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Brain-based Learning: Beliefs and Practice in one Australian Primary School Implementing a Neuroscience Pedagogical Framework

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Abstract: Pedagogy grounded in neuroscience is an influential approach in Australian schools, despite concerns regarding teachers' beliefs in several neuromyths that go on to pervade their practice. This paper reports on a small study that explored teachers' beliefs and implementation of brain-based learning in one Australian primary school whose pedagogy is specifically underpinned by neuroscience. Survey data collected from 14 teachers were analysed using simple descriptive statistics and content analysis. Findings indicated that these teachers, despite having some accurate brain-based knowledge, were still prone to endorsing common neuromyths regardless of the school's teaching and learning framework, years at the school, overall teaching experience or level of qualification, with beliefs influencing classroom practice whether correct or misinformed. Further, school professional learning and universities were listed as primary sources of information for these teachers. This study underscores the importance of schools and universities providing opportunities for timely and up-to-date professional learning.

Introduction

The merging of two disciplines, science and education, provides insights into how the brain processes learning. As such, it offers an attractive way forward in the development of research-based classroom practice (Bruer, 1997; Hook & Farah, 2013; Hughes et al., 2020). Significantly, this partnership, referred to as "neuroeducation" (Ansari et al., 2012), has provoked much debate, with critics claiming the promise of neuroscience and education working together has been largely unrealised (Macdonald et al., 2017). Despite some additional criticism, such as that posed by Bowers and Holyoak (2016) who state that the potential for neuroscience to inform education has been overinflated, interest in neuroeducation has continued to flourish with a wide body of literature highlighting the level of interest and adoption shown by teachers (Dekker et al., 2012; Goswami, 2006; Hook & Farah, 2013; Im et al., 2018).

Despite this debate, there is evidence that when implemented with fidelity, some benefits to student learning can be achieved through brain-based practices, such as those considerate of how emotion affects learning (Immordino-Yang & Damasio, 2007) and the importance of the environment in typical brain development (Sanchez, 2017). There is also evidence to suggest, however, that where teachers engage in practices informed by misconceptions, both teachers and students may experience adverse effects in the form of, for instance, misguided use of time and resources, and ineffective instruction respectively (Dinham, 2016). Furthermore, these misconceptions have been reported to plague educational settings both in Australia and internationally (Grospietsch & Lins, 2021; Newton & Salvi, 2020; Torrijos-Muelas et al., 2021). In short, the potential for neuroscience-based pedagogy to contribute to improved learning outcomes for students is currently attenuated by prevailing misconceptions, otherwise known as neuromyths (Grospietsch & Lins, 2021; Torrijos-Muelas et al., 2021).

Whilst there has been a plethora of large-scale research on teachers' knowledge, or lack of knowledge, about neuroscience across mixed settings (Bassett et al., 2020; Bruer, 2016; Torrijos-Muelas et al., 2021), no single study has investigated the understanding and application of neuroscience in a school-based setting which has a whole school neuroscience policy and lays claim to using a brain-based pedagogical framework. This small-scale study uses a simple online survey to investigate the accuracy of neuroscience-based beliefs about learning held by teachers in this specific setting, and how their beliefs inform classroom practice. This narrow, specific focus offers insight into teachers' beliefs in a specific "neuroscience" school setting, further contributing to understandings of both the prevalence and contextual influences on brain-based learning knowledge and practice in schools.

This study aimed to advance current knowledge about teachers' understandings of brain-based learning, the source of their understandings and how brain-based learning is subsequently implemented. Three research questions framed this study:

1. What are teachers' beliefs about brain-based learning?
2. In what ways do teachers' beliefs about brain-based learning influence their classroom practice?
3. What factors inform or influence these beliefs?

The findings from this study have implications for the provision of induction and professional learning in school contexts where teachers are expected to effectively implement brain-based pedagogy in their classrooms, and for teachers to become critical consumers of information.

In the following section, we review the existing literature pertaining to the proposed benefits and concerns of brain-based learning, teachers' knowledge and beliefs in brain-based learning, commonly held neuromyths, and the sources of these misconceptions. The next section of this paper details and justifies the methods of data collection and analysis employed. Further to this, we present and discuss the findings from this study, followed by a consideration of the limitations of the study. Finally, we outline the potential implications of these findings for schools, universities, and future research.

