, & Jin, 2015), and throughout Latin America (Gleichgerrcht, Lira Luttges, Salvarezza, & Campos, 2015). One of the most frequently endorsed neuromyths, ranging from 56-91%, is educator belief in the idea that students learn best when instruction is tailored to their particular “learning style” (Dekker et al., 2012; Deligiannidi & Howard-Jones, 2015; Howard-Jones et al., 2009; Pei et al., 2015; Van Dijk & Lane, 2018).

Neuromyth Studies Beyond K-12 Education

A few studies have examined neuromyth endorsement beyond K-12 teachers. Van Dijk and Lane (2018) examined neuromyth endorsement among preservice, K-12, and higher education instructors in the United States, finding that, although higher education instructors were less likely to endorse neuromyths than preservice or K-12 teachers, their rate of neuromyth endorsement was still over 50%. Similarly, Gleichgerrcht and colleagues (2015) compared neuromyths endorsement across 3,451 higher education instructors and K-12 teachers working in Argentina (n = 551), Chile (n = 598), Peru (n = 2,222), and other Latin American countries (n = 80, including Mexico, Nicaragua, Colombia, and Uruguay), finding that higher education instructors were less likely to endorse neuromyths than K-12 teachers.

Macdonald and colleagues (2017) compared neuromyths endorsement across educators, individuals with self-reported neuroscience background, and the general public. Results from this study revealed individuals with self-reported neuroscience backgrounds endorsed the fewest neuromyths (M = 46%) as compared to educators (M = 56%) and the general public (M = 68%). Similar to previous studies, Macdonald and colleagues (2017) found the most commonly endorsed neuromyths across groups were related to learning styles (general public M = 93%, educators M = 76%, high neuroscience exposure M = 78%) and dyslexia, (general public M = 76%, educators M = 59%, high neuroscience exposure M = 50%).

Howard-Jones (2014) identified the most persistent neuromyths endorsed across K-12 through higher education as being due to “cultural distance” between neuroscience and education, tracing persistent myths about the brain and learning as germinating from “seeds of confusion,” “cultural conditions,” and “biased distortions of scientific data” (pp. 817-819). Palis (2016) examined neuromyth endorsement among 145 community-college students, finding a similar pattern of endorsement as with preservice teachers, higher education instructors, and the general public, in which learning styles and the hemispheric dominance neuromyth were endorsed most widely (92-95%) among college-age students.

Findings

Section One of this study focuses on neuromyths and general knowledge about the brain. The survey included 23 statements that were adapted from three prior surveys (see Section Five: Methodology for survey development). The findings present data related to awareness of neuromyths and general knowledge about the brain by professional role, highest degree completed, reading journals, teaching and course development across formats, institution level, institution type, instructor role, number of years teaching, number of years as an instructional designer, gender, age, time since highest degree completed, and level of highest degree completed.

Awareness of Neuromyths and General Knowledge about the Brain: Professional Roles

Table 1 provides the descriptive data reporting percent correct responses (i.e., accurate responses) by respondents for each of the 23 statements broken down by professional roles (instructors, instructional designers, and administrators). For example, 15% of instructors answered Statement 1 correctly (i.e., accurately) while 13% of instructional designers and 11% of administrators answered the statement correctly (i.e., accurately). The percent correct responses ranged from 11% to 94% across all 23 statements. Table 1 also provides the answer key for the 23 statements. For example, Statement 1 is incorrect while Statement 4 is correct. Table 1 includes eight neuromyths (1, 2, 3, 5, 6, 8, 12, and 19) and 15 general statements about the brain (4, 7, 9, 10, 11, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23).

Table 1

Neuromyths and General Statements about the Brain: Percent Correct (Accurate) Responses by Role

Neuromyths and General Statements about the Brain	Percent Correct (Accurate) Responses by Role			Answer Key
	Instructors	Instructional Designers	Administrators	Correct or Incorrect
1. Listening to classical music increases reasoning ability.*	15%	13%	11%	Incorrect
2. A primary indicator of dyslexia is seeing letters backwards.*	23%	27%	24%	Incorrect
3. Individuals learn better when they receive information in their preferred learning styles (e.g., auditory, visual, kinesthetic).*	26%	46%	35%	Incorrect
4. On average, males have bigger brains than females.	28%	24%	17%	Correct
5. Some of us are “left-brained” and some are “right-brained” due to hemispheric dominance and this helps explain differences in how we learn.*	28%	41%	28%	Incorrect
6. We only use 10% of our brain.*	47%	57%	50%	Incorrect
7. Normal development of the human brain involves the birth and death of brain cells.	56%	64%	56%	Correct

8. It is best for children to learn their native language before a second language is learned.*	61%	64%	63%	Incorrect
9. The brains of males and females develop at different rates.	60%	57%	57%	Correct
10. Learning is due to modifications in the brain.	67%	64%	58%	Correct
11. Learning is due to the addition of new cells to the brain.	69%	68%	66%	Incorrect
12. There are critical periods in human development after which certain skills can no longer be learned.*	70%	74%	80%	Incorrect
13. Learning occurs through changes to the connections between brain cells.	75%	82%	74%	Correct
14. Information is stored in networks of cells distributed throughout the brain.	78%	82%	77%	Correct
15. Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain.	82%	82%	77%	Correct
16. The left and right hemispheres of the brain work together.	82%	80%	74%	Correct
17. When a brain region is damaged, other parts of	83%	81%	85%	Correct

the brain can sometimes take up its function.				
18. Brain development has finished by the time children reach puberty.	88%	87%	84%	Incorrect
19. Learning problems associated with developmental differences in brain function cannot be improved by education.*	89%	88%	90%	Incorrect
20. Individual learners show preferences for the mode in which they receive information (e.g., visual, auditory, kinesthetic).	90%	89%	88%	Correct
21. Production of new connections in the brain can continue into old age.	91%	93%	91%	Correct
22. We use our brain 24 hours a day.	91%	93%	92%	Correct
23. Mental capacity is genetic and cannot be changed by experiences.	93%	91%	94%	Incorrect

*Neuromyth statements
Note: 22 statements were adapted from Dekker et al. (2012) and Macdonald et al. (2017) with one statement adapted from Herculano-Houzel (2002).

Professional Role and Median Percent Correct

The Kruskal-Wallis H test revealed that instructional designers (*Mdn* = 68) had a greater awareness of neuromyths and general information about the brain than instructors (*Mdn* = 66), and administrators (*Mdn* = 65; *p* = 0.043). However, follow-up post-hoc tests indicated that there were no significant differences between the groups. Additionally, there were no significant differences between full-time (*Mdn* = 66) and part-time instructors (*Mdn* = 66) and awareness of neuromyths and general information about the brain (see Figure 5).

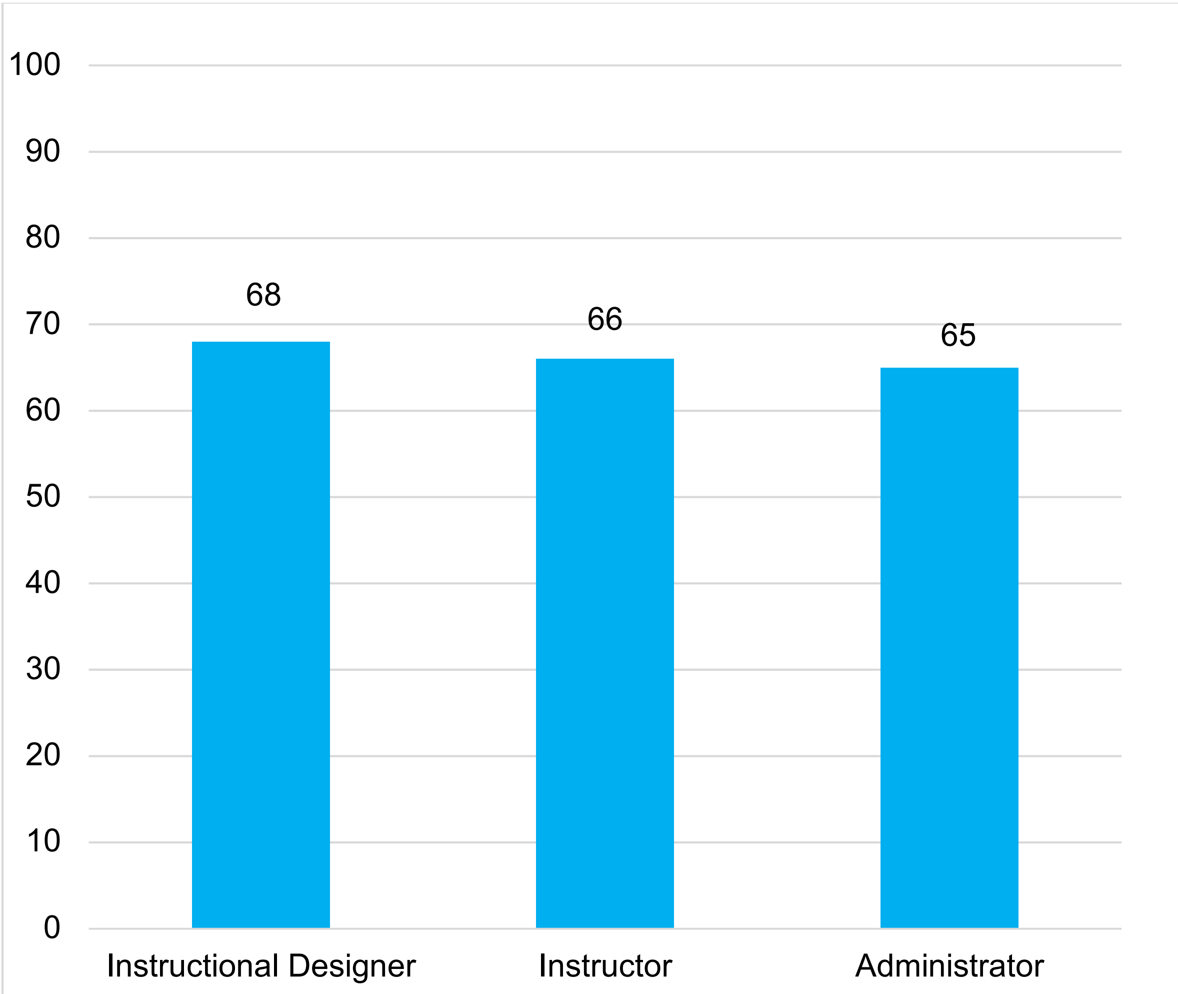

Figure 5. Professional Role: Median Percent Correct Responses for Neuromyths and General Statements about the Brain

Reading Journals and Median Percent Correct

The Kruskal-Wallis H test revealed a significant difference (p<0.001) between respondents who read and did not read journals related to neuroscience, MBE science, and psychology and awareness of neuromyths and general information about the brain. The findings showed that respondents who read journals related to neuroscience (*Mdn* = 78), MBE science (*Mdn* =74) and psychology (*Mdn* = 70) had a greater awareness of neuromyths and general information about the brain than those who did not read journals related to neuroscience (*Mdn* = 65), MBE science (*Mdn* =65) and psychology

(*Mdn* = 65; see Figure 6).

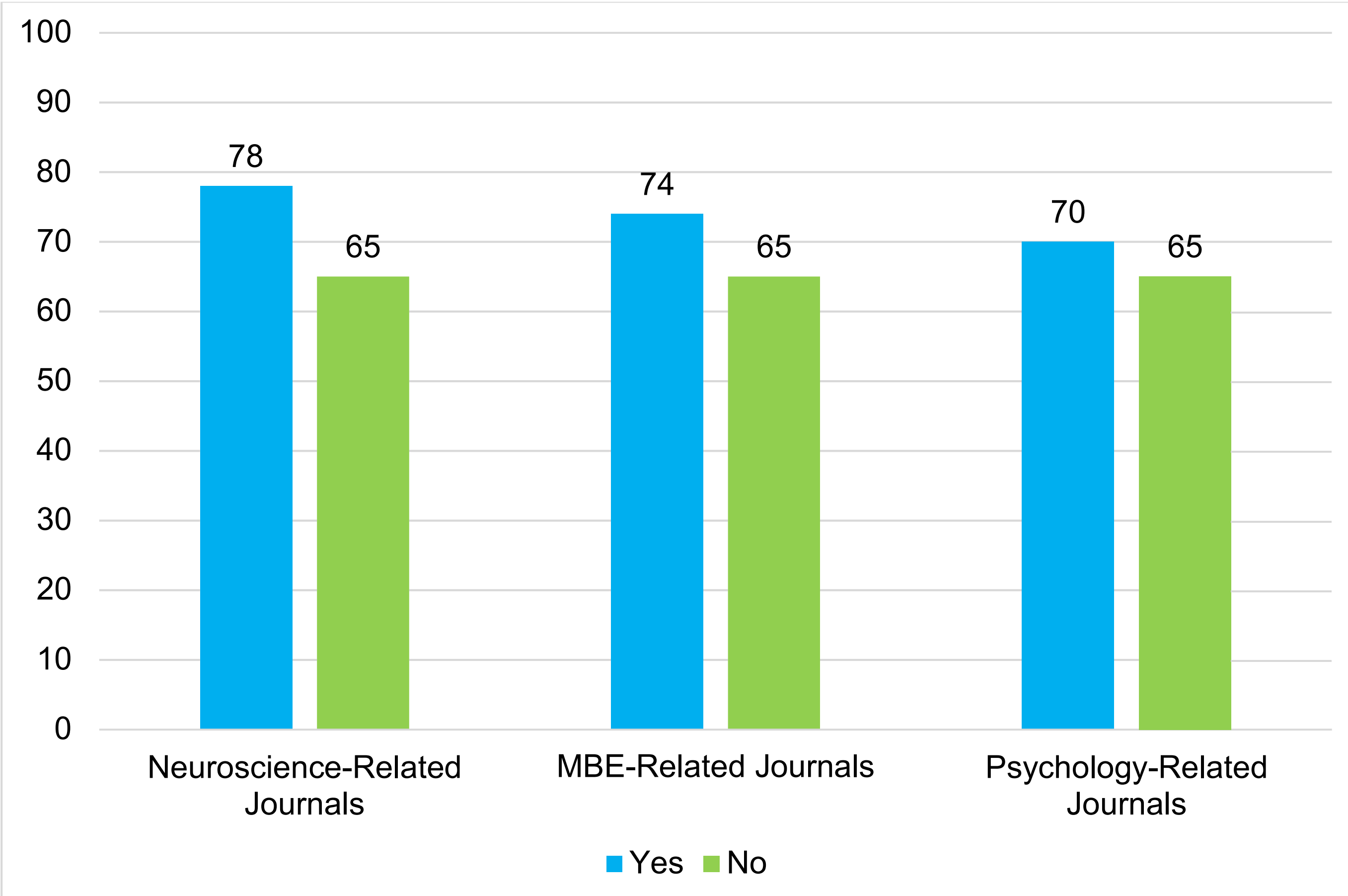

Figure 6. Reading Journals: Median Percent Correct Responses for Neuromyths and General Statements about the Brain

Demographics and Median Percent Correct

The Kruskal-Wallis H-test revealed a significant effect with highest degree completed (p = 0.008). Post-hoc tests revealed a significant difference between respondents who had earned terminal degrees and those with master's degrees ($p<0.019$) with respect to awareness of neuromyths and general information about the brain. Respondents who had earned terminal degrees (e.g., Ph.D., Ed.D., DBA, JD, MD; *Mdn* = 68) had a greater awareness of neuromyths and general information about the brain than those with master's (*Mdn* = 65), and associate's/bachelor's degrees (*Mdn* = 59).

There were no significant differences found between institution type (public, private, for-profit) or institution level (two-year, four-year, other) in awareness of neuromyths and general information about the brain. Additional analyses revealed no significant differences between demographic categories (time from highest degree earned, number of years teaching, number of years as an instructional designer, age, and gender) in awareness of neuromyths and general information about the brain.

Teaching and Course Development Across Formats and Median Percent Correct

Of the 929 respondents, 77% (n = 715) self-identified as “teaching” and 83% (n = 775) self-identified as “developing online, blended/hybrid, and on-campus courses” over the past 12 months. Table 2 provides an overview of the course formats by those who self-identified as teaching and developing courses. The study revealed there were no significant differences between respondents who taught online, blended/hybrid, and on-campus in awareness of neuromyths and general knowledge about the brain. Further, there were also no significant differences between respondents who developed online, blended/hybrid, and on-campus courses in awareness of neuromyths and general knowledge about the brain (see Table 2).

Table 2

Awareness of Neuromyths and General Statements about the Brain: Course Development and Teaching Across Formats

Course Format & Role	Course Development		Teaching	
	n	median % correct	n	median % correct
On-Campus	77	70	93	65
Blended/ Hybrid	39	61	32	61
Online	236	66	208	65
Both On-Campus and Blended/ Hybrid	44	61	55	65
Both On-Campus and Online	82	70	120	65
Both Blended/ Hybrid and Online	148	65	81	65
All three: On-Campus, Blended/ Hybrid and Online	149	70	126	70
Total	775	67	715	67

Implications

Neuromyths are false beliefs about the brain. Advancements in the learning sciences, particularly in neuroscience with non-invasive brain imaging, have dispelled many common neuromyths such as individuals use only 10% of their brain or are right or left-brained. These advancements have also debunked misconceptions about critical periods in human development when learning must take place or certain skills cannot be learned (OECD, 2007). Research shows that the human brain continues to change throughout life in response to experiences, learning skills or recovering from injury, referred to as neuroplasticity. Furthermore, there has been no scientific evidence to support some of the most pervasive neuromyths such as students learn better when they are taught to their preferred learning styles (Newtown & Miah, 2017; Simmonds

2014; Pashler, McDaniel, Rohrer, & Bjork, 2009) or that classical music increases reasoning abilities, intelligence, or spatial ability (McKelvie & Low, 2002; Pietschnig, Voracek, & Formann, 2010; Waterhouse, 2006).

Research studies worldwide show a susceptibility to believing in neuromyths across K-12 and higher education. Therefore, it is recommended that IHEs dispel and debunk neuromyths through learning opportunities, such as learning communities and ongoing professional development, that include research and advancements from the learning sciences and MBE science. Instructors, instructional designers, and administrators all have key roles in the course development process; therefore, it is important that learning communities and professional development be inclusive of all educational groups to support learning and student success across on-campus, blended/hybrid, and online formats.

Section Two: Awareness of Evidence-Based Practices in Higher Education

Evidence-based practices are a systematically developed body of knowledge that build upon collecting, processing, and implementing research findings to inform and improve teaching practices (Chrisman et al., 2014; Elliott, 2001). In academic contexts, evidence-based practices can inform teaching by maximizing the utility of research findings for teaching purposes (Elliott, 2001). The learning sciences bridge research and practice to support improved student performance through learning environments (Sawyer, 2014). Within the learning sciences, MBE science bridges research and practice to inform pedagogy through the intersection of neuroscience, psychology, and education.

Learning Sciences

The learning sciences is an interdisciplinary field that includes “cognitive science, educational psychology, computer science, anthropology, sociology, information sciences, neurosciences, education, design studies, instructional design, and other fields” (Sawyer, 2008, p. 1). The learning sciences emerged in 1991 and focus on “design and implementation of real-world educational systems – curricula, software, teaching practices, and social and interactional patterns – and also conduct basic scientific investigations” (Sawyer, 2014, p. 21). Research findings from the learning sciences provide new insight into the human learning process and have important implications for both instructional design and teaching (Guerreiro, 2017; Tokuhama-Espinosa, 2011).

Mind, Brain, and Education Science

MBE science is a field within the learning sciences concerned with the human teaching-learning dynamic that intersects neuroscience, psychology, and education (Tokuhama-Espinosa, 2013, 2019; see Figure 7). MBE science has become increasingly recognized on a national and international level. Since its inception in the late 1990s and the founding of the International Mind, Brain, and Education Society (IMBES) in 2007, research at the intersection of neuroscience, psychology, and education has contributed to a better understanding of this teaching-learning dynamic (Fischer, 2004). MBE science research explores the neuronal bases of core cognitive functions, such as memory, attention, executive functions, as well as the relationships between affect and cognition; sleep and learning; social interaction and mental constructs, among others. As the field grows and more research is brought to the attention of general educators, the influence of MBE science has steadily increased each year.

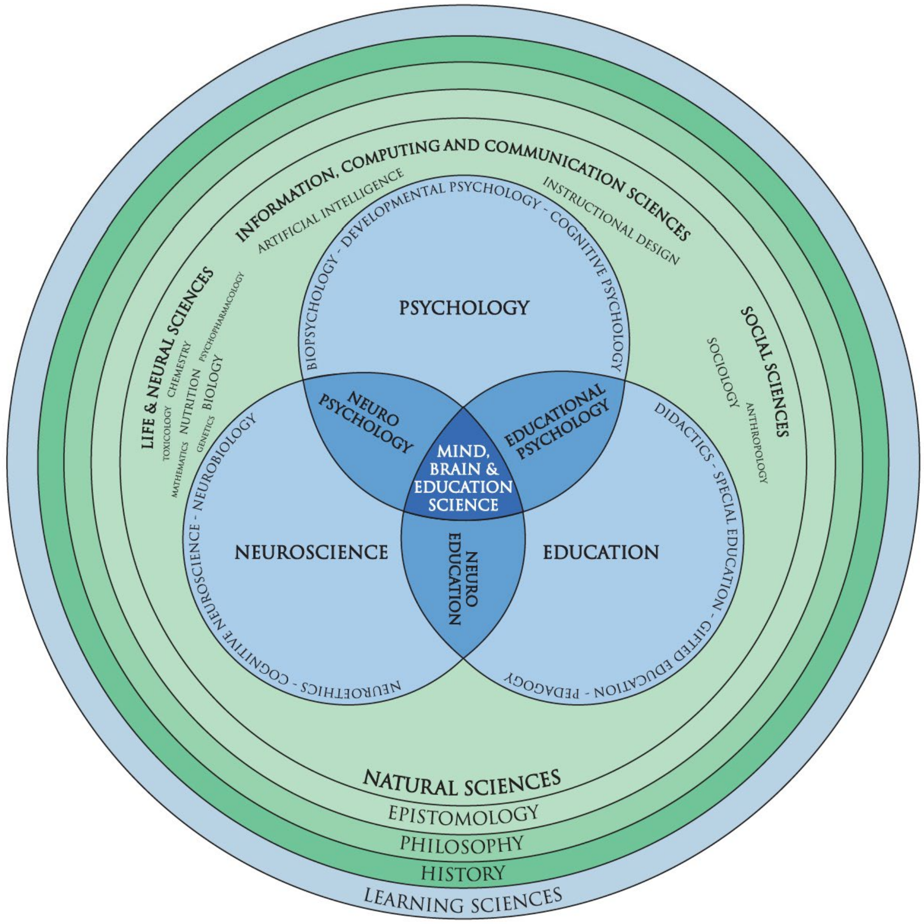

Figure 7. MBE science conceptual framework, Tokuhama-Espinosa, 2019 ©

Research from MBE science provides critical insight into how humans learn. Only a few decades ago, the adult brain was considered to be "stable and unchanging, except for the inevitable decline that occurs with aging" (Gage, 2004, p. 135). However, research on brain development and neuroplasticity reveals that the brain continues to change over the lifetime (Pickersgill, Marin, & Cunningham-Burley, 2015; Pitts-Taylor, 2010). Research using brain imaging devices, such as task-based functional magnetic resonance imaging (fMRI), provides new insights into learning (Shewokis, Ayaz, Curin, Izzetoglu & Onaral, 2013) through measures of changes in brain function. Such studies improve the understanding of neuroplasticity and its implications for learning.

Knowledge about universal and individualized aspects of the human brain and learning have the potential to reshape traditional views of teaching. It is known that human brains are unique (Hathaway, 2015), and based on both genetic makeup and individual experiences. Research related to the brain and learning supports student-centered learning models that allow for flexible learning experiences and account for individual learner differences and human variation (Hinton, Fischer, & Glennon, 2012).

For instance, research on brain plasticity, mathematics, literacy, and language learning provide evidence that learning experiences are continuously changing the brain (Hinton et al., 2012). This supports the claim that abilities are not fixed (Dweck, 2008) and can be enhanced through appropriate pedagogical tools (Hardiman, 2012). Additionally, new research about the brain explains the dynamic and iterative process between the individual and the environment, with each new experience shaping the interpretation of following experiences through the process of radical neuroconstructivism (Tokuhama-Espinosa, 2019; van Glaserfeld, 1995).

Research pertaining to thinking skills, such as transfer across contexts (Bransford & Schwartz, 2001) and the development of critical thinking (Halpern, 1999) has also made its way into practical teaching methodologies, through research in the learning sciences. Some studies, related to instructional design convey ways in which sensory information and the interplay between auditory and visual processing contribute to learning (Mayer, 2008). Cognitive load theory considers both the structure of information and the cognitive architecture, which allow learners to process information, providing educators with critical information related to instructional design, instruction, working memory, and collaborative learning (Kirschner, Sweller, & Kirschner, 2018; Paas, Renkl, & Sweller, 2003). Collectively, Mind (psychology), Brain (neuroscience) and Education (pedagogy and didactics) science provides a strong foundational understanding of evidence-based practices that support teaching and learning.

Findings

Section Two of this study focuses on evidence-based practices. The survey included 28 statements from the learning sciences and MBE science. The findings present data from this study related to evidence-based practices and professional role, highest degree completed, reading journals, teaching and course development across formats, institution level, institution type, instructor role, number of years teaching, number of years as an instructional designer, gender, age, time since highest degree completed, and level of highest degree completed.

Evidence-Based Practices: Professional Roles

Table 3 provides descriptive data reporting the percent correct responses (i.e., accurate responses) by respondents for each of the 28 general statements representing evidence-based practices from the learning sciences and MBE science broken down by professional roles (instructors, instructional designers, and administrators). For example, 26% of instructors answered Statement 1 correctly (i.e., accurately) while 40% of instructional designers and 31% of administrators answered the statement correctly (i.e., accurately). The percent correct responses ranged from 26% to 99% across all responses. Table 3 also provides the answer key for the 28 statements. For example, Statement 1 is incorrect while Statement 4 is correct.

Table 3

General Statements from the Learning Sciences and MBE Science Representing Evidence-Based Practices*: Percent Correct (Accurate) Responses by Role*

General Statements from the Learning Sciences and MBE Science	**Percentage of Correct (Accurate) Responses by Role**			**Answer Key**
	Instructors	Instructional Designers	Administrators	Correct or Incorrect
1. Rereading course materials is an effective strategy for learning.	26%	40%	31%	Incorrect
2. Differentiated instruction is individualized instruction.	40%	53%	44%	Incorrect
3. Testing, in general, tends to detract from learning.	54%	59%	50%	Incorrect
4. Information that is studied over longer periods of time is better remembered than the same information studied over shorter periods of time.	55%	63%	54%	Correct
5. Universal Design for Learning is a framework to improve and optimize teaching and learning for all people based on scientific insights into how humans learn.	58%	87%	74%	Correct
6. With respect to memory, massed instruction is superior to spaced instruction.	58%	70%	63%	Incorrect
7. Human memory works much like a digital recording device or video camera in that it accurately records the events we have experienced.	69%	79%	74%	Incorrect
8. Focused attention is essential for learning new information.	70%	74%	60%	Correct
9. Frequent, low stakes tests do not enhance learning.	72%	84%	83%	Incorrect
10. Human brains seek and often quickly detect novelty.	72%	66%	66%	Correct
11. Learning should be spaced out over time.	76%	87%	78%	Correct

12. Experts and novices approach solving problems in essentially the same way.	76%	84%	73%	Incorrect
13. Human brains are relatively as unique as fingerprints.	77%	77%	78%	Correct
14. The brain acts as a filter to help us to pay attention to what is important.	77%	75%	83%	Correct
15. Decorative graphics can enhance learning when applied to course materials.	78%	57%	70%	Correct
16. Multitasking while studying increases productivity.	82%	84%	84%	Incorrect
17. Production of new neuronal connections in the brain continues over the lifetime.	87%	90%	87%	Correct
18. You can train certain parts of the brain to improve their functioning.	88%	89%	91%	Correct
19. Intelligence is fixed at birth.	89%	89%	86%	Incorrect
20. Metacognition plays a role in learning.	89%	95%	94%	Correct
21. Repeated practice and rehearsal of learned material or a skill will help to consolidate it in long-term memory.	93%	94%	95%	Correct
22. The mind connects new information to prior knowledge.	95%	99%	95%	Correct
23. Meaningful feedback accelerates learning.	96%	99%	98%	Correct
24. Stress can impair the ability of the brain to encode and recall memories.	97%	94%	99%	Correct
25. Maintaining a positive atmosphere in the classroom helps promote learning.	98%	96%	98%	Correct
26. Explaining the purpose of a learning activity helps engage students in that activity.	98%	99%	96%	Correct
27. Sleep has a role in memory consolidation.	99%	94%	97%	Correct

28. Emotions can affect human cognitive processes, including attention, learning and memory, reasoning, and problem-solving.	99%	99%	99%	Correct

Professional Role and Median Percent Correct

The Kruskal-Wallis H test revealed significant differences between instructors, instructional designers, and administrators in awareness of evidence-based practices ($p < 0.001$). Post-hoc tests revealed instructional designers (*Mdn* = 83) had a greater awareness of evidence-based practices than administrators (*Mdn* = 80; $p = 0.028$) and instructors (*Mdn* = 79; $p < 0.001$; see Figure 7). There were no significant differences between full-time (*Mdn* = 79) and part-time instructors (*Mdn* = 79) and awareness of evidence-based practices.

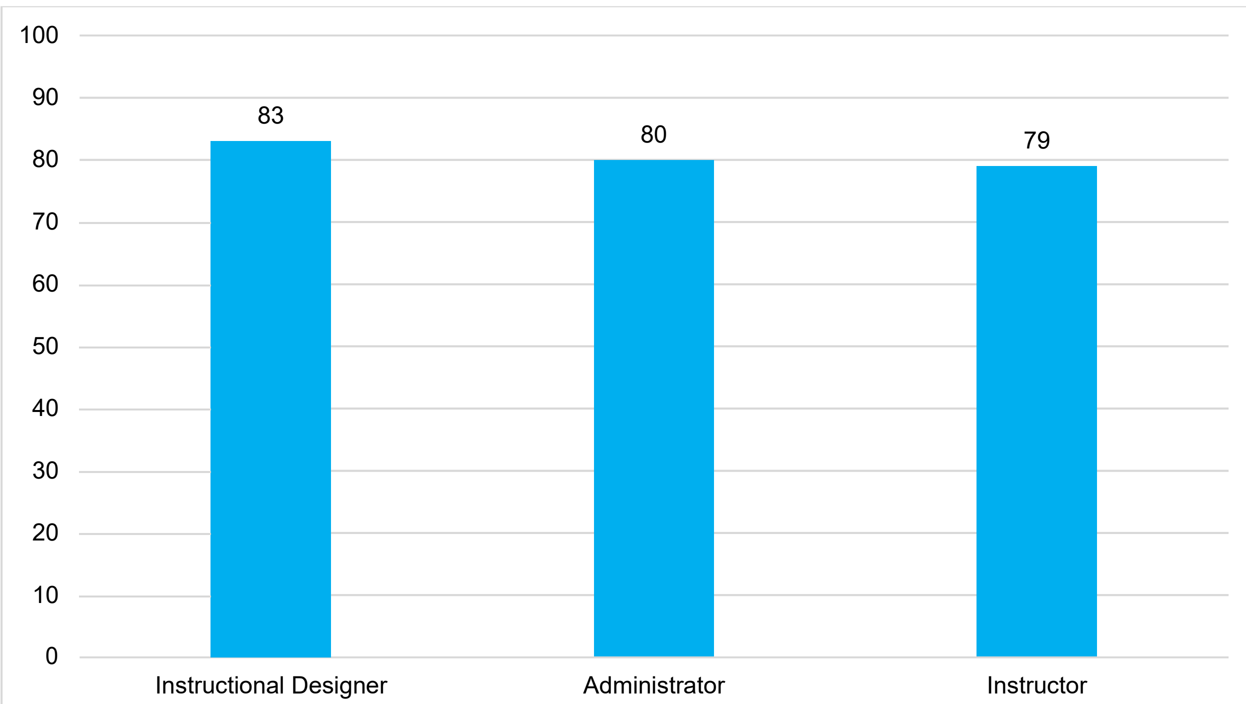

Figure 7. Professional Role: Median Percent Correct to Statements for Evidence-Based Practice Statements

Highest Degree Completed, and Median Percent Correct

The Kruskal-Wallis H test revealed there were no significant differences between highest degree completed and awareness of evidence-based practices. Respondents who had earned terminal degrees (e.g., Ph.D., Ed.D., DBA, JD, MD; *Mdn* =80), master's degrees, (*Mdn* = 80), and associate's/bachelor's degrees (*Mdn* = 78) had similar levels of awareness of evidence-based practices.

Reading Journals and Median Percent Correct

The Kruskal-Wallis H test revealed a significant difference ($p<0.001$) between respondents who read and did not read journals related to MBE science, neuroscience, and psychology and percent in awareness of evidence-based practices. The findings showed that respondents who read journals related to MBE science (*Mdn* =82), neuroscience (*Mdn* = 82), and psychology (*Mdn* = 82) had a greater awareness of evidence-based practices than those who did not read journals related to MBE science (*Mdn* =79), neuroscience (*Mdn* = 79), and psychology (*Mdn* = 79; see Figure 8).

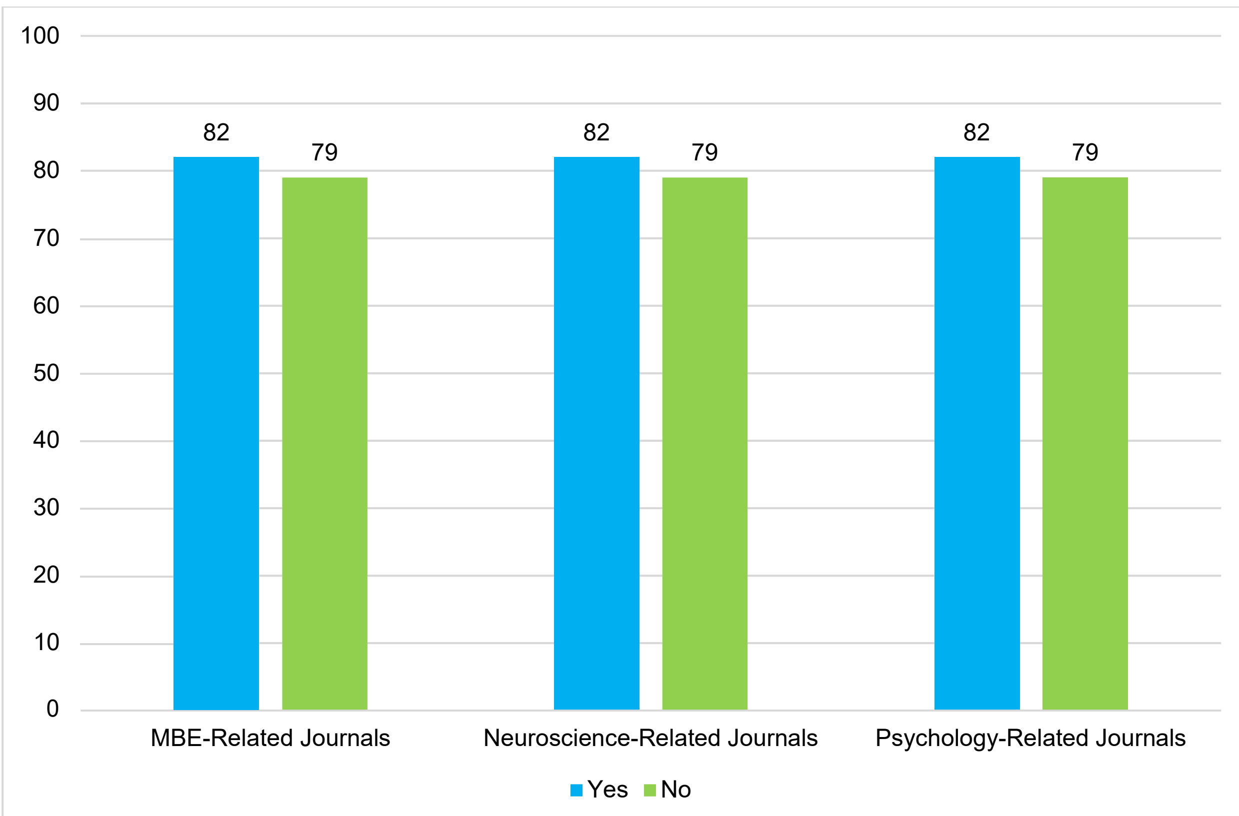

Figure 8. Reading Journals: Median Percent Correct to Evidence-based Practice Statements

Demographics and Median Percent Correct

There were no significant differences between institution type (public, private, for-profit) or institution level (two-year, four-year, other) and awareness of evidence-based practices. Additional analyses revealed no significant differences between demographic categories (level of highest degree completed, time from highest degree earned, number of years teaching, number of years as an instructional designer, age, and gender) and awareness of evidence-based practices.