Literature Review

Brain-based learning is a term that appears frequently in literature. Whilst there is no agreed-upon universal definition, Jensen and Jensen (2008, p. 4) define it as "learning in accordance with the way the brain is naturally designed to learn". In essence, brain-based learning is that approach to learning that has a direct connection to scientific understandings of the brain, its development, and the learning environment and activity that leverages and nurtures how the brain works. More recently, contemporary literature incorporates scientific terminology such as neuroscience (Carter et al., 2020), evidence-based (Macdonald et al., 2017) or scientific research (Torrijos-Muelas et al., 2021) to make clearer the intended scientific basis for this approach. The inclusion of brain-based learning has gained a foothold in teachers' instructional decision-making based on its purported benefits. To illustrate, brain-based learning has been shown to inform student learning (Fischer et al., 2007; Goswami, 2006; Kwok & Ansari, 2019), teacher effectiveness (Hardiman et al., 2012; Hughes et al., 2020), and inform departmental policy-making (Hardiman et al., 2012; Macdonald et al., 2017). Jensen and Jensen (2008) go so far as to suggest that brain-based learning heralds the coming of an entirely new paradigm of teaching that is poised to radically reform the education system.

Concerningly, international studies have warned that teachers' misunderstanding of brain-based learning may potentially result in harmful pedagogical practices (Organisation for Economic Cooperation and Development [OECD], 2007). Caine and Caine, as far back as 1991, indicated that many schools and individuals are engaged in brain-based teaching without any clear understanding of the underpinning principles. Put more simply, ideas used to defend and justify particular practices presented under the banner of brain-based learning or neuroeducation have little or no foundation in contemporary neuroscience, a situation of which many educators seem to be unaware. To that end, teachers' knowledge of brain-based learning or neuroscience in education has been extensively researched over the past three decades with consistent, international evidence of misunderstanding, misconceptions and potentially harmful pedagogical practices based on misunderstood neuroscience (Lithander et al., 2021; Newton & Salvi, 2020; Rousseau, 2021). Referred to as neuromyths (Grospietsch & Lins, 2021; Torrijos-Muelas et al., 2021), Dekker et al. (2012), Sanky (2008), and Scott and Curran (2010) contest that there are critical consequences where neuromyths are left to persist and flourish in education.

There is a range of neuromyths reported in the literature, including that: we only use 10% of the brain (Dündar & Mersin, 2016; Hughes et al., 2020; Macdonald et al., 2017), there are left and right brain learners (Dekker et al., 2012; Hughes et al., 2020), exercise can improve left and brain working together (Dekker et al., 2012; Hughes et al., 2020), and children are less attentive after consuming sugary drink or snacks (Hughes et al., 2020; Im et al., 2018; Macdonald et al., 2017). The most pervasive neuromyth, nationally and globally, is that of learning styles. The visual, kinaesthetic, auditory (VKA) classification is perhaps the most well-cited learning style model (Dündar & Mersin, 2016; Newton & Miah, 2017; Papadatou-Pastou et al., 2021; Torrijos-Muelas et al., 2021) which categorises individuals as visual, auditory, or kinaesthetic learners. This concept has been heavily criticised in the literature (Papadatou-Pastou et al., 2017; Pashler et al., 2008; Rohrer & Pashler, 2012) and categorised as a neuromyth by the Centre for Educational Research and Innovation (OECD, 2007).

Despite the lack of credible evidence to support learning styles, United Kingdom researchers, Newton and Salvi (2020) conducted a systematic review of 37 studies, representing 15,405 educators from 18 countries around the world. The researchers aggregated scores from all studies concluding that 89.1% of teachers believed that individuals learn better when information is presented to them in their own learning style. No country or school setting was immune to this belief with all 37 studies showing most educators believed this neuromyth, with Dündar and Mersin's (2016) research in Turkey reporting that as many as 97.6% of teachers supported learning styles as accurate. Comparable findings were recently reported by Hughes et al. (2020) in their study of 228 Australian teachers, with survey results indicating that 79% of practicing teachers across government, Catholic and independent schools believe students learn better when they receive information in their preferred learning style.