Teaching and Course Development Across Formats and Median Percent Correct

The study revealed no significant differences between respondents who taught online, blended/hybrid, and on-campus and awareness of evidence-based practices. There were also no significant differences between respondents who developed online, blended/hybrid, and on-campus courses and awareness of evidence-based practices (see Table 4).

Table 4

Evidence-Based Practices: Course Development and Teaching Across Formats and Median Percent Correct

Course Format & Role	Course Development		Teaching	
	n	median % correct	n	median % correct
On-Campus	77	79	93	79
Blended/ Hybrid	39	82	32	80
Online	236	79	208	79
Both On-Campus and Blended/ Hybrid	44	79	55	79
Both On-Campus and Online	82	82	120	82
Both Blended/ Hybrid and Online	148	82	81	79
All three: On-Campus, Blended/ Hybrid and Online	149	82	126	82
Total	775	82	715	79

Implications

Evidence-based practices provide critical insight for educators on learning and course design from the learning sciences, and on pedagogy from MBE science. These research-informed practices are foundational to teaching and learning across on-campus, blended/hybrid, and online formats.

The proliferation of brain-related training products through popular media and the internet make it difficult for educators to discern what is evidence-based and can lead to misunderstandings and misconceptions about brain function and learning (Beck, 2010; Dekker et al., 2012). Evidence-based practices are essential for informing course design and pedagogy. Therefore, it is recommended that IHEs make evidence-based practices a component of comprehensive professional development for instructors, instructional designers, and administrators.

Section Three: Professional Development, Predictors of Neuromyths and Evidence-Based Practices, and Interest in Scientific Knowledge about the Brain

Professional development is a broad term used to describe knowledge and practice enhancement. Within education, professional development may reference "a wide variety of specialized training, formal education, or advanced professional learning intended to help administrators, teachers, and other educators improve their professional knowledge, competence, skill, and effectiveness" (The Glossary of Educational Reform, 2013, para. 1).

Professional development varies across IHEs as does the terminology used to describe the experience. It can include continuing education, professional learning, or staff development. Professional development offerings can also include, but are not limited to, attending workshops, certificates of completion, certificates that award academic credit, and Massive Open Online Courses (MOOCs). Professional development may be offered through onsite, blended/hybrid, or online formats. Additionally, it can be asynchronous, synchronous, and self-paced, and/or involve independent research.

Requirements for attending professional development are dependent upon an IHE and may be related to specific program regulations, accreditation, or licensure. Professional development may be offered or sought to gain knowledge, to advance careers, to assist new employees with onboarding (i.e., familiarizing new employees with policies, protocol, etc.), develop or refine expertise, and maintain certification requirements. Motivation to attend voluntary professional development can be linked to interest, quality, and value of the program, desire to enhance professional roles, and personal fulfillment (Anderson, 2008).

Findings

Categorical linear regression was used to determine if professional development was a predictor of awareness of neuromyths and general knowledge about the brain, and evidence-based practices. Dependent variables included percent correct responses to neuromyths and general statements about the brain as well as percent correct responses to evidence-based practice statements from the learning sciences and MBE science. Predictors included types of professional development. There were three datasets, (1) neuroscience, (2) psychology, and (3) MBE science, that addressed five types of professional development, including (i) professional training, (ii) workshops, (iii) certificate(s) of completion, (iv) certificate(s) with credit and (v) MOOC(s).

The results were very consistent with each of the five types of professional development predicting awareness of neuromyths, general knowledge about the brain, and evidence-based practices. Tables 5, 6, and 7 provide the unstandardized beta coefficients (B), standard error of the beta coefficients (SE), t-values (*t*), and p-values (*p*) for each analysis.

Table 5

Completed Neuroscience-Related Professional Development: Predictor of Awareness

	B	SE	t	p
Professional Training				
Neuromyths and General Knowledge about the Brain	71	1.3	54.0	<0.001
Evidence-Based Practices	82	1.0	82.4	<0.001
Workshops				
Neuromyths and General Knowledge about the Brain	70	1.2	59.5	<0.001
Evidence-Based Practices	83	0.9	91.7	<0.001
Certificate of Completion				
Neuromyths and General Knowledge about the Brain	72	2.6	27.8	<0.001
Evidence-Based Practices	81	2.0	41.1	<0.001
Certificate with Credit				
Neuromyths and General Knowledge about the Brain	69	2.2	31.3	<0.001
Evidence-Based Practices	82	1.7	49.3	<0.001
MOOC				
Neuromyths and General Knowledge about the Brain	71	2.0	35.4	<0.001
Evidence-Based Practices	83	1.5	54.9	<0.001

Table 6

Completed MBE Science-Related Professional Development: Predictor of Awareness

	B	SE	t	p
Professional Training				
Neuromyths and General Knowledge about the Brain	70	1.1	65.7	<0.001
Evidence-Based Practices	83	0.8	103.8	<0.001
Workshops				
Neuromyths and General Knowledge about the Brain	70	1.0	70.2	<0.001
Evidence-Based Practices	83	0.8	110.2	<0.001
Certificate of Completion				
Neuromyths and General Knowledge about the Brain	69	2.0	34.9	<0.001
Evidence-Based Practices	84	1.5	55.4	<0.001
Certificate with Credit				

Neuromyths and General Knowledge about the Brain	69	1.8	37.7	<0.001
Evidence-Based Practices	84	1.4	60.2	<0.001
MOOC				
Neuromyths and General Knowledge about the Brain	71	1.9	37.2	<0.001
Evidence-Based Practices	84	1.5	57.4	<0.001

Table 7

Completed Psychology-Related Professional Development: Predictor of Awareness

	B	SE	t	p
Professional Training				
Neuromyths and General Knowledge about the Brain	70	1.0	71.8	<0.001
Evidence-Based Practices	82	0.7	112.4	<0.001
Workshops				
Neuromyths and General Knowledge about the Brain	70	1.0	68.5	<0.001
Evidence-Based Practices	82	0.8	106.3	<0.001
Certificate of Completion				
Neuromyths and General Knowledge about the Brain	65	0.6	105.2	<0.001
Evidence-Based Practices	79	0.5	162.9	<0.001
Certificate with Credit				
Neuromyths and General Knowledge about the Brain	Insufficient data	Insufficient data	Insufficient data	Insufficient data
Evidence-Based Practices	Insufficient data	Insufficient data	Insufficient data	Insufficient data
MOOC				
Neuromyths and General Knowledge about the Brain	71	2.2	32.0	<0.001
Evidence-Based Practices	83	1.7	49.7	<0.001

Interest and Value of Scientific Knowledge about the Brain and Its Influence on Learning

The majority of the respondents, regardless of professional role, found scientific knowledge about the brain and its influence on learning to be of interest and value (see Figure 9). Of the respondents, 88% (n = 777), agreed and strongly agreed they have an interest in learning more about the brain and its influence on learning. The majority of respondents agreed or strongly agreed (89%; n = 798) that they find scientific knowledge about the brain and its influence on learning interesting. Furthermore, respondents strongly agreed that they find scientific knowledge about the brain and its influence on learning valuable to their teaching practice (83%; n = 741), course development (86%; n = 760), and professional development (84%; n = 746).

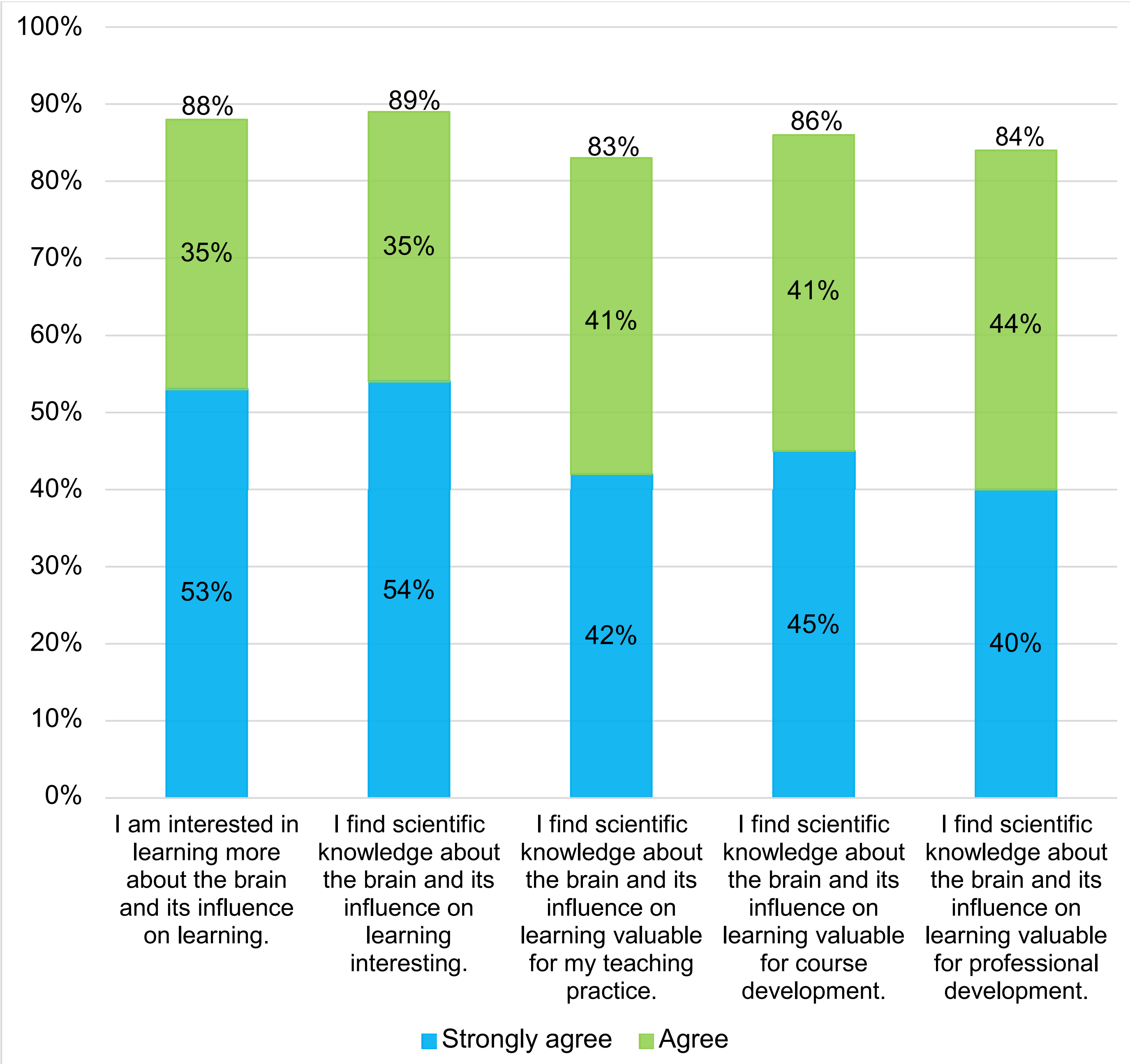

Figure 9. Value and interest in scientific knowledge about the brain and its influence on learning

Implications

Within contemporary education, development of online and blended/hybrid courses often includes design teams or may pair an instructor (subject matter expert) with an instructional designer (García-Cabrero et al., 2018; Oregon State University, n.d.; University of Central Florida, n.d.). Similarly, instructors teaching on campus may work with teams on the integration of new technologies into courses such as simulation labs (e.g. augmented reality, virtual reality) or creating assignments that engage students with innovative new applications or the learning management system. Therefore, there are many individuals with key roles that support both course development and instruction.

Professional development provides instructors and instructional designers with foundational knowledge and skills that are transferred to course development and instruction. Research in the learning sciences and MBE science provides critical information about the human learning process that can support instructional design and teaching. This research is fundamental to dispelling neuromyths and supporting pedagogy through evidence-based practices. IHEs around the world offer professional development to enhance teaching and instructional design to meet the needs of an increasingly diverse student population. However, as this study has revealed, instructors, instructional designers, and administrators can be susceptible to believing neuromyths and may not be fully aware of evidence-based practices from the learning sciences and MBE science. Furthermore, this study reveals a high level of interest among professionals in higher education to learn more about the brain and its influence on learning. Therefore, IHEs should identify strategies to integrate content from the learning sciences and MBE science into professional development to support, improve, and enhance learning for students by addressing neuromyths and increasing awareness of evidence-based practices that can be transferred to courses across all learning modalities, including on-campus, blended/hybrid, and online.

Section Four: Conclusions and Recommendations

More than ever, research from the learning sciences and MBE science provides critical insight to inform design and pedagogical practices that engage diverse students in dynamic and evolving learning environments. While not all educators may be familiar with these emerging sciences, professional development can increase awareness since instructors and instructional designers have such key roles in course development, instruction, and learning. Instructors bring and share subject-matter expertise and professional experience across hundreds of disciplines through undergraduate, graduate, and certificate programs and courses offered annually through on-campus, blended/hybrid, and online formats. Increasingly within IHEs, instructional designers are working collaboratively with instructors to support and enhance student learning through course development. Therefore, it is critical that administrators are aware of research and evidence-based practices from the learning sciences and MBE science that can be integrated to support instructional design, teaching, and learning.

Conclusions

This international study revealed that instructors, administrators, and instructional designers are aware of many evidence-based practices from the learning sciences and MBE science. However, there is a susceptibility to believing in neuromyths. These beliefs may stem from misconceptions, misunderstanding and/or misrepresented or overgeneralized concepts related to neuroscience from popular media, outdated information, or lack of scientific literacy. The findings from this study indicate that research and information from the learning sciences and MBE Science may increase awareness of neuromyths, general knowledge about the brain, and evidence-based practices.

Self-directed learning and professional development emerged as key factors in awareness of neuromyths, general knowledge about the brain, and evidence-based practices. Respondents who read journals related to neuroscience, psychology, and MBE science had higher percent correct responses for identifying neuromyths and evidence-based practices. Similarly, attending professional development related to the learning sciences was found to be a predictor of awareness of neuromyths and general knowledge about the brain, and evidence-based practices.

Instructional designers were found to have a greater awareness of neuromyths, general information about the brain, and evidence-based practices than instructors and administrators. This may be associated with curricula related to instructional design certificate and degree programs. The study also revealed that respondents who had advanced degrees were less susceptible to believing neuromyths. This may be linked to increased educational exposure to research and information from the learning sciences and MBE science through courses.

This study indicates there is very high interest among instructors, instructional designers, and administrators in scientific knowledge about the brain and its influence on learning. Furthermore, all three groups found scientific knowledge about the brain and its influence on learning to be valuable to teaching practice, course development, and professional development. Therefore, there is an emergent opportunity for IHEs to integrate research and evidence-based practices from the learning sciences and MBE science into professional development to support teaching, course development, and learning. Professional development provides unique opportunities for IHEs to share current and emerging research from the learning sciences and MBE science with instructors, instructional designers, and administrators to support teaching and learning. From workshops and seminars to MOOCs and certificate programs, professional development can bring together instructors, instructional designers, and administrators to dispel and debunk neuromyths while sharing evidence-based practices to support and enhance learning across educational modalities.

Recommendations

Course development and delivery are often collaborative and usually enhanced by professional development experiences. Therefore, all educators who are engaged in teaching, course development, and professional development should be aware of neuromyths, general information about the brain, and evidence-based practices.

There are three recommendations based on the findings of this study.

First, it is recommended that IHEs assess the awareness of neuromyths, general information about the brain, and evidence-based practices among their instructors, instructional designers, and administrators. Metacognition, the awareness of one's own knowledge and beliefs (Meichenbaum, 1985), is foundational to teaching and learning. Therefore, it is important for educators to be aware of neuromyths and evidence-based practices that could influence their beliefs and practices. IHEs should also review current professional development to examine alignment and integration of the learning sciences and MBE science.

Second, it is recommended that instructors, instructional designers, and professional development administrators engage in self-directed learning, such as reading journals in their fields, the learning sciences, and MBE science. IHEs can facilitate this process by sharing open access resources. Centers for teaching and learning can also generate reading lists and open-access resources from the learning sciences and MBE science. To start, Appendix C includes a general list of resources and journals related to the learning sciences.

Third, it is recommended that IHEs review current professional development to examine alignment and integration of the learning sciences and MBE science. Further integration of information from the learning sciences and MBE science, including current and emerging research, can expand and enhance educators' knowledge throughout their careers. This is important, particularly for instructors, since research shows there is a relationship between an instructor's beliefs and her/his instructional practices (Brownlee, Ferguson & Ryan, 2017; Knapp, 2013; Nie, Tan, Liau, Lau, & Chua, 2013;

Stein & Wang, 1988). Professional development that integrates research related to the learning sciences and MBE science can dispel deeply rooted beliefs in neuromyths while concurrently increasing awareness of the brain and evidence-based practices that support course development, teaching, and learning.

The questions answered and raised by this study point to many opportunities for future research, which include, but are not limited to the following questions:

- How and to what extent do commercial products for the brain and learning contribute to the belief in neuromyths?
- Does believing in neuromyths affect an educator's beliefs and instructional practices?
- How and to what extent does the integration of the learning sciences and MBE science into professional development affect the design of learning environments, pedagogical practices, and learning outcomes across learning modalities?
- How and to what extent do current training programs on the learning sciences and MBE science improve student learning outcomes?

Future research should add to and expand the literature on neuromyths and evidence-based practices within higher education that commenced with this study. Finally, educators are invited to replicate this study and encouraged to construct and test new interventions that will lead to quality tertiary education.

Section Five: Methodology

Purpose and Significance

The purpose of this international, non-experimental study was to investigate the awareness and predictors of neuromyths, general knowledge about the brain, and evidence-based practices related to the learning sciences and MBE science among instructors, instructional designers, and professional development administrators who work in higher education across on-campus, blended/hybrid, and online environments at two- and four-year higher education institutions. An objective of the research design was to obtain a large sample of educators involved in instruction, instructional design, and professional development worldwide from a diverse range of IHEs and across disciplines. Notably, this study is the first to compare the awareness and predictors of neuromyths, general knowledge about the brain, and evidence-based practices from the learning sciences and MBE science among instructors, instructional designers, and administrators in higher education across on-campus, blended/hybrid, and online educational formats.

Research Questions

The following four research questions guided this study.

1. Are there differences among (a) professional roles (instructor, instructional designer, professional development administrator), (b) instructional or course development formats (on-campus, blended/hybrid, online), (c) demographic categories and awareness of neuromyths, general knowledge about the brain, or evidence-based practices from the learning sciences and MBE science?

2. Does reading journals related to neuroscience, psychology, and MBE science increase awareness of neuromyths, general knowledge about the brain, or evidence-based practices?

3. Is professional development a predictor of (a) awareness of neuromyths and general knowledge about the brain, and/or (b) awareness of evidence-based practices?

4. Is there an interest among instructors, instructional designers, and administrators in scientific knowledge about the brain and its influence on learning?

Respondents

This study included an online survey invitation that was sent out electronically to the Online Learning Consortium (OLC) membership that included 65,780 emails across higher education institutions in the United States and worldwide. A total of 13,992 surveys were opened with 877 clicks on the survey link; this does not include surveys that were forwarded on to others within higher education.

To increase participation in this study, a snowball sampling technique was also used. OLC members who received the email were asked to share the invitation with professional and personal contacts who work as instructors, instructional designers, or professional development administrators at two- and four-year higher education institutions in the United States and worldwide who work across on-campus, blended/hybrid, or online environments.

A total of 1,290 surveys were completed of which 929 met the criteria for inclusion based on:

- Consent to participate in the study;
- Identified role within the institution as an instructor, instructional designer, or administrator who works with professional development;
- Completed 95% or more of the section on neuromyths and general statements about the brain, and
- Completed 95% or more of the section on evidence-based practices.

Of the 929 respondents, 926 completed 100% of both sections on the (a) neuromyths and general statements about the brain, and (b) the evidence-based practices.

Measures

The survey for this study was comprised of three sections. Section 1 was adapted from two surveys: (a) Dekker and colleagues (2012) and (b) Macdonald and colleagues (2017). The Dekker et al. (2012) survey included 32 statements about the brain and its influence on learning. The Dekker (2012) sample included K-12 teachers in the United Kingdom and the Netherlands. Macdonald and colleagues (2017) adapted the Dekker survey for a US-based sample that included educators, individuals with a self-reported neuroscience background, and the general public. Modifications by Macdonald et al. (2017) from the Dekker survey included the replacement of two questions and revising the answer format from Correct/Incorrect/I Don’t Know to True/False. Additionally, some of the Dekker questions that had false responses were modified by Macdonald and colleagues to elicit true responses.

The focus of this study was on higher education (instructors, instructional designers, and administrators) and not K-12 education. Eight (8) of the 32 statements were replicated from the Dekker et al. (2012) survey. Seven (7) statements that were modified for the Macdonald survey were included, and one (1) statement was added from the Herculano-Houzel (2002) survey. Seven (7) statements were modified based on the Dekker et al. (2012) statements and adaptations by Macdonald (2017) for a total of 23 statements. Additionally, the answer format for Section 1 and 2 reflected the format used by Dekker and colleagues (2012) which included Correct, Incorrect, and I Don’t Know. Table 8 provides a breakdown of the survey questions that were adapted, modified or added to this study from prior studies. Statements adapted by Dekker and colleagues (2012) are shaded in gray, Macdonald and colleagues (2017) shaded in blue, and Herculano-Houzel (2002) shaded in orange. Statements modified for this study from the Dekker and Macdonald surveys are shaded in yellow. Statements that were not included are shaded in red. In Table 8 the left column shows the statements from the Dekker survey with modifications made by Macdonald et al. The right column of Table 8 identifies which survey was utilized for the statement selection for this study, if a statement was modified, and if a statement was added. The eight neuromyth statements included with this study were selected from the Dekker et al. (2012) and Macdonald et al. (2017) surveys.

Table 8

Questions Adapted, Modified, Added, and Deleted from Prior Surveys

Neuromyth and Statements about the Brain	**Survey Statements**
1. We use our brains 24 hours a day. (Correct)	Statement selected from Dekker et al. (2012)
2. When a brain region is damaged other parts of the brain can take up its function. (Correct)	
3. We only use 10% of our brain. (Incorrect)*	
4. Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic). (Incorrect)*	
5. Normal development of the human brain involves the birth and death of brain cells. (Correct)	
6. Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain. (Correct)	
7. Production of new connections in the brain can continue into old age. (Correct)	
8. Individual learners show preferences for the mode in which they receive information (e.g., visual, auditory, kinesthetic) (Correct)	
9. The left and right hemisphere of the brain always work together. (Correct); Dekker et al. (2012) The left and right hemisphere of the brain work together, (True), Macdonald et al. (2017); Modified by Macdonald et al. (2017)	Statement selected from Macdonald et al. (2017)
10. Children must acquire their native language before a second language is learned. If they do not do so neither language will be fully acquired. (Incorrect); Dekker et al. (2012) It is best for children to learn their native language before a second language is learned. (False); Modified by Macdonald et al. (2017)*	
11. Learning is not due to the addition of new cells to the brain. (Correct); Dekker et al. (2012)	

Learning is due to the addition of new cells to the brain. (False); Modified by Macdonald et al. (2017)	
12. Learning occurs through modification of the brains' neural connections. (Correct); Dekker et al. (2012) Learning occurs through changes to the connections between brain cells. (True); Modified by Macdonald et al. (2017)	
13. Listening to classical music increases children's reasoning ability. (Incorrect); Dekker et al. (2012) Listening to classical music increases reasoning ability. (False); Modified by Macdonald et al. (2017)*	
14. Learning problems associated with developmental differences in brain function cannot be remediated by education. (Incorrect); Dekker et al. (2012)* Learning problems associated with developmental differences in brain function cannot be improved by education. (False); Modified by Macdonald et al. (2017)	
15. Brain development has finished by the time children reach secondary school. (Incorrect); Dekker et al. (2012) Brain development has finished by the time children reach puberty. (False); Modified by Macdonald et al. (2017)	
16. Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners (Incorrect); Dekker et al. (2012) Some of us are "left-brained" and some are "right-brained" and this helps explain differences in how we learn. (False), Modified by Macdonald et al. (2017)* Some of us are "left-brained" and some are "right-brained" due to hemispheric dominance and this helps explain differences in how we learn. (Incorrect); Modified for 2018 Study	Statement modified for this Current Study
17. The brains of boys and girls develop at *the same rate*. (Incorrect); Dekker et al. (2012) The brains of boys and girls develop at different rates. (True); Modified by Macdonald et al. (2017) The brains of males and females develop at different rates. (Correct)**;** Modified for 2018 Study	
18. Boys have bigger brains than girls. (Correct); Dekker et al. (2012) Boys have bigger brains than girls, *on average.* (T); MacDonald et al. 2017 On average, males have bigger brains than females. (Correct); Modified for 2018 Study	

19. There are critical periods in childhood after which certain things can no longer be learned. (Incorrect); Dekker et al. (2012) There are specific periods in childhood after which certain things can no longer be learned. (False); Modified by Macdonald et al. (2017)* There are critical periods in human development after which certain skills can no longer be learned. (Incorrect); Modified for 2018 Study	
20. Mental capacity is hereditary and cannot be changed by the environment or experience. (Incorrect); Dekker et al. (2012) Mental capacity is genetic and cannot be changed by the environment or experience. (False); Modified by Macdonald et al. (2017) Mental capacity is genetic and cannot be changed by experiences. (Incorrect); Modified for 2018 Study	
21. A common sign of dyslexia is seeing letters backwards. (False) Added by Macdonald et al. (2017)* A primary indicator of dyslexia is seeing letters backwards. (Incorrect); Modified for 2018 Study	
22. Information is stored in the brain in a network of cells distributed throughout the brain. (Correct); Dekker et al. (2012) Information is stored in networks of cells distributed throughout the brain. (Correct); Modified for 2018 Study	
23. Learning is due to modifications in the brain. (Correct); Herculano-Houzel, 2002	Statement selected Herculano-Houzel (2002)
Academic achievement can be affected by skipping breakfast. (Correct); Dekker et al. (2012)	Statements not Included from Dekker et al. (2012) survey
Vigorous exercise can improve mental function. (Correct); Dekker et al. (2012)	
It has been scientifically proven that fatty acid supplements (omega-3 and omega-6) have a positive effect on academic achievement. (Incorrect; Dekker et al. (2012)	
Regular drinking of caffeinated drinks reduces alertness. (Correct); Dekker et al. (2012)	
Short bouts of coordination exercises can improve integration of left and right hemispheric brain function. (Incorrect); Dekker et al. (2012)	
When we sleep, the brain shuts down. (Incorrect); Dekker et al. (2012)	

Children are less attentive after consuming sugary drinks and/or snacks, (Incorrect); Dekker et al. (2012)	
Circadian rhythms ("body-clock") shift during adolescence, causing pupils to be tired during the first lessons of the school day. (Correct); Dekker et al. (2012)	
Exercises that rehearse coordination of motor-perception skills can improve literacy skills. (Incorrect); Dekker et al. (2012)	
There are sensitive periods in childhood when it's easier to learn things. (Correct); Dekker et al. (2012) There are specific periods in childhood when it's easier to learn certain things. (T); Modified by Macdonald et al. (2017)	Statements not Included from either Dekker et al. (2012) or Macdonald et al. (2017)
If pupils do not drink sufficient amounts of water (=6–8 glasses a day) their brains shrink, (Incorrect); Dekker et al. (2012) If students do not drink sufficient amounts of water their brains shrink. (False); Modified by Macdonald et al. (2017)	
Environments that are rich in stimulus improve the brains of pre-school children. (Incorrect); Dekker et al. (2012) Children must be exposed to an enriched environment from birth to three years old or they will lose learning capacities permanently. (False); Modified by Macdonald et al. (2017)	

*Neuromyth statements adapted from Dekker et al. (2012) and Macdonald et al. (2017)

Section 2 included 28 statements related to teaching, learning, and the brain from the learning sciences and MBE science that were developed by the research team for this study.

Section 3 included 21 questions that focused on demographics, including: primary role (instructor, instructional designer, administrator), educational modality (i.e., teaching or developing courses for on-campus, blended/hybrid, online), institution level (two-year, four-year), institution type (public, private, for-profit), instructor role (full-time, part-time), number of years teaching, number of years as an instructional designer, gender, age, time since highest degree completed, and level of highest degree completed (associate/bachelor's, master's, terminal, other). Questions in Section 3 also focused on professional development (e.g., training, journal reading, etc.) and value and interest in scientific knowledge about the brain and its influence on learning.

Research Methods

The data was analyzed using the Statistical Package for the Social Sciences (SPSS) for Windows, version 24. A significance criterion of $\alpha = 0.05$ was used for each analysis. The Kruskal-Wallis H test (ANOVA by ranks) was selected as a non-parametric method for data analysis given the unequal sample sizes among the respondents and the distributional difference between them. This study was approved by the Institutional Review Board at Drexel University.

The Kruskal-Wallis H test was conducted to evaluate differences among the three professional roles (instructor, instructional designer, administrator) on median for percent correct responses to questions about neuromyths and general statements about the brain ([# of correct responses to 23 questions / 23] * 100%). A Kruskal-Wallis H test was also conducted to evaluate differences among the three groups on median for percent correct responses to questions about evidence-based practices from the learning sciences and MBE science ([# of correct responses to 28 questions / 28] * 100%).

To examine if professional development was a factor in predicting awareness of neuromyths, general knowledge about the brain, or evidence-based practices, categorical linear regression analyses were performed for percent correct answers on (a) neuromyths and general knowledge about the brain (dependent variable) and for percent correct answers on (b) evidence-based practices (dependent variable) with the five types of professional development offered across neuroscience, psychology, and MBE science (predictors).

Overall, the methods selected aligned with the research questions and the sample sizes of the respondents. Cronbach's alpha, a coefficient of reliability, was used to measure consistency across survey items for the neuromyths and general statements about the brain, and evidence-based practices. The alpha coefficient was .756 for the 23 neuromyths items, and .732 for the 28 evidence-based practices items, which revealed internal consistency.

Section Six: Demographics

A total of 929 respondents participated in this international study, which included full-time instructors (33%; n = 305), part-time instructors (13%; n = 122), instructional designers (26%; n = 239), administrators involved in professional development (18%; n = 172), and others (10%; n = 91; see Table 9 and 10). The respondents worked in four-year institutions (68%; n = 619), two-year institutions (18%; n = 167) and worked at other types of institutions (14%; n = 125; see Table 11). Over half of the respondents worked at public institutions (61%; n = 553) followed by private institutions (28%; n = 258), for-profit institutions (7%; n = 62), and other types of institutions (4%; n = 39; see Table 12).

Table 9

Primary Role

	Frequency	Percent
Instructor, full-time	305	33%
Instructor, part-time	122	13%
Instructional designer	239	26%
Administrator involved in professional development	172	18%
Other	91	10%
Total	929	100%

Note: Data depicted in Figure 1 in the Executive Summary

Table 10

Other Positions: Responses provided by respondents

Administrative Manager	Emeritus professor
Administrative over instructional design	Faculty and Instructional Designer Full Time
Administrator (non-PD program)	Grant Compliance Officer
Administrator involved in online learning development and growth	Head of academic program
Administrator of academic programs	I am both a professor and in charge of our teaching and learning center
Administrator who teaches	Information Literacy Instructor
Administrator/Professor	Instructional Designer/part-time instructor
Advisor	Instructional Developer
Associate Professor and Director of Technology Enhanced Learning	Instructional Support

Board member/Prof Development	Instructor and Instructional Design
Both an instructor and an administrator	Instructor, ID, and administrator
Chairperson/Professor	Librarian
Coordinator of Instructional Design	Librarian - Faculty
Coordinator of Online Learning	Online librarian
Counselor	PhD Student
Dean of Instruction	Professional Development Officer
Dean-General Education and Professional Development	Program Lead
Dean, and part-time faculty	Program Director
Director for Development/Service enter	Publisher
Director of Online Technology	Research and Planning (Prior Instructional Design Supervisor)
Director, Tutoring Center	Research and teaching faculty
E-learning instructional support	Researcher
Educational Developer	Textbook publisher/ Instructional Designer
Educational Technologist	Tutoring Center Administrator Online Learning & Educational Technology Coordinator

Table 11

Institutional Level

	Frequency	Percent
Two-Year Institution	167	18%
Four-Year Institution	619	68%
Other	125	14%
Total	911	100%

Note: Data depicted in Figure 2 in the Executive Summary

Table 12

Institutional Type

	Frequency	Percent
Public	553	61%
Private	258	28%
For-Profit	62	7%
Other	39	4%
Total	912	100%

Note: Data depicted in Figure 3 in the Executive Summary

The majority of the respondents (88%; n = 788) were from the United States while 12% (n = 112) were international (see Figure 10 and Table 13). Respondents from the United States represented 48 of 50 states. A total of 45 countries were represented from around the world. Twenty-nine participants did not answer this question.