According to Kim and Sankey (2018), the prevalence of teachers' beliefs in neuromyths is not unexpected given the contemporary focus on student achievement and associated accountabilities for both schools and teachers. The advertised potential of neuromyths such as learning styles as a science-based approach to lifting student outcomes is undoubtedly attractive for teachers and schools looking for ways to meet ever-escalating performative demands (Sabarwal et al., 2021). The correlation between teachers' beliefs and their pedagogical decision-making is reported in a number of studies. For example, studies have considered the influence of teachers' beliefs on the teaching of creativity (Bereski & Kárpáti, 2018), the use of technology (Jones, 2017; Kim et al., 2013), approaches to the teaching of literacy (Mo, 2020), civics and citizenship (Reichert et al, 2021) and science (Nation & Feldman, 2022). Across these studies and others, teachers' beliefs are described as a kind of filter for instruction. Put simply, these beliefs are likely to inform what practices become, or do not become, part of the teaching and learning environment. Where teachers hold beliefs about teaching and learning constitutive of neuromyths, their practice is likely to be shaped by these misconceptions (Rousseau, 2021).

Dinham (2016) raises several concerns regarding the unfettered deployment of such neuromyths in schools. He draws attention to the cost to schools of taking up these unsupported approaches, such as in the provision of professional learning and resources, and time wasted on their implementation. Further, Dinham (2016) argues that students are duped into seeing themselves as learners in particular ways or believing that certain approaches to their learning will be beneficial. In a related concern, teachers may adjust their teaching to work in ways that may limit student experience (such as focusing on particular ways of engaging with new learning with particular children). At a broader level, Kim and Sankey (2018) argue that the implementation of strategies aligned with neuromyths places the credibility of the teaching profession at risk. As they state (2018, p. 1222), "surely parents and society as a whole should expect that teachers are properly informed and not basing their practices on mistaken beliefs".

In contrast, some researchers are seemingly less concerned about teachers' beliefs and implementations of these neuromyths. Horvath et al. (2018), for example, question the assumption that "believing neuromyths negatively impacts teaching", suggesting that this "may in itself be a neuromyth" (p. 1). This study from the University of Melbourne found that 50 internationally recognised, award-winning teachers from the United Kingdom, the United States and Australia held similar levels of beliefs in neuromyths to their non-award-winning colleagues; thus, indicating that neuromyths have little to no impact on perceived teacher effectiveness. Krammer et al. (2021), in a study of 255 pre-service teachers in Austria, also found there to be no substantial difference in academic achievements between those pre-service teachers who believed in neuromyths compared to those who rejected them. A serious weakness in this argument, however, is high academic achievement and awards do not necessarily corroborate teachers' competence and effective classroom practice.

Several explanations have been put forth to explain the reasons for the existence and persistence of neuromyths as part of teachers' belief systems and enacted practice. The challenge of accurately interpreting scientific research (Zadina, 2015), the influence of popular media that serves as a key source of information regardless of its scientific rigour (Dekker et al., 2012), the reinforcement of entrenched ideas (Rousseau, 2021), along with the prevalence of commercially produced pedagogical programs (Grospietsch & Lins, 2021; Howard-Jones et al., 2020) that claim to be based in neuroscience have all been put forth in the research literature as potential contributors to this phenomenon.

Interpreting scientific research, without a strong scientific background, is challenging. Given the high level of scientific literacy required to accurately interpret and understand empirical research, Pasquinelli (2012) argues that it is no surprise that misconceptions arise when non-scientists, such as many educators, access publications. Education researchers have criticised the presentation of neuroscience reports and research for being inaccessible to educators due to scientific jargon (Dekker et al., 2012; Hardiman et al., 2012) and technical language (Pasquinelli, 2012; Torrijos-Muelas et al., 2021). These researchers have not, however, made clear the extent to which teachers themselves have voiced these concerns. In a small-scale study of 30 teachers in Singapore, Tham et al. (2019) explored this assumption finding that translating scientific abstracts into appropriate teacher language did not significantly alter beliefs and instead recommended that a social constructivist epistemology with dialogue between colleagues as a more effective strategy to support teachers to make meaning from these scientifically based texts. The financial cost to access scientific journals was also cited as a reason educators increasingly turn to potentially non-peer-reviewed, open-access popular media publications rather than reviewing original sources of data (Ansari & Coch, 2006). These accessibility challenges have given the media a large and robust platform to influence education (Dekker et al., 2012; Grospietsch & Mayer, 2019; Hardiman et al., 2012).