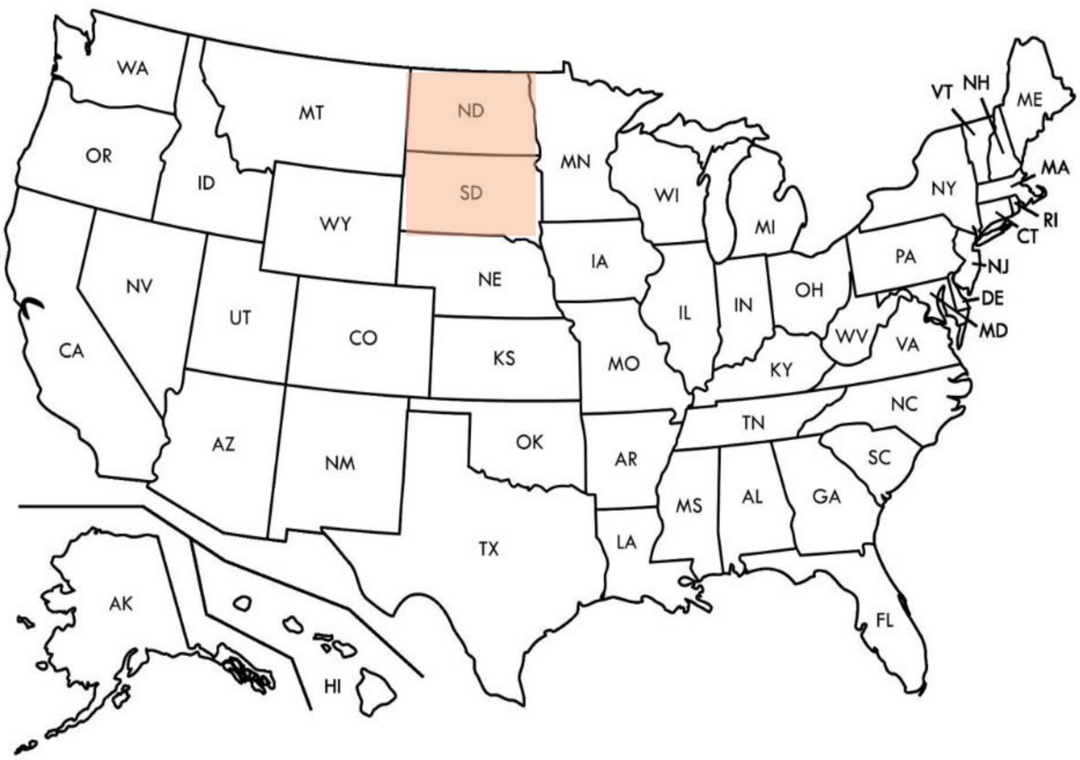

Figure 10. States represented in this study in the United States are in white while states not represented are shaded (i.e., North Dakota, South Dakota)

Table 13

Countries Represented in the Study

1. Argentina	16. Iceland	31. New Zealand
2. Armenia	17. India	32. Norway
3. Australia	18. Indonesia	33. Pakistan
4. Bahamas	19. Iran	34. Poland
5. Barbados	20. Israel	35. Portugal

6. Belgium	21. Italy	36. Russia
7. Brazil	22. Jamaica	37. Singapore
8. Bulgaria	23. Japan	38. South Africa
9. Burundi	24. Jordan	39. Swaziland
10. Canada	25. Lebanon	40. Tanzania
11. Colombia	26. Malaysia	41. Thailand
12. Costa Rica	27. Malta	42. Trinidad and Tobago
13. Dominica	28. Mexico	43. Ukraine
14. France	29. Namibia	44. United Kingdom
15. Germany	30. Netherlands	45. United States

Of those who responded, 69% (n = 620) self-identified as female, 27% (n = 244) male, 1% (n = 8) non-binary, and 3% (n = 27) chose not to respond (see Figure 11). The majority of the respondents were age 35-44 (27%; n = 242), 45-54 (29%; n = 258), and 55-64 (22%; n = 199) years old. Approximately 20% of respondents were 25-34 (10%; n = 88), 65 years or older (9%; n = 85), and 18-24 (1%; n = 5) years old. (see Figure 12). Two percent selected “I choose not to respond” (n = 22). Thirty participants did not answer this question.

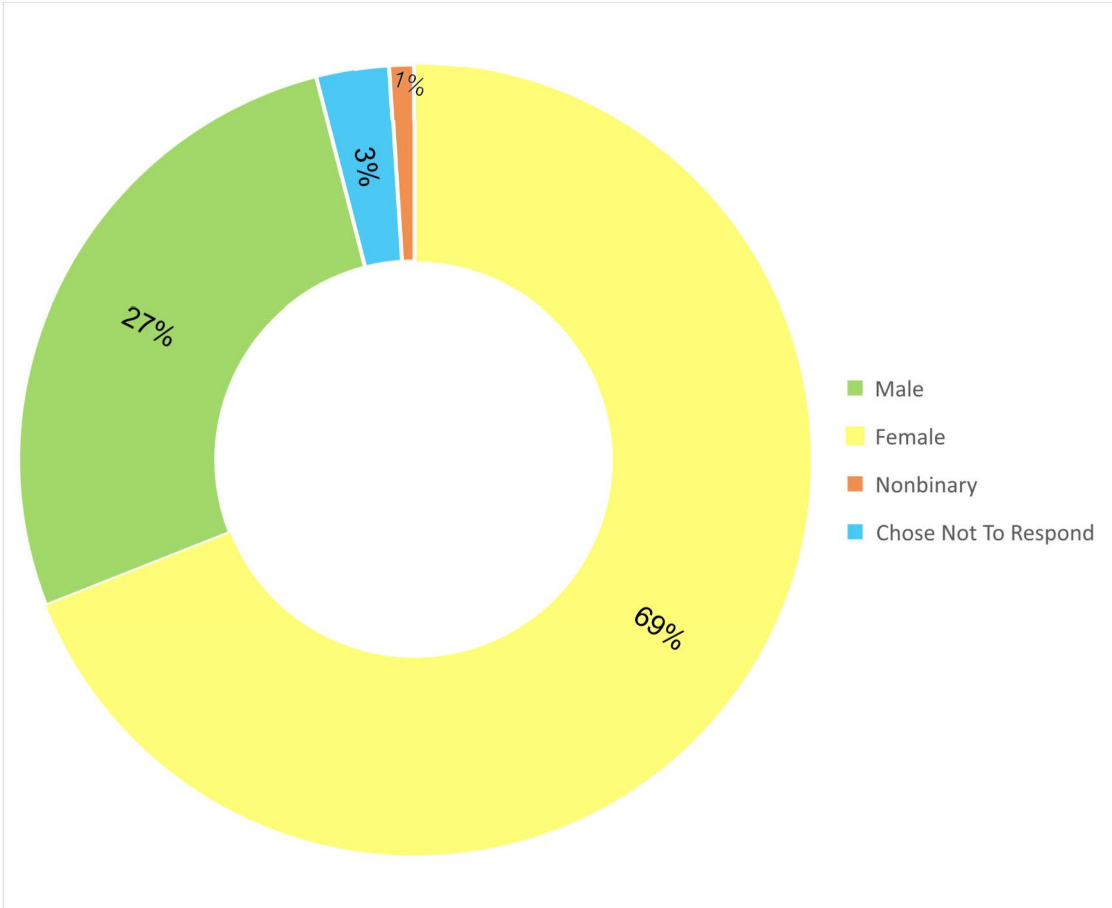

Figure 11. Gender of Respondents

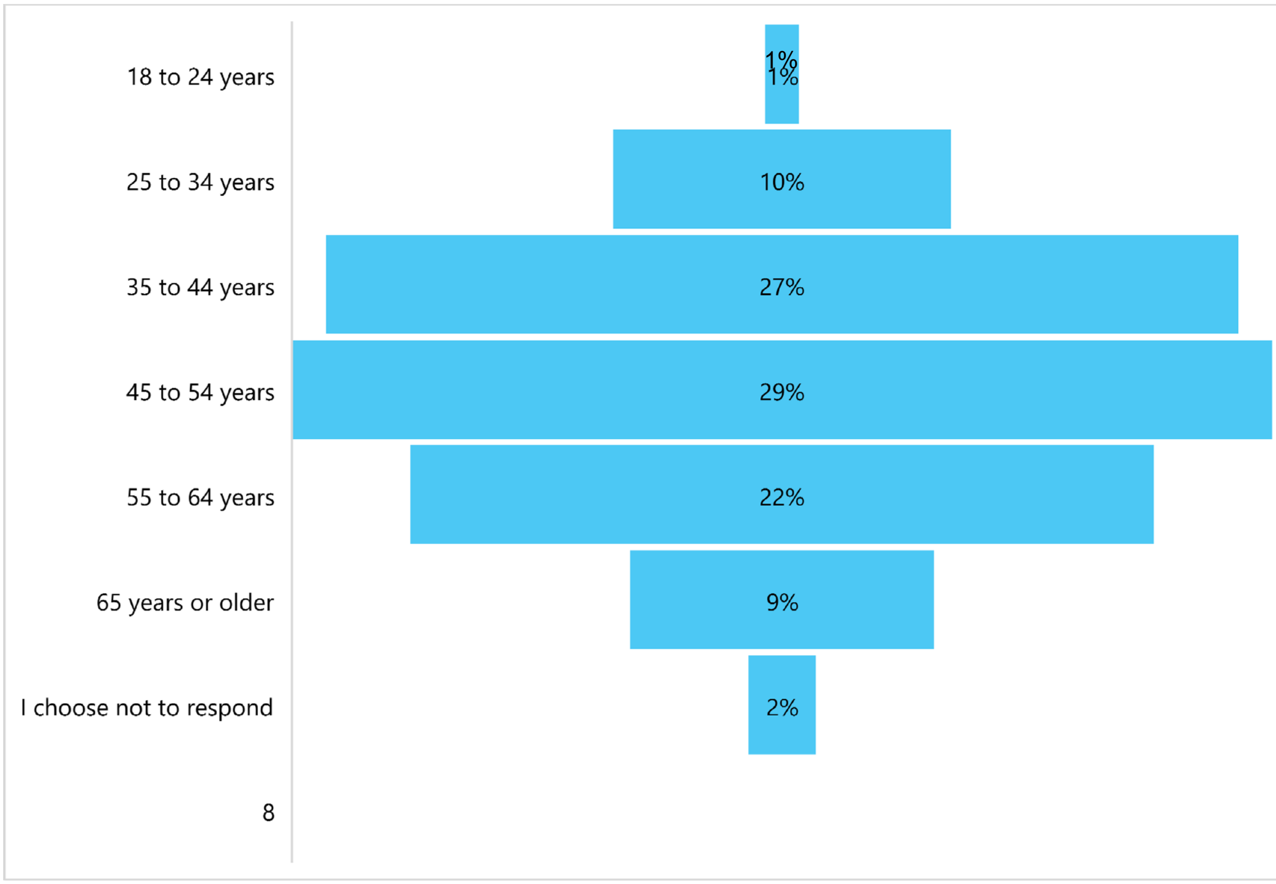

Figure 12. Age of Respondents

Degree completion ranged from associate's/bachelor's (3%; n = 32) to master's (46%; n = 413) and terminal degree (Ph.D., Ed.D., DBA, JD, MD; 47%; n = 414). Four percent (n=40) of respondents selected "other" (see Table 15). Thirty participants did not answer this question. In regard to time from highest degree completed, responses ranged from less than 1 year (6%; n = 58) to 15 years or more (33%; n = 293; see Table 17). Thirty-one participants did not answer this question. The fields of study for the highest degree completed were very diverse and expansive with the highest representation from the field of Education (47%; n = 420) followed by the Humanities (10%; n = 89) and Social Sciences (8%; n = 70; see Table 16). Other fields provided by the respondents are in Table 18. Thirty participants did not answer this question.

Table 15

Highest Degree Completed

	Frequency	Percent
Associate/Bachelors	32	3%
Masters	413	46%
Terminal Degree	414	47%
Other	40	4%
Total	899	100%

Table 16

Time from Highest Degree Completed

	Frequency	Percent
Less than 1 year	58	6%
1-4 years	190	21%
5-9 years	206	23%
10-14 years	151	17%
15+ years	293	33%
Total	898	100%

Table 17

Field of Highest Degree Completed

	Frequency	Percent
Arts	12	1.0%
Business	65	7.0%
Education	420	47.0%
Engineering & Applied Sciences	27	3.0%
Health Sciences	16	2.0%
Humanities	89	10.0%
International	4	0.5%
Law	5	0.5%
Medicine	5	0.5%
Nursing	29	3.0%
Professional Studies	11	1.0%
Public Health	5	0.5%
Science	49	6.0%

Social Science	70	8.0%
Other	92	10.0%
Total	899	100.0%

Table 18

Other Fields: Responses provided by respondents

Adult Education	Information Systems
Anthropology	Information Technology
Applied Economics	Instructional Design
Behavioral Neuroscience	Instructional Technology
Communication Studies	Intercultural Relations
Communications and Instructional Technology	Library and Information Studies
Communications/Media	Linguistics
Computer Information Systems	Literature
Computing Technology in Education	Mathematics
Consumer Science	Neurobiology
Counseling	Physical Therapy
Educational Technology	Psychology
English	Public administration
English Language and Literature	Public Policy & Education Leadership
Foreign Languages	School Counseling
Geography	School Psychology
Higher Education Leadership	Social Psychology
Higher Education	Social Work
Hospitality	Spanish
Human Resource Development	Sports Management
Humanities and Library Science	Theology
Informatics	Urban Services/Urban Education
Information Science	Veterinary
Information Science and Technology	Information Science and Technology

A total of 715 (77%) respondents self-identified as having taught courses over the past 12 months. The data revealed 29% (n = 208) taught only online while 13% (n = 93) taught only classroom (on-campus) courses, and 4% (n = 32) taught only blended/hybrid courses. Over half of the respondents taught across a combination of instructional modalities, including classroom and blended/hybrid (8%; n = 55);

classroom and online (17%; n = 120); blended/hybrid and online (11%; n = 81); and classroom, blended/hybrid and online (18%; n = 126).

Respondents who self-identified as instructing courses taught across the following types of programs: associate's (12%; n = 108) and bachelor's (17%; n = 155), graduate (10%; n = 93), and professional certificate/certification (6%; n = 52). Respondents also taught across a combination of programs, such as undergraduate and graduate (11%; n = 99), or graduate and professional certificate/certification (4%; n = 40).

A total of 775 (83%) respondents indicated that they developed courses over the past 12 months. The data revealed 30% (n = 236) of respondents developed online courses, while 10% (n = 77) developed classroom (on-campus) courses, and 5% (n = 39) developed blended/hybrid courses. Over half of all respondents who self-identified as instructors developed courses across a combination of formats, including classroom and blended/hybrid (6%; n = 44); classroom and online (11%; n = 82); blended/hybrid and online (19%; n = 148); classroom, blended/hybrid, and online (19%; n = 149).

Respondents who self-identified as developing courses worked with the following types of programs: associate's (11%; n = 99) and bachelor's (16%; n = 151), graduate (11%; n = 103), and professional certificate/certification (7%; n = 69). Many respondents developed courses across a combination of programs, such as bachelor's and graduate (12%; n = 111) or graduate and professional certificate/certification (5%; n = 51).

Section Seven: Answer Keys with Research Supported Responses

The statements and answers below align with the order of the questions in the survey.

Neuromyths and General Statements about the Brain

1. We use our brain 24 hours a day. **Correct**

Contrary to the widespread myth that the "brain shuts down while you sleep," the brain never ceases to function. Research shows that during sleep, the brain is actively involved in memory consolidation and reconsolidation (Walker, Brakefield, Hobson, & Stickgold, 2003). Consolidation of perceptual and motor learning, as well as different forms of complex skill acquisition, occurs during sleep (Karni, Tanne, Rubenstein, Askenasy, & Sagi, 1994; Stickgold, James, & Hobson, 2000; Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002).

2. It is best for children to learn their native language before a second language is learned. **Incorrect**

It was once thought that a person should learn their native language before embarking on a new one because children needed a firm foundation in one language before learning a second or subsequent language. However, it is now evident that children can learn multiple languages at the same time (Berken, Gracco, & Klein, 2017). Furthermore, in the 1920s bilingualism was thought to have a negative impact on intelligence (Saer, 1928). This was largely due to documentation of a decrease in reading speed in bilingual children. However, it was later found that this normalizes by the fourth grade (O'Brian & Wallot, 2016). Current research shows the benefits of bilingualism include extended executive function capacity (Bialystok, 2012). Additionally, bilingualism enhances the ability to overcome neural insults (Stern, 2012; Saur, 2010). from injury to disease to aging that can impact their function and survival (Farley & Watkins, 2018).

3. On average, males have bigger brains than females. **Correct**

Advanced imaging techniques, such as magnetic resonance imaging (MRI) and positron emission tomography (PET), contribute to research on sex differences in the brain (Grabowska, 2016). A meta-analysis of over 5,000 publications was conducted from 1990-2013 on sex-related differences in the brain at varying age levels (Ruigrok et al. 2014). Ruigrok and colleagues (2014) found regional sex differences in volume and tissue density reporting that some sections of the male brain (left amygdala, hippocampus) are consistently larger than in female brains, and some sections of the female brain (left frontal pole, inferior and middle frontal gyri) are consistently larger than in the male brain. However, research studies show that "males have larger brains than females, even after controlling for body size" (van der Linden, 2017, p. 78). Although differences in brain architecture and volume exist, "studies clearly show that females and males do not differ in levels of general intelligence" (Grabowska, 2016, p. 207).

4. When a brain region is damaged, other parts of the brain can sometimes take up its function. **Correct**

The nervous system is characterized by neuroplasticity. The brain has the ability to respond to our internal and external environment by adapting both structure and function (Cramer, et al. , 2011). Research shows that "following brain structural damage, both connectivity maps and behavioural skills can at least be partially restored through intense practice and rehabilitation" (Turolla, Venneri, Farina, Cagnin, & Cheung, 2018, p. 1). In "A Tale of Two Cases: Lessons for Education from the Study of Two Boys Living with Half their Brains," Dr. Mary Helen Immordino-Yang (2007) provided research conducted with two boys who each had one brain hemisphere removed (Nico his right and Brooke his left) to control severe epilepsy. According to Immordino-Yang (2007):

> When a child is missing the brain areas that would normally be required to perform a particular task, and yet manages to successfully compensate, we are given a unique opportunity to learn about the emotional and motivational aspects of their recovery, as well as about cognitive compensation for basic neuropsychological skill. (p. 67)

5. We only use 10% of our brain. **Incorrect**

Advancements in technology and neuroimaging show that the brain is highly active, even during sleep (National Institute of Neurological Disorders and Stroke, 2018). According to Barry Gordon, a neurologist at Johns Hopkins University, "It turns out though, that we use virtually every part of the brain, and that [most of] the brain isactive almost all the time" (para 5). The deep-rooted myth about using just 10% of the brain has been associated with Jean Pierre Flourens who in the 1800s removed bits of brain from animals to measure behavior affect and Karl Lashley who in the 1930s stimulated the brain with low frequency electric shocks to measure response (Frank & Orbach, 1982; Yidirim, & Sarikcioglu, 2007). One of the most-cited connections to this neuromyth is attributed to William James (1907), who stated in *The Energies of Men*, "We are making use of only a small part of our possible mental and physical resources" (p. 323). Urban legend often links this neuromyth to Albert Einstein "who once told an interviewer that he only used 10 percent of his brain" (Uncapher, 2016, para. 7). Technology has advanced sufficiently in the past 100 years to debunk this myth through sophisticated neuroimaging techniques that measure chemical, electrical, structural, magnetic changes due to oxygenation, and others that show the extended use of all brain areas.

6. The left and right hemispheres of the brain work together. **Correct**

The human brain is divided into two hemispheres: right and left. Both hemispheres play a critical role in behavior. While each hemisphere of the brain controls movement and feeling in the opposite half of the body, the two hemispheres work together through the corpus callosum which is composed of approximately 200 million nerve fibers (Goldstein & Mesfin, 2017; van der Knaap & van der Ham, 2011). Rather than focusing on the type of "localizationism" which was popular in the 1880s-1950s, current research points to elaborate networks that crisscross the hemispheres through important hubs. Hubs themselves are located in distinct hemispheres (for example, Broca's Area is a key hub for language and is in the left frontal lobe of 95% of humans), but the skills depend on the broader networks, which are spread across the two hemispheres.

7. Some of us are "left-brained" and some are "right-brained" due to hemispheric dominance and this helps explain differences in how we learn. **Incorrect**

There is nothing the human brain does that is limited to a single hemisphere. The traditional concept of "localizationism" from the last 1800s has shifted to complex neuronal networks throughout the brain and neuroplasticity (Acharya, Shukla, Mahajan & Diwan, 2012; Corballis, 2014; Vilasboas, Herbet, & Duffau, 2017). While each hemisphere is associated with specific behaviors such as spatial ability, visual imagery, logic, language, etc., individuals are not "left-brained" or "right-brained" since the two hemispheres share information through the corpus callosum (Rogers, 2013; Goldstein & Mesfin, 2017). Most people (95%) are left-hemisphere dominant for language (Knecht et al., 2000), and this hemispheric dominance exerts a control and inhibitory function over the right hemisphere (Corballis & Morgan, 1978), through cortico-cortical inhibitory control (Stens et al., 2002; Pascual-Leone et al., 1998), or cortico-thalamo-cortical inhibitory control (Ahissar & Oram, 2013). In the context of developmental injury, the normal developmental pattern of establishing left-hemisphere dominance for language can be interrupted, causing the development of a compensatory, crossed-dominance pattern of language cortex (DeVos, Wyllie, Geckler, Kotagal, & Comair, 1995).

8. The brains of males and females develop at different rates. **Correct**

Multiple studies have shown that male and female brains show increased divergence "in physical characteristics, behavior, and risk for psychopathology" (Lenroot & Giedd, 2010, p. 46; also see Hafner, 2003; Kessler et al., 2005). Brain imaging techniques and postmortem examinations have shown that, depending upon age, different sections of the brain develop at different rates in males and females as early as early childhood (Cuevas, Calkins, & Bell, 2016), likely due to different chronological onsets of hormonal changes and paralleling general physiological development of the rest of the body. Men and women have the same hormones but in different levels. The brain is impacted by high levels of testosterone in males and estrogen and progesterone in females (Paus, Pui-Yee Wong, Syme, & Pausova, 2017), which influences development.

9. Brain development has finished by the time children reach puberty. **Incorrect**

The brain continues to create new connections until death. While brain size and cranial measurements stabilize around nine years of age, neuronal connections continue to form throughout the life span (Blakemore, 2018; Sercombe, 2014). Advances in research and neuroimaging show that the brain continues to develop, “challenging longstanding assumptions that the brain was largely finished maturing by puberty” (Johnson, Blum, & Giedd, 2010, p. 216). Research indicates that the frontal lobes are the last to fully develop and new findings suggest that these do not reach structural maturity until the third decade of life.

10. There are critical periods in human development after which certain skills can no longer be learned. **Incorrect**

There is no critical period for human development after which certain skills cannot be learned. The brain can and does learn throughout the lifespan and this is manifested in new neural connections – neuroplasticity. While the literature supports the existence of critical periods of learning, “the neuroscientific understanding of lifetime ‘plasticity’ shows that people are always open to new learning” (Organisation of Economic Co-operation and Development, 2007, p. 9). While there may be critical periods during gestation and the initial formation of the human brain, there are no critical periods for anything learned in educational contexts after birth; life experience, rather than chronological age, plays a far greater role in learning potential.

11. Information is stored in networks of cells distributed throughout the brain. **Correct**

It is still unknown how information is stored within the brain. It is clear that the storage of information in the brain is a highly complex process requiring the interaction of a number of circuits, networks, and structures in different areas of the brain (Battaglia, Benchenane, Sirota, Pennartz, & Wiener, 2011). While the hippocampus is an essential part of memory networks in the brain, research points to this structure as a hub for connections belonging to intricate memory networks composed of several structures throughout the brain (Battaglia, Benchenane, Sirota, Pennartz, & Wiener, 2011). That is, complex cognitive abilities like memory and attention, as well as domain-specific learning, such as in language or math, are thought to be distributed throughout the brain in complex networks.

12. Learning is due to the addition of new cells to the brain. **Incorrect**

The brain is a complex network with approximately one hundred billion neurons and trillions of intra-connections (Bonmati, Bardera, & Boada, 2016, para. 1). Throughout the lifetime, the brain continues to change “chemically, physically, and functionally based on sensory and other inputs” (Merzenich, 2017, p. 4). Research has shown that learning involves synaptic plasticity that is related to neuronal firing and integration (Bukalo, Campanac, Hoffman, & Fields, 2013), meaning new synapses, not new neurons, are the basis for learning. Functional brain changes follow cognitive and motor task learning that can be mapped to functional connectivity among brain networks (Patel, Spreng, & Turner, 2013) comprised of multiple and organized synapses. Through advancements in neuroimaging technology, researchers are able to show discrete cognitive changes during problem solving tasks, in which task learning occurs in stages of encoding, solving, and responding (Tenison, Fincham, & Anderson, 2016) that reflect changes in the number of synapses, not of neurons. Adult neurogenesis, which is defined as “ the formation of new neurons from neural stem and progenitor cells” (Begega, Alvarez-Suarez, Sampedro-Piquero, & Cuesta, 2017, p. 3), occurs to a limited degree within the hippocampus, the subventricular zone, the cerebellum, the hypothalamus, and most recently and controversially: within the neocortex (Ryu et al., 2016). Though the established and potential implications for adult neurogenesis are profound, it is clear that, under normal circumstances, new neurons play a minor role in the plasticity of the nervous system.

13. Individuals learn better when they receive information in their preferred learning styles (e.g., auditory, visual, kinesthetic). **Incorrect**

Learning styles is one of the most widespread myths in education (Pashler, McDaniel, Rohrer & Bjork, 2008; Reiner & Willingham, 2010; Roher & Pashler, 2012). Despite repeated testing of hypotheses relating to learning styles, there is no evidence to date showing that individuals learn better when they receive information in their preferred learning styles (Newtown & Miah, 2017; Newtown & Miah, 2017). Teaching to learning styles may actually hinder learning or affect a student’s self-perception. If “diagnosed” with a specific learning style (e.g., “you are a visual learner”), students may feel compelled to seek out stimuli in that modality, fostering a fixed mindset (Vaughan, 2017). In 2006, a learning styles challenge was put forth by a team of underwriters offering $1,000 and then moving it up to $5,000 to provide scientific evidence supporting this myth (Wallace, 2014). To date, there has not been a payout.

14. Learning occurs through changes to the connections between brain cells. **Correct**

Learning occurs through well-functioning memory and attention systems. Both memory and attention are possible due to changes in connections, between brain cells (Bear, Connors, & Paradiso, 2016). New memory formation and attuned attentional systems require a “rewiring” of the connections within the brain resulting from experience. There are several mechanisms by which the connectivity between two neurons can be modified, some with very brief effects, and others making permanent changes.

15. A primary indicator of dyslexia is seeing letters backwards. **Incorrect**

Research shows that people with dyslexia have difficulty decoding written words relating to the mapping of sounds to letters (Barquero et al., 2014; Moats, 2009; Siegel, 2006). Although individuals with dyslexia may reverse letters when reading and spelling, this is also relatively common in typically developing readers (Treiman et al., 2014). Dyslexia is a neurodevelopmental disorder that affects the ability to read effectively. In all world languages, children with dyslexia have primary difficulties recognizing and manipulating phonological units (Goswami, 2007). Phonological and orthographic processing are byproducts of the functional integrity of the temporal parietal junctures in the brain’s left hemisphere (Pugh et al., 2000; Shaywitz, 2003). Dyslexic subtypes include dysphonetic, surface, mixed, and reading comprehension deficits (US Dept. of Education & National Institute of Literacy, 2014). Dysphonetic dyslexia is characterized by the inability to use a phonological route to connect graphemes and phonemes, resulting in over-reliance on orthographic cues to identify words (Grizzle & Sims, 2009). Surface dyslexia, by contrast, is characterized by the ability to sound out phonemes in words but an inability to recognize words in text with automaticity (Cao, Bitan, & Booth, 2008). Mixed dyslexia is the most severe subtype of dyslexia and is characterized by difficulties in phonological processing, word recognition, and language comprehension. Reading comprehension deficits are characterized by an inability to derive meaning from print despite good reading mechanics, often associated with working memory and/or executive function deficits (Nation & Snowling, 1998).

16. Normal development of the human brain involves the birth and death of brain cells. **Correct**

The birth and death of brain cells is a normal, and necessary, part of brain development (Lagercrantz, 2013). During early brain development, neural connections and neurons proliferate, rapidly creating a structure with more neurons and connections than the individual will have in adult life (Tierney & Nelson, 2009). The overproduction of these neurons is balanced out through apoptosis, also referred to as programmed cell death (Tierney & Nelson, 2009). A key part in the shaping of the neural connections involves axon and synaptic pruning (Riccomagno & Kolodkin, 2015). Connections that are rarely used are eliminated, leading to a more efficient system that has adapted to the demands of the individual's environment (Johnson, Blum, & Giedd, 2009). It was once thought that adult brains could not generate new brain cells; however, "even in old age, the brain still produces about 700 new neurons in the hippocampus per day" (Harvard Health Publishing, 2016, para. 5).

17. Mental capacity is genetic and cannot be changed by experiences. **Incorrect**

The principle of neuroplasticity states that the nervous system can change its structure, function, and connections in response to intrinsic or extrinsic stimuli (Cramer et al., 2011; Khan et al., 2017). Research on brain plasticity suggests that learning experiences can continuously change the brain (Hinton et al., 2012). Neuroplasticity has important implications for learning since it suggests that human abilities are not fixed and can be modified through experiences and enhanced through appropriate instruction and instructional design (Hardiman, 2012). Additionally, the brain is changed as a result of experience throughout the lifespan, which has important implications for adult learning. While genes play an important role in intelligence, the environment also influences mental capacity.

18. Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain. **Correct**

Research shows that the brain continuously changes in response to environmental demands (Hötting & Röder, 2013). Studies show that intensive training can result in both white and grey matter changes (Zatorre, Fields & Johansen-Berg, 2012). One study on foreign language training showed increases in gray matter volume in the hippocampus and the superior temporal gyrus, and this increase correlates positively with after-training performance (Mårtensson et al., 2012). Other studies on piano playing (Steele, et al., 2013), working memory training (Buschkuehl et al., 2012), and even meditation (Tang et al., 2012) show increases in white matter in the brain, suggesting that all new learning modifies the shape and structure of the brain.

19. Individual learners show preferences for the mode in which they receive information (e.g., visual, auditory, kinesthetic). **Correct**

The human brain seeks information through all modalities in order to understand its context and to make decisions (Kidd & Hayden, 2015). According to Pashler and colleagues (2008), "The existence of preferences, as we interpret it, amounts simply to the fact that people will, if asked, volunteer preferences about their preferred mode of taking in new information and studying" (p. 108). However, there is no evidence supporting that individuals learn better through their preferred learning style (Newtown & Miah, 2017; Pashler et al., 2008).

20. Learning problems associated with developmental differences in brain function cannot be improved by education. **Incorrect**

Research shows that learning problems associated with developmental differences can be improved with education. In dyslexia, phonological interventions for students with dyslexia improve phonological decoding skills and result in atypical brain activation profiles to return to typical patterns (Shaywitz et al., 2004; Simos et al., 2002; Spironelli et al., 2010), for example. In dyscalculia, neural markers are emerging with interventions that strengthen numerical processing (Butterworth et al., 2011). Individuals with Down syndrome, with relative strength in visuospatial processing as compared to verbal processing, show improved learning from instruction with visual supports as compared to verbally-based instruction (Fidler & Nadel, 2007; Pinter et al., 2001).

21. Learning is due to modifications in the brain. **Correct**

Modifications in the brain are associated with learning. Advancements in brain imaging, such as fMRI and fNIR, provide new insights into structural and functional reorganization in the brain associated with learning new skills and developing expertise (Chang, 2014). Research reveals that experience and practice leads to changes at the synaptic level in the brain; these changes in brain connectivity are an essential part of the learning process (Bear, Connors, & Paradiso, 2016) and neuroplasticity, "which refers to the brain's ability to change its structure and function" (Chang, 2014, p. 35).

22. Listening to classical music increases reasoning ability. **Incorrect**

The Mozart effect was coined in 1991 and has been associated with the idea that listening to classical music "improves the brain" (Hammond, 2013), increases intelligence (Waterhouse, 2006), and even increases spatial ability (McKelvie & Low, 2002). However, there are no studies to date that show that listening to classical music lives up to this widespread myth (McKelvie & Low, 2002; Pietschnig, Voracek, & Formann, 2010; Waterhouse, 2006). While it is “attractive to believe” that exposure to classical music can improve reasoning, recall, and learning, the premise of “syncing the brain to musical rhythms has not been proven” (Tokuhama-Espinosa, 2017, p. 41).

23. Production of new connections in the brain can continue into old age. **Correct**

The human brain has been described as “plastic” due to the malleability of neuronal connectivity and circuitry (Power & Schlaggar, 2017). The term neuroplasticity comes from the Greek word “plastos,” meaning “molded” which refers to the brain being able to reorganize itself by forming new neural connections in response to learning, experience, or injury (Frostig, 2012; Demarin, Morović, & Bene, 2014). The human brain continues to change throughout the lifespan (Demarin, Morović, & Bene, 2014).

General Statements from the Learning Sciences and MBE Science

1. Metacognition plays a role in learning. **Correct**

Extensive research demonstrates that “students' metacognition has been linked to increased learning, improved performance and greater achievement of educational goals” (Stolp & Zabrucky, 2009, p. 9) as well as to cumulative improvements in a person’s knowledge and thinking (Reif, 2008). Instruction in metacognition has also been shown to help students learn and retain life skills such as self-regulating thought and actions, overcoming biases, and resisting prejudice (Lau, 2015).

2. Learning should be spaced out over time. **Correct**

Spacing study sessions over time, also called distributed practice or spaced versus massed practice, tends to enhance retention of information, compared to massed practice or cramming (Carpenter et al., 2012). There are several reasons why this effect might happen, including the association of a wider set of contextual cues to the studied information, and possibly, enhancement of brain mechanisms for encoding new information. However, it is most likely that spacing learning over time permits sleep-dependent consolidation of memory (Stickgold, 2006), avoids the mind-wandering caused by massed practice (Metcalfe & Xu, 2016), and facilitates the completion of learning cycles (Pedaste, et al. 2015), which improve learning effectiveness. The research on spacing suggests that spreading study over time is a potent and practical way to retain more information in less total study time.

3. Focused attention is essential for learning new information. **Correct**

Within cognitive theory, there is a longstanding principle stating that encoding new information into memory involves conscious, effortful processing (Griffith, 1976; MacKay, 1987; MacKay & Burke, 1990; Tyler, Hertel, McCallum & Ellis, 1979). In general, processing information in a “deep” or meaningful way leads to better recall

(Craik & Lockhart, 1972; Craik & Tulving, 1975), and dividing attention during the formation of new memories decreases the likelihood of recall (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996: DeWinstanley & Bjork, 2002). Furthermore, effects such as change blindness (Rensink, 2002; Rensink, O'Regan, & Clark, 1996) offer a dramatic illustration of how little information about a visual scene is retained in the absence of focused attention. In this phenomenon, substantial changes to a scene may not be noticed even after a number of viewings, particularly if they are in portions of the scene that are not central to the picture's theme and thus fail to attract focused attention.

4. Maintaining a positive atmosphere in the classroom helps promote learning. **Correct**

"Stress in humans influences memory formation (i.e., the process from encoding to storage)" (Lindau, Almkvist, & Mohammed, 2016, p. 156). Short-term stress can negatively impact the learning process, even hours after a specific incident occurred, while exposure to long-term stress can create chemical imbalances in the brain. Research on emotional contagion, "tendency to mimic emotional expressions and experiences of others in a social interaction," can also influence the learning environment (Bhullar, 2012). Instructors can help nurture a positive learning environment by being attentive to student needs, cultural differences, and setting clear expectations for performance and behavior, among others.

5. Repeated practice and rehearsal of learned material or a skill will help to consolidate it in long-term memory. **Correct**

Memory consolidation, broadly speaking, refers to the processes that strengthen a memory over time, after the memory is initially created, resulting in a stable representation in long term memory (see McGaugh, 2000 for a review) and/or habituation. Multiple mechanisms contribute to memory consolidation, including sleep, emotional arousal, and the reorganization of memory representations over time (McGaugh, 2000). However, practice that involves retrieving or rehearsing the information from memory over multiple episodes, promotes consolidation and reconsolidation in long-term memory (Parle, Singh, & Vasudevan, 2006; Racsmány, Conway, & Demeter, 2010; Roediger & Butler, 2011).