A significant source of information for society, including educators, is popular media. The media has been heavily criticised for the creation of neuromyths for publishing sensationalist press releases without due diligence into findings (Dekker et al., 2012; Grospietsch & Lins, 2021; Hardiman et al., 2012). Knowingly or unknowingly, the media became the conduit between neuroscience and education which has not only driven but also perpetuated common neuromyths. The award-winning sci-fi movie, Neil Burger's "Limitless" starring Bradley Cooper is a case in point, based on the premise of the neuromyth that "we only use 10% of the brain". This takes the role of the media even further into disseminating neuromyths into the public forum.

Once neuromyths take hold, Macdonald et al. (2017) argue that adoption extends beyond education to become an entrenched societal belief. While most of the international research has focused on teachers' beliefs in school settings, Macdonald et al.'s (2017) study extended to include 3,045 members of the public and found neuromyths to be a deeply entrenched societal belief. These researchers found the reach of popular media has influenced the public into believing common neuromyths with 93% endorsing the existence of learning styles. While most of the international literature focuses on in-service teachers across all school settings, this study alluded to myths being more widely believed as common knowledge. This may be a plausible rationale for Grospietsch and Mayer's (2019) findings showing pre-service teachers in Australia come to university with pre-existing beliefs in neuromyths, with 93% of pre-service teachers believing in the existence of learning styles. Thomas et al. (2019) caution against mistaking neuroscience "window dressing" (p. 478) marketing with evidence-based principles.

Literature to this point has been important to highlight the existence of neuromyths in education systems across the world. Published research has been mostly large-scale, with participants being qualified teachers from both primary and secondary or pre-service teachers. The opportunity now exists for further refined research focusing on defined contexts and conditions. This study provides an important opportunity to investigate teachers' beliefs and implementation of brain-based learning in one primary school setting with a neuroscience framework in place. This small-scale study investigates what teachers, who are employed in a school with a neuroscience-based, whole-school-based pedagogy, perceive as current and accurate concerning brain-based learning, and further, to understand how their beliefs inform classroom practice.

Methodology

In this study, a mixed-methods online survey was administered to 14 teachers from a specific primary school that operates within a neuroscience framework. This school made the decision four years before this study to focus its attention on developing a framework of teaching and learning that would see teachers across all year levels, from Prep (five-six years of age) to Year 6 (eleven-twelve years of age), implement brain-based learning practices in their classrooms. With an increasing enrolment of students with trauma, the school began by working with an external provider to develop teachers' understanding and application of trauma-informed practices. Specific practices, such as morning check-ins became non-negotiables in the classrooms. As a result, the school then adopted another programme made available to schools systemwide known as PAUSE and began further professional development with the staff on the basics of neuroscience, how the brain works and the language and pedagogy of brain-based learning. Teachers took on practices such as brain breaks, physical activity, and learning styles as part of their practice. While the school has diligently in-serviced new teachers to the school on trauma-informed practices, limited professional learning continued about other topics of neuroscience and aligned pedagogy after this initial introduction, yet the 'branding' has remained.

Current teachers from the school site were invited to participate via email through the school administration following ethics approval from the University Human Research Ethics (H21REA226) and school system authorities. Participants were invited to complete an anonymous online survey. Of the 39 teachers invited to participate, 16 survey responses were submitted giving a response rate of 41%. Two of the submitted surveys were incomplete and excluded from data analysis giving a total of 14 completed surveys and a response rate of 35%. This was deemed satisfactory given the problematic, ongoing, low response rates reported in the research literature (Madariaga et al., 2017).

Participating teachers were diverse across overall teaching experience (Table 1), the amount of time spent in this specific school setting (Table 2) and level of qualification (Table 3). A fair distribution of participants across overall teaching experience was achieved, with teachers of up to five years, five to 10 years and 10 to 15 years of teaching experience responding to the survey.

How many years have you been a teacher?		
Answer	**Count**	**Percentage**
0-5yrs	**4**	**28.57%**
5-10yrs	**4**	**28.57%**
10-15yrs	**4**	**28.57%**
15yrs+	**2**	**14.29%**

Table 1: Years of teaching experience

Time spent in this school setting was highly relevant to the nature of this study given that participants may not have been on staff at the time when the school first introduced the neuroscience focus. Demographic data demonstrated that most of the participants were relatively new to the school with nine out of the 14 teachers having been there less than three years (Table 2).

How many years have you worked at this school?		
Answer	Count	Percentage
0-3yrs	9	64.29%
3-6yrs	4	28.57%
6+yrs	1	7.14%

Table 2: Years employed in specific school setting

Most of the teachers (42.86%) held an undergraduate degree as their highest qualification, with other participants indicating they held a postgraduate and/or a Master degree (Table 3).

What is your highest educational qualification?		
Answer	Count	Percentage
Undergraduate Degree	6	42.8%
Postgraduate Degree	3	21.4%
Masters	4	28.5%

Table 3: Teachers' highest qualification

The online survey used in this study consisted of five key parts:

A. demographic information including teaching experience and qualification;
B. five statements asking participants to rate, on a three-level scale, their level of belief;
C. an associated three-level scale asking to what extent their belief informs practice;
D. open-ended question regarding related classroom practice; and
E. a multiple-choice question to select two main sources of learning including a free text box for participant entry.

The survey has its roots in the early work of Dekker et al. (2012), used for a similar purpose and repeatedly administered, with adaptations, across a range of international studies with reported reliability and validity (Carter et al., 2020; Dekker et al., 2012; Torrijos-Muelas et al., 2021). The most recent adaptation of Dekker et al.'s survey was developed and administered by Hughes et al. in 2020 involving a large-scale sample of Australian teachers from non-specific school settings. For the purposes of our study, an adaptation of Hughes et al.'s (2020) survey was undertaken and administered based on its national relevance and the adaptations already included in their survey. For example, Hughes et al. (2020) reduced the number of questions/statements in the survey and included an open-ended qualitative response, appropriate adjustments for this study at hand. The use of pre-validated surveys, even where adaptations are made, is considered an appropriate approach in exploratory studies (Punch & Oancea, 2014) such as the research reported in this paper.

Three further adaptations were made to Hughes et al.'s (2020) survey for this study. First, we reduced the length of the instrument from 22 statements to five being mindful of teacher workload and survey fatigue (Cohen et al., 2017). The five statements included in the survey (consisting of two correct brain facts and the three most common neuromyths) were intentionally selected based on the work of Torrijos-Muelas et al.'s (2021) systematic analysis of 24 similar studies on teachers' knowledge of brain-based learning. Second, three-scale response choices (accurate/inaccurate/unsure and not at all/a little/a lot) were added for each statement, unlike Hughes et al.'s (2020) survey where only a dichotomous response was available; thus strengthening response sensitivity (Cohen et al., 2017; Tovazzi et al., 2020). Lastly, building on Hughes et al.'s (2020) inclusion of a single overarching open-ended question about practice, this survey includes this question for every statement, thus increasing the specificity of participant responses about brain-based practice.

Simple descriptive statistical analysis (Cohen et al., 2017; Punch & Oancea, 2014) was applied to the survey responses for parts A, B, C and E. This approach is appropriate where analysis aims to describe data so that a particular situation or phenomenon can be better understood (Cohen et al., 2017). Frequency counts of responses to each question (Laura & James, 2014) were developed and where appropriate, also reported as percentages.

The following steps were taken:

1. All survey data were aggregated into a comprehensive spreadsheet using excel.
2. Whole participant group data were analysed for demographic characteristics.
3. Comparative analysis was undertaken between identified demographic groups and each of their survey responses; for example, teachers with more than three years of
4. employment at this school setting and their level of belief in each of the statements.
5. Comparative analysis based on descriptive statistics was undertaken between the level of beliefs and the reported degree of implementation in practice.
6. Comparative analysis based on descriptive statistics was undertaken between teaching experience and time at the school site and sources of professional learning about brain-based learning.

Subsequent to this, section D was analysed for commonly used words in each participant's response using inductive content analysis (Schreier, 2019). High-frequency words were categorised into pedagogical themes including differentiation based on learning styles, brain breaks, and brain gym activities. The following section presents and discusses key findings from this study.

Findings and Discussion

Three key findings emerged from this exploratory study of teachers' brain-based learning beliefs and the prevalence of neuromyths: 1. Neuromyths are widely believed by teachers regardless of years of teaching experience or time spent in this specific school setting, 2. Teachers' beliefs, accurate or inaccurate, influence their current classroom-based practice, and 3. Teachers predominantly source their information from school-based professional learning. In the following sections, we present and discuss these findings.

Teachers' Beliefs About Brain-Based Learning

The teachers in this study demonstrate similar beliefs in neuromyths found to be prevalent in previous studies despite the schools' commitment to a pedagogical framework grounded in brain-based learning. Of the 14 participants in this study, more than 70% indicated that the three false statements provided in the survey (statements 2, 3 and 4 in Table 4) were accurate, with 71.4% endorsing statements 2 and 3, and 100% believing that students learn best when instruction is delivered in their preferred learning style.

	Question	Accurate	Not Accurate	Unsure
1	Academic achievement can be affected by skipping breakfast. (Accurate)	71.43%	21.43%	7.14%
2	Differences in the left brain/right brain can help explain individual differences among learners. (Inaccurate)	71.43%	0.00%	28.57%
3	Children are less attentive after consuming sugary drinks/snacks. (Inaccurate)	71.43%	7.14%	21.43%
4	Individuals learn better when they receive information in their preferred learning style. (Inaccurate)	100.00%	0%	0%
5	Regular moderate exercise can improve mental function. (Accurate)	100.00%	0%	0%

Table 4: Aggregated responses to brain-based statements

Strong belief in the learning style neuromyth found in this study mirrors that previously reported in Australian and international research. Research reviewed by Torrijos-Muelas et al. (2021) highlights learning styles as the most prevalent neuromyth among teachers. Similarly, Australian studies recently completed by Kim and Sankey (2018) and Carter et al. (2020) amongst preservice teachers at Sydney University and Hughes et al. (2020) who surveyed 228 in-service teachers reported learning styles to be the most common neuromyth. Furthermore, reflective of the findings from this study with 71.4% of teachers endorsing the left/right brain neuromyth (Statement 2 in Table 4), both Kim et al. (2018) and Hughes et al. (2020) also report the majority of participants in their study (>85%) endorse this myth.

In contrast, Carter et al. (2020) reported only 46% of the 1836 pre-service teachers believed this myth. Carter's study is atypical to most however in that a pre-requisite for participation was the completion of two university modules explicitly addressed neuromyths. This may indicate that where specific coursework is provided to preservice teachers at university on brain-based learning, this may serve to limit some widely accepted misconceptions. In combination with findings from the study at hand, inaccurate brain-based beliefs, consistent with international research findings extending over a period of 17 years, seemingly continue to flourish among contemporary educators.

Interestingly, while findings from this study show neuromyths to be present across all participant groups, there are some demographic variations. Analysis revealed that teachers who had been at the school for up to three years held significantly differing levels of beliefs from those teachers who had been on staff for a longer period in relation to particular statements (Table 5). For example, 100% of teachers who had been at the school for more than three years (n=5) correctly identified that skipping breakfast affects academic achievement in comparison to 55% of teachers (n=9) working at the school for less than three years.

		0-3yrs in school			3+ years in school		
	Statement	**Accurate**	**Not Accurate**	**Unsure**	**Accurate**	**Not Accurate**	**Unsure**
1	**Academic achievement can be affected by skipping breakfast. TRUE**	**55%**	**33%**	**11%**	**100%**	**0%**	**0%**
2	**Differences in the left brain/right brain can help explain individual differences among learners. FALSE**	**66%**	**33%**	**0%**	**80%**	**0%**	**20%**
3	**Children are less attentive after consuming sugary drinks/snacks. FALSE**	**88%**	**11%**	**0%**	**40%**	**20%**	**40%**
4	**Individuals learn better when they receive information in their preferred learning style. FALSE**	**100%**	**0%**	**0%**	**100%**	**0%**	**0%**
5	**Regular moderate exercise can improve mental function. TRUE**	**100%**	**0%**	**0%**	**100%**	**0%**	**0%**

Table 5: Brain-based beliefs and participant time employed at the school site

Further, these longer-serving teachers also refute the neuromyth concerning sugar twice