6. Experts and novices approach solving problems in essentially the same way. **Incorrect**

Research on problem solving shows that there are essential differences between experts and novices in their approaches to solve a problem within their domain. Experts who have extensive training in a specific domain solve problems faster and more successfully compared to novices (Larkin et al., 1980). This can be explained by the differences in cognitive processes involved in problem solving (Egan & Schwartz, 1979; Rowland, 1992; Sarsfield, 2014; Tawfik et al., 2017). Novices often rely on the surface features of the problem whereas experts tend to rely on the structural features such as underlying principles (Ertmer et al., 2008; Goldstein, 2014). This comes down to habituation and rehearsal: the brain adapts to what it does most. Some researchers suggest that experiences allow experts to create mental models that they use to recognize patterns and underlying principles (Ertmer et al., 2008; Glaser & Chi, 1988). Based on the theory of knowledge acquisition (Anderson, 2010; Fotts & Posner, 1967), the transition from novice stage to expert stage of problem solving is characterized by increased automated responses and expanded factual networks that result in more efficient problem solving in terms of speed and accuracy.

7. Differentiated instruction is individualized instruction. **Incorrect**

Differentiated instruction is often presumed to mean individual instruction and creating assignments unique to each learner. However, differentiated instruction focuses on meeting students where they are in their learning (Tomlinson, 2008, 2017). Differentiated instruction can include providing options for readings or choice in selecting topics for assignments that meet the same stated outcomes. “Differentiated instruction is becoming critical in higher education due to student diversity and background knowledge” (Pham, 2012, p.13). One way that differentiation is achieved is through Universal Design for Learning (UDL) in which basic common denominators of learning create the conditions under which all can learn (Rose & Meyer, 2006). UDL guidelines support all learners through multiple means of engagement (affective network), representation (recognition networks), and action and expression (strategic networks).

8. Rereading course materials is an effective strategy for learning. **Incorrect**

Although re-reading course materials is a favored study strategy among college students (Karpicke et al., 2009), its value as a study activity is limited, when compared to other alternative study activities (Dunlosky, Rawson, March, Nathan, & Willingham, 2013). Rereading sessions, which are typically massed (grouped together close in time), tend not to produce significant improvement in memory in return for the time invested (Callender, & McDaniel, 2009). This may be because readers tend to construct their initial understanding of a text on the first reading and tend not to change this understanding when they read the text again (Callender, & McDaniel, 2009). While rereading text is one of the preferred study strategies by learners, it is among the least productive, according to Brown, Roediger, and McDaniel (2014),

9. Explaining the purpose of a learning activity helps engage students in that activity. **Correct**

Research indicates that students learn more when a lesson’s purpose is communicated clearly (Fraser, Walber, Welch, & Hattie, 1987). Clearly communicating the goals and objectives of a learning activity engages students in the learning process which can increase their attention and focus, supporting a more meaningful learning experience. “Simply put, when students understand the purpose of a lesson, they learn more” (Fisher & Frey, 2011, p. 3).

10. Decorative graphics can enhance learning when applied to course materials. **Correct**

Graphics can be used within an on-campus classroom or online environment to bring attention to a specific concept or idea as well as to further support course content. Clark and Mayer (2008) and Sung and Mayer (2012), share that relevant graphics with text can foster deeper cognitive processing in learners to communicate an instructional message. However, adding irrelevant graphics may not support learning. Too much information, particularly irrelevant content, can result in cognitive overload and affect task completion/performance (Shibli & West, 2018). Furthermore, graphic organizers can enhance learning by allowing "students to see connections among topics, how activities relate to learning objectives, and how they will demonstrate understanding of the lesson's goals" (Hardiman, 2012, p. 83).

11. Meaningful feedback accelerates learning. **Correct**

Feedback is important for student learning (Tweyma & Heward, 2018). However, it is not feedback for the sake of feedback that is beneficial. According to Hattie and Timperley (2007), "To be effective, feedback needs to be clear, purposeful, meaningful, and compatible with students' prior knowledge and to provide logical connections" (p. 104). Effective feedback needs to have particular characteristics, for example, it must be useful (Harks, Rakoczy, Hattie, Besser, & Klieme, 2014), meaningful (Hattie & Timperley, 2007), specific and differentiated (Tweyma & Heward, 2018), and timely (Boud, & Molloy, 2013; Juwah et al., 2004).

12. Information that is studied over longer periods of time is better remembered than the same information studied over shorter periods of time. **Correct**

The spacing effect, also known as the distribution of practice effect or distributed practice, is a well-established principle in learning and memory (Smolen, Zhang & Byrne, 2016). Furthermore, the advantage of studying in a spaced or distributed fashion is a robust and long-lasting one. In one study of long-term memory for Spanish vocabulary items, increasing the spacing between study sessions produced an improvement that was detectable eight years after the items were originally learned (Bahrick & Phelps, 1987). Other researchers have investigated the neural basis for this effect, reporting that spacing may promote the genesis and survival of brain cells in areas that are critical for memory (Sisti, Glass, & Shors, 2007).

13. The mind connects new information to prior knowledge. **Correct**

The constructivist approach indicates that all learning builds on an individual's prior experience and knowledge (Ültanir, 2012). According to neuroscientific fact, the mind filters new information with previous knowledge in order to construct reality (Ültanir, 2012). Neuroconstructivism, a related area of study, posits the neural basis of the construction of reality, focusing on the experience-dependent synaptic, cellular, chemical, and structural changes in the brain that are essential to memory and learning (Mareschal et al., 2007). This is related to the MBE science concept that "all new learning passes through the filter of prior experience" (Tokuhama-Espinosa, 2017, p.47).

14. Universal Design for Learning is a framework to improve and optimize teaching and learning for all people based on scientific insights into how humans learn. **Correct**

The Center for Applied Special Technology (CAST) has spent over three decades developing the Universal Design for Learning guidelines. According to CAST, "Universal Design for Learning is a framework to improve and optimize teaching and learning for all people based on scientific insights into how humans learn" (n.d., para. 1). UDL guidelines stress the importance of providing multiple means of (a) engagement, (b) representation, and (c) action, and expression. According to Tobin (2014):

> Adopting UDL principles in order to create online course content allows higher education faculty members to reach out, not only to learners with disabilities, but also to learners who are increasingly using mobile devices to connect to campus and to each other. (p. 13)

15. With respect to memory, massed instruction is superior to spaced instruction. **Incorrect**

According to Miles (2016), "Memory research has shown that information is retained far longer when instruction and reviews of learned content are given in spaced intervals (spaced distribution) rather than during one uninterrupted session (massed distribution)" (p. 412). While spaced learning and distributed practice may take longer than massed instruction and practice, information is retained longer when it is spaced (Missouri Department of Education, 2012). Depending on the complexity of the information, different amounts of spacing results in superior learning (less complex ideas require less time).

16. Frequent, low stakes tests do not enhance learning. **Incorrect**

Replacing infrequent, high-stakes exams with frequent low-stakes quizzes can raise performance and reduce achievement gaps for underprepared college students (Pennebaker, Gosling, & Ferrell, 2013). Among one study of high schoolers, frequent in-class quizzing was perceived by students as helpful and reduced test anxiety associated with higher-stakes exams (Agarwal, D'Antonio, Roediger, McDermott, & McDaniel, 2014). Quizzing promotes the transfer of learning (Carpenter, 2012; Thomas, Weywadt, Anderson, Martinez-Papponi, & McDaniel, 2018). Continuous formative testing has been shown to maximize long-term retention and retrieval (Lahey, 2014).

17. Sleep has a role in memory consolidation. **Correct**

Research studies indicate that sleep plays an important role in memory and learning. According to the Division of Sleep Medicine at Harvard Medical School (2007), “sleep itself has a role in the consolidation of memory, which is essential for learning new information” (para. 2). Sleep consolidation is the process of transforming new information encoded in the awake state into stable mental representations in long-term memory (Diekelmann & Born, 2010; Stickgold, 2006). Research studies on sleep and memory suggest that sleep has a positive effect on motor memory (Fischer, Hallschmid, Elsner, & Born, 2002; Walker et al., 2002), declarative memory (Plihal & Born, 1997), visual discrimination (Stickgold et al., 2000) and task performance (Stickgold, James, & Hobson, 2000).

18. Emotions can affect human cognitive processes, including attention, learning and memory, reasoning, and problem-solving. **Correct**

There is no decision making without emotion (Immordino-Yang, 2007; 2010); affect influences cognition. Research shows that emotion has a substantial influence on cognitive processes, including perception, attention, learning, memory, reasoning, and problem solving (Tyang, Amin, Saad, & Malik, 2017). Emotion has also been found to have a strong influence on attention, encoding, and retrieval (Kensigner, 2009; Tyang et al., 2017).

19. Human brains are relatively as unique as fingerprints. **Correct**

A groundbreaking study conducted by Yale University (Finn et al., 2015) found that neural connectivity patterns are unique to an individual and can be identified and matched to an individual during a number of different tasks. Put succinctly, as humans can be identified by their fingerprints, they can also be identified by the unique ways their brain processes information. Similarly, just as everyone’s face has similar parts (two ears, one nose, one mouth, and so on; Tokuhama-Espinosa, 2008), people’s brains have similar parts, but no two faces and no two brains are identical. It is important to note, however, that the dynamic and iterative learning process means that neuronal circuits can be modified experience to experience, meaning the neural pattern changes with every new experience. As no two people have the exact same experiences in life, their neural networks are also distinct.

20. You can train certain parts of the brain to improve their functioning. **Correct**

Neuroplasticity reveals that the brain continues to change throughout the lifespan (Pickersgill, Marin, & Cunningham-Burley, 2015; Pitts-Taylor, 2010) and that overt training of certain functions leads to modifications in brain function. This change is the result of experience, training, learning, and/or injury. Brain areas do not work in isolation. Rehearsal of neuronal networks that subserve different functioning can improve the particular sub-area. For example, rehearsal of working memory improves working memory networks (Snowball et al, 2013). Research shows that cognitive rehabilitation, which consists of diverse interventions, reinforces, strengthens and restores impaired skills in specific domains (Barman, Chatterjee, & Bhide, 2016). It should be noted you cannot improve the functioning of any part of the brain as long as it is functioning normally; however, you can improve your ability to do any skill through learning and practice.

21. Stress can impair the ability of the brain to encode and recall memories. **Correct**

Stress influences learning. However, stress is not always bad. Certain levels of stress are important for learning (eustress). Toxic stress, however, in which an individual experiences distress over time can impair the ability to encode and recall memories (Finsterwald & Alberini, 2014). While stress impacts learning in all humans, what stresses one person may not stress another. Studies in the early 20th century by Yerks and Dodson (1908) showed that optimal performance, including learning, occurs with an individually appropriate level of stress. One-hundred years later, Lupien, Maheu, Flocco, and Schramek (2007) showed that the combination of neurotransmitters needed to solidify new learning is interrupted by chemicals released during negative stress.

22. Intelligence is fixed at birth. **Incorrect**

While evidence indicates that there is a hereditary influence on intelligence (Plomin & von Stumm, 2018; Wadsworth, Corley, & DeFries 2014), it is also known that a person's intelligence is not determined solely by genes and, hence, is not fixed at birth (Chung, Fieguth, & Wong, 2018; Tokuhama-Espinosa, 2018). The environmental influences on intelligence are undeniable, with intelligence being ever-changing throughout an individual's life (Rinaldi, & Karmiloff-Smith, 2017; Tokuhama-Espinosa, 2018; Turkheimer & Horn, 2014), it can also be changed with training (Au et al., 2015; Swanson & McMurran, 2018). This means that while there is a genetic component to learning, the environment (life experiences) changes intelligence over and across the lifespan.

23. Production of new neuronal connections in the brain continues over the lifetime. **Correct**

It was long believed that the human brain did not develop after certain critical periods in life. However, it is now known that connections among neurons grow throughout a human being's life—a process known as "neuroplasticity" (Doidge, 2007). Neuroplasticity is defined by Demarin, Morović, and Bene (2014) as the "brain's ability to change, remodel and reorganize for purpose of better ability to adapt to new situations" (p. 209). New neural connections form throughout one's lifetime in response to the environment and experience and include all learning.

24. The brain acts as a filter to help us to pay attention to what is important. **Correct**

The brain is characterized by selective attention which is the process of attending to specific stimuli while ignoring others (Goldstein, 2014) for the sake of conserving energy (cognitive load). In the 1950s, Broadbent's filter model of attention showed that attended information is separated from unattended signals at an early stage of information processing by the brain (Goldstein, 2014). Based on the load theory of attention proposed by Forster and Lavie (2008), during low-load tasks, there are cognitive resources available to process task-irrelevant information together with task-relevant information. On the other hand, during high-load tasks, people use all their processing capacity so there are no cognitive resources available to process task-irrelevant information.

25. Multitasking while studying increases productivity. **Incorrect**

Several studies link multitasking during studying to a decrease in efficiency and/or performance. The time needed to complete academic tasks increases while distracted by instant messages (Bowman, Levine, Waite, & Gendron, 2010) or other online activities (Subrahmanyam et al., 2013). Multitasking during lectures is associated with poorer retention of class concepts (Ellis, Daniels, & Jauregui, 2010) as well as with lower academic achievement (Junco, 2012; Junco & Cotton, 2012). Furthermore, individuals who are prone to multitasking tend to have inflated views of their own ability to do so (Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013), leading to the illusion of improved productivity when this is not the case. Lastly, research on academic achievement in college students reveals clear decrements associated with multitasking with technology while studying or in class, particularly technologies such as instant messaging and social media that lend themselves to task switching and interruptions (Junco, 2012; Junco & Cotton, 2012).

26. Human memory works much like a digital recording device or video camera in that it accurately records the events we have experienced. **Incorrect**

People commonly believe that human memory records information relatively faithfully and completely, like a camera does (Simons & Chabris, 2011), but this belief is incompatible with contemporary memory theory. There is broad consensus among experts that the construction of memory encoding, storage, and retrieval is an active and constructive process that is highly influenced by pre-existing beliefs, expectations, and knowledge (Bransford & Johnson, 1972; DeWinstanley & Bjork, 2002; Loftus & Palmer, 1972). Unlike digital recording devices, memory is also highly subject to biases, errors, and omissions (Chabris & Simons, 2010; Nickerson & Adams, 1979; Schachter, 1999).

27. Human brains seek and often quickly detect novelty. **Correct**

The brain processes an enormous number of visual images per hour: an estimated 36,000 per hour (Wilmes et al., 2008). This mental stimulus is augmented by the other senses (auditory, kinesthetic, olfactory, gustatory), and would overwhelm the brain if there was not a hierarchy. With this volume of information, the brain quickly identifies changes in an environment: a new classroom design, the instructor’s outfit, notes on a whiteboard. Hardiman (2003) cited a series of studies conducted by Zentell (1983) that showed students were more apt to lose attention and leave their seats when classroom design and structure went unchanged versus students in classrooms that were occasionally altered.

28. Testing, in general, tends to detract from learning. **Incorrect**

Taking tests of various formats and types is a form of retrieval practice, known today as one of the most robust ways to promote memory for studied information (Brown, Roediger, & McDaniel, 2014; Carpenter, 2012; Karpicke & Roediger, 2008; Roediger & Butler, 2011). Testing can even potentiate or promote the learning of new, not-yet-studied information (Chan, Meissner, & Davis, 2018). Testing also supports transfer of learning, for example, to new contexts or question types (Carpenter, 2012; Thomas, Weywadt, Anderson, Martinez-Papponi, & McDaniel, 2018).

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Appendix A

Survey

International Study: Higher Education Pedagogical Perspectives & Practices

This survey consists of three sections: (1) General Statements about the Brain; (2) General Statements from the Learning Sciences, and (3) Demographics and Professional Background.

Section One: General Statements about the Brain

Directions: Read the statements carefully. Indicate whether you believe the statement is "Correct" or "Incorrect." If you do not know, select "I Don't Know."

	Correct	Incorrect	I Don't Know

1. We use our brain 24 hours a day.
2. It is best for children to learn their native language before a second language is learned.
3. On average, males have bigger brains than females.
4. When a brain region is damaged, other parts of the brain can sometimes take up its function.
5. We only use 10% of our brain.
6. The left and right hemispheres of the brain work together.
7. Some of us are "left-brained" and some are "right-brained" due to hemispheric dominance and this helps explain differences in how we learn.
8. The brains of males and females develop at different rates.
9. Brain development has finished by the time children reach puberty.
10. There are critical periods in human development after which certain skills can no longer be learned.
11. Information is stored in networks of cells distributed throughout the brain.
12. Learning is due to the addition of new cells to the brain.
13. Individuals learn better when they receive information in their preferred learning styles (e.g., auditory, visual, kinesthetic).
14. Learning occurs through changes to the connections between brain cells.
15. A primary indicator of dyslexia is seeing letters backwards.
16. Normal development of the human brain involves the birth and death of brain cells.
17. Mental capacity is genetic and cannot be changed by experiences.
18. Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain.
19. Individual learners show preferences for the mode in which they receive information (e.g., visual, auditory, kinesthetic).

20. Learning problems associated with developmental differences in brain function cannot be improved by education.
21. Learning is due to modifications in the brain.
22. Listening to classical music increases reasoning ability.
23. Production of new connections in the brain can continue into old age.

24. In reflecting upon your responses within Section One, identify the sources on which you based your responses?
    Select all that apply.
    - ❑ What I learned during my undergraduate education
    - ❑ What I learned during my graduate education
    - ❑ Professional development programs within the institution(s) where I have previously worked
    - ❑ Professional development programs within the institution(s) where I currently work
    - ❑ Professional development programs outside of institutions where I have worked
    - ❑ Conferences
    - ❑ Online Course(s)
    - ❑ Webinar(s)
    - ❑ Colleagues from work
    - ❑ Friends
    - ❑ Family
    - ❑ TV Shows
    - ❑ TV Commercials
    - ❑ Movies
    - ❑ Books
    - ❑ Textbooks
    - ❑ Journals
    - ❑ Social Media
    - ❑ Magazine Articles
    - ❑ Magazine Ads
    - ❑ Newspapers
    - ❑ Internet Searches
    - ❑ Facebook
    - ❑ Intuition
    - ❑ I don't know
    - ❑ Other _________

Section Two: General Statements from the Learning Sciences

Directions: Read the statements carefully. Indicate whether you believe the statement is "Correct" or "Incorrect." If you do not know, select "I Don't Know."

	Correct	**Incorrect**	**I Don't Know**
1. Metacognition plays a role in learning.			
2. Learning should be spaced out over time.			
3. Focused attention is essential for learning new information.			
4. Maintaining a positive atmosphere in the classroom helps promote learning.			
5. Repeated practice and rehearsal of learned material or a skill will help to consolidate it in long-term memory.			
6. Experts and novices approach solving problems in essentially the same way.			
7. Differentiated instruction is individualized instruction.			

8. Rereading course materials is an effective strategy for learning.
9. Explaining the purpose of a learning activity helps engage students in that activity.
10. Decorative graphics can enhance learning when applied to course materials.
11. Meaningful feedback accelerates learning.
12. Information that is studied over longer periods of time is better remembered than the same information studied over shorter periods of time
13. The mind connects new information to prior knowledge.
14. Universal Design for Learning is a framework to improve and optimize teaching and learning for all people based on scientific insights into how humans learn.
15. With respect to memory, massed instruction is superior to spaced instruction.
16. Frequent, low stakes tests do not enhance learning.
17. Sleep has a role in memory consolidation.
18. Emotions can affect human cognitive processes, including attention, learning and memory, reasoning, and problem-solving.
19. Human brains are relatively as unique as fingerprints.
20. You can train certain parts of the brain to improve their functioning.
21. Stress can impair the ability of the brain to encode and recall memories.
22. Intelligence is fixed at birth.
23. Production of new neuronal connections in the brain continues over the lifetime.
24. The brain acts as a filter to help us to pay attention to what is important.
25. Multitasking while studying increases productivity.
26. Human memory works much like a digital recording device or video camera in that it accurately records the events we have experienced.
27. Human brains seek and often quickly detect novelty.
28. Testing, in general, tends to detract from learning.

29. In reflecting upon your responses within Section Two, which sources influenced your responses?

    Select all that apply.

- ❑ What I learned during my undergraduate education
- ❑ What I learned during my graduate education
- ❑ Professional development programs within the institution(s) where I have previously worked
- ❑ Professional development programs within the institution(s) where I currently work
- ❑ Professional development programs outside of institutions where I have worked
- ❑ Conferences
- ❑ Online Course(s)
- ❑ Webinar(s)
- ❑ Colleagues from work
- ❑ Friends
- ❑ Family
- ❑ TV Shows
- ❑ TV Commercials
- ❑ Movies
- ❑ Books
- ❑ Textbooks
- ❑ Journals
- ❑ Social Media
- ❑ Magazine Articles
- ❑ Magazine Ads
- ❑ Newspapers
- ❑ Internet Searches

- ❑ Facebook
- ❑ Intuition
- ❑ I don't know
- ❑ Other ______________

Section Three: Demographic and Professional Background Information

Note. Base your responses on the college/university in which you are currently employed. If you work at more than one college/university, base your response on your primary affiliation.

1. Identify your primary role at your institution.
   - ❑ Instructor, full-time
   - ❑ Instructor, part-time
   - ❑ Instructional designer
   - ❑ Administrator involved in professional development
   - ❑ Other ______________________________

2. Over the past 12 months, "I have taught" with the following type(s) of program(s):
   Please estimate the percentage that fits each program.
   - ❑ Undergraduate – Associate's degree program(s)
   - ❑ Undergraduate – Bachelor's degree program(s)
   - ❑ Graduate – Master's, Doctoral degree program(s)
   - ❑ Professional Certificates/Certifications program(s)
   - ❑ I do not teach

   Please estimate the percent of time that aligns with each type of program in which you have taught over the past 12 months. The total sum should be 100%. Select all that apply.

3. Over the past 12 months, "I have developed courses" with the following type(s) of program(s):
   Please estimate the percentage that fits each program.
   - ❑ Undergraduate – Associate's degree program(s)
   - ❑ Undergraduate – Bachelor's degree program(s)
   - ❑ Graduate – Master's, Doctoral degree program(s)
   - ❑ Professional Certificates/Certifications program(s)
   - ❑ I do not develop courses

   Please estimate the percentage of time that aligns with each type of program in which you developed courses over the past 12 months. The total sum should be 100%. Select all that apply.

4. Over the past 12 months, "I have taught courses" in the following type(s) of format(s):

   Please estimate the percentage that fits each format.

   For the purpose of this study, the following definitions are being used.

   Classroom Course: Course activity is organized around scheduled class meetings held onsite at an institution or another location.
   Blended/Hybrid Course: Online activity is mixed with classroom meetings, replacing a significant percentage, but not all required face-to-face instructional activities.
   Online Course: All course activity is done online; no requirements for on-campus activity.

   - ❑ Classroom Course(s)
   - ❑ Blended/Hybrid Course(s)
   - ❑ Online Course(s)
   - ❑ I do not teach courses

   Please estimate the percentage of time that aligns with each format in which you taught courses over the past 12 months. The total sum should be 100%. Select all that apply.

5. Over the 12 months, "I have developed courses" in the following type(s) of format(s):
   Please estimate the percentage that fits each format.

   For the purpose of this study, the following definitions are being used.

   Classroom Course: Course activity is organized around scheduled class meetings held onsite at an institution or another location.
   Blended/Hybrid Course: Online activity is mixed with classroom meetings, replacing a significant percentage, but not all required face-to-face instructional activities.
   Online Course: All course activity is done online; there are no required face-to-face sessions within the course and no requirements for on-campus activity.

   - ❑ Classroom Course(s)
   - ❑ Blended/Hybrid Course(s)
   - ❑ Online Course(s)
   - ❑ I do not develop courses

   Please estimate the percentage of time that aligns with each format in which you developed courses over the past 12 months. The total sum should be 100%. Select all that apply.

6. What is the name of college/university in which you are currently working?
   - o Name ___________________
   - o I choose not to respond.

7. Identify the type of college/university in which you work.

2-Year
4-Year
Other

Public
Private
Other

8. Identify the country in which your affiliated college/university is located.
   - o Drop down list of countries

9. If your college/university is located in the United States, please identify the state in which it is located.
   - o Drop down list of states

10. Have you completed or do you plan to complete professional training, conferences or workshops that focus on Neuroscience, Psychology, or Mind, Brain, and Education Science (Neuroeducation, Educational Neuroscience)?

	Professional Training	**Workshop(s)**	**Certificate of Completion**	**Certificate with Credit** (undergraduate, graduate)	**MOOC** (Massive Open Online Course)
Neuroscience	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to
Psychology	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to
Mind, Brain, and Education Science (Neuroeducation, Educational Neuroscience)	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to	• Have completed • Have not completed but plan to complete • Have not completed and do not plan to

11. Indicate the number of years you have been engaged in the following activities.

	Less than 1 year	**1-4 years**	**5-9 years**	**10-19 year**	**20 years or more**	**Not Applicable**
Teaching courses on-campus (classroom courses)						
Teaching online courses						
Teaching blended/hybrid courses						
Working as an instructional designer						
Working as a professional development administrator						
Other						

12. What is your gender?

- ❑ Male
- ❑ Female
- ❑ Nonbinary
- ❑ Transgender
- ❑ I choose not to respond

13. Which of the following best describes your age at the time of this survey?
- ❑ Under 18 years
- ❑ 18 to 24 years
- ❑ 25 to 34 years
- ❑ 35 to 44 years
- ❑ 45 to 54 years
- ❑ 55 to 64 years
- ❑ 65 years or older
- ❑ I choose not to respond

14. What is the highest level of education you have completed?
- ❑ Associate's Degree
- ❑ Bachelor's Degree
- ❑ Completed some postgraduate
- ❑ Master's Degree
- ❑ Doctoral Degree
    - o Ph.D. — Doctor of Philosophy
    - o EdD — Doctor of Education
    - o DBA — Doctor of Business Administration
    - o JD — Juris Doctor
    - o MD — Doctor of Medicine
- ❑ Other ____________________

15. Identify the field of your highest completed degree.
- ❑ Arts
- ❑ Business
- ❑ Divinity
- ❑ Education
- ❑ Engineering & Applied Sciences
- ❑ Health Sciences
- ❑ Humanities
- ❑ International
- ❑ Law
- ❑ Medicine
- ❑ Nursing
- ❑ Professional Studies
- ❑ Public Health
- ❑ Science
- ❑ Social Science
- ❑ Other__________

16. How many years ago did you complete your highest degree?
- ❑ Less than 1 year
- ❑ 1-4 years
- ❑ 5-9 years
- ❑ 10-14 years
- ❑ 15+ years

17. Do you read journals focused on Neuroscience, Psychology, or Mind, Brain, and Education Science (Neuroeducation, Educational Neuroscience)?

	Yes	No	Plan to
Neuroscience	❍	❍	❍
Psychology	❍	❍	❍
Mind, Brain, and Education Science (Neuroeducation, Educational Neuroscience)	❍	❍	❍
Other – fill in other fields you may read	❍	❍	❍
Other – fill in other fields you may read	❍	❍	❍

18. If you answered, "yes" to any part of the prior question, **list four** of the most relevant journals you read or subscribe to.

____
____
____
____

19. Identify any of the following educational resources used in your working environment. *Select all that* apply.
- ❑ Brain Gym
- ❑ Peak
- ❑ Lumosity
- ❑ Fit Brains
- ❑ Elevate
- ❑ Neuronation
- ❑ Memorado
- ❑ Not applicable
- ❑ Human Benchmark
- ❑ Other
- ❑ None of these educational resources are used in my working environment
- ❑ I choose not to respond

20. Indicate how valuable you find knowledge of the workings of the brain and its influence on learning.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I find scientific knowledge about the brain and its influence on learning valuable for my teaching practice.					
I find scientific knowledge about the brain and its influence on learning valuable for course development.					
I find scientific knowledge about the brain and its influence on learning valuable for professional development.					
I find scientific knowledge about the brain and its influence on learning interesting.					
I am interested in learning more about the brain and its influence on learning.					

21. Is there anything that you would like to share based on this survey?

____
____
____

Appendix B

Neuromyth and Statements About the Brain with Responses: Correct, Incorrect, and I Don't Know

*Statements are in the same order as the survey.

*Statements	Correct			Incorrect			I Do Not Know		
	Instructors	ID	Admin	Instructors	ID	Admin	Instructors	ID	Admin
1. We use our brain 24 hours a day.	91%	93%	92%	5%	2%	3%	4%	5%	5%
2. It is best for children to learn their native language before a second language is learned.	61%	64%	63%	16%	14%	19%	23%	22%	18%
3. On average, males have bigger brains than females.	28%	24%	17%	40%	43%	45%	32%	33%	38%
4. When a brain region is damaged, other parts of the brain can sometimes take up its function.	83%	81%	85%	5%	8%	4%	11%	11%	11%
5. We only use 10% of our brain.	47%	57%	50%	31%	28%	33%	22%	15%	17%
6. The left and right hemispheres of the brain work together.	82%	80%	74%	9%	8%	14%	9%	12%	12%
7. Some of us are "left-brained" and some are "right-brained" due to hemispheric dominance and this helps explain differences in how we learn.	28%	41%	28%	57%	46%	54%	15%	13%	18%
8. The brains of males and	60%	57%	57%	16%	18%	14%	24%	25%	29%

females develop at different rates.									
9. Brain development has finished by the time children reach puberty.	88%	87%	84%	5%	3%	5%	7%	10%	11%
10. There are critical periods in human development after which certain skills can no longer be learned.	70%	74%	80%	17%	12%	11%	13%	14%	9%
11. Information is stored in networks of cells distributed throughout the brain.	78%	82%	77%	4%	3%	6%	18%	15%	17%
12. Learning is due to the addition of new cells to the brain.	69%	68%	66%	10%	10%	14%	21%	22%	20%
13. Individuals learn better when they receive information in their preferred learning styles (e.g., auditory, visual, kinesthetic).	26%	46%	35%	65%	46%	57%	9%	8%	8%
14. Learning occurs through changes to the connections between brain cells.	75%	82%	74%	3%	2%	2%	22%	16%	24%
15. A primary indicator of dyslexia is seeing letters backwards.	23%	27%	24%	52%	44%	51%	25%	29%	25%
16. Normal development of the human brain involves the birth	56%	64%	56%	21%	11%	17%	23%	25%	27%

and death of brain cells.									
17. Mental capacity is genetic and cannot be changed by experiences.	93%	91%	94%	3%	2%	2%	4%	7%	4%
18. Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain.	82%	82%	77%	4%	4%	4%	14%	14%	19%
19. Individual learners show preferences for the mode in which they receive information (e.g., visual, auditory, kinesthetic).	90%	89%	88%	7%	7%	7%	3%	4%	5%
20. Learning problems associated with developmental differences in brain function cannot be improved by education.	89%	88%	90%	5%	3%	4%	6%	9%	6%
21. Production of new connections in the brain can continue into old age.	91%	93%	91%	3%	2%	2%	6%	5%	7%
22. Listening to classical music increases reasoning ability.	15%	13%	11%	45%	34%	41%	40%	53%	48%
23. Learning is due to modifications in the brain.	67%	64%	58%	10%	10%	9%	23%	26%	33%

Evidence-Based Practice Statements and Responses: Correct, Incorrect, and I Don't Know

*Statements are in the same order as the survey.

Statements	Correct			Incorrect			I Do Not Know		
	Instructors	ID	Admin	Instructors	ID	Admin	Instructors	ID	Admin
1. Metacognition plays a role in learning.	89%	95%	94%	1%	0%	0%	10%	5%	6%
2. Learning should be spaced out over time.	76%	87%	78%	11%	4%	13%	13%	9%	9%
3. Focused attention is essential for learning new information.	70%	74%	60%	20%	17%	27%	10%	9%	13%
4. Maintaining a positive atmosphere in the classroom helps promote learning.	98%	96%	98%	1%	1%	0.6%	1%	3%	1%
5. Repeated practice and rehearsal of learned material or a skill will help to consolidate it in long-term memory.	93%	94%	95%	4%	3%	3%	3%	3%	2%
6. Experts and novices approach solving problems in essentially the same way.	76%	84%	73%	10%	8%	9%	14%	8%	18%
7. Differentiated instruction is individualized instruction.	40%	53%	44%	32%	28%	34%	28%	19%	22%
8. Rereading course	26%	40%	31%	67%	47%	60%	7%	13%	9%

materials is an effective strategy for learning.									
9. Explaining the purpose of a learning activity helps engage students in that activity.	98%	99%	96%	1%	1%	3%	1%	0%	1%
10. Decorative graphics can enhance learning when applied to course materials.	78%	57%	70%	10%	34%	15%	12%	9%	15%
11. Meaningful feedback accelerates learning.	96%	99%	98%	1%	0%	0%	3%	1%	2%
12. Information that is studied over longer periods of time is better remembered than the same information studied over shorter periods of time.	55%	63%	54%	24%	19%	26%	21%	18%	20%
13. The mind connects new information to prior knowledge.	95%	99%	95%	2%	1%	2%	3%	0%	3%
14. Universal Design for Learning is a framework to improve and optimize teaching and learning for all people based on scientific insights into how humans learn.	58%	87%	74%	5%	7%	12%	37%	6%	14%

15. With respect to memory, massed instruction is superior to spaced instruction.	58%	70%	63%	5%	2%	4%	37%	28%	33%
16. Frequent, low stakes tests do not enhance learning.	72%	84%	83%	12%	10%	7%	16%	6%	10%
17. Sleep has a role in memory consolidation.	99%	94%	97%	0%	1%	1%	1%	5%	2%
18. Emotions can affect the human cognitive processes, including attention, learning and memory, reasoning, and problem-solving.	99%	99%	99%	0%	0%	0%	1%	1%	1%
19. Human brains are relatively as unique as fingerprints.	77%	77%	78%	3%	1%	5%	20%	22%	17%
20. You can train certain parts of the brain to improve their functioning.	88%	89%	91%	2%	1%	1%	10%	10%	8%
21. Stress can impair the ability of the brain to encode and recall memories.	97%	94%	99%	2%	3%	1%	1%	3%	0%
22. Intelligence is fixed at birth.	89%	89%	86%	2%	4%	2%	9%	7%	12%
23. Production of new neuronal connections in the brain	87%	90%	87%	4%	3%	2%	9%	7%	11.0%

continues over the lifetime.									
24. The brain acts as a filter to help us to pay attention to what is important.	77%	75%	83%	7%	8%	6%	16%	17%	11%
25. Multitasking while studying increases productivity.	82%	84%	84%	5%	5%	6%	13%	11%	10%
26. Human memory works much like a digital recording device or video camera in that it accurately records the events we have experienced.	69%	79%	74%	19%	15%	19%	12%	6%	7%
27. Human brains seek and often quickly detect novelty.	72%	66%	66%	7%	6%	9%	21%	28%	25%
28. Testing, in general, tends to detract from learning.	54%	59%	50%	20%	18%	27%	26%	23%	23%

Appendix C

Publications and Resources

Journals

Journal of the Learning Sciences
https://www.tandfonline.com/toc/hlns20/current

Mind, Brain, and Education Science Journal
https://onlinelibrary.wiley.com/journal/1751228x

Neuromyths

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Mind, Brain, and Education Science and Learning Sciences

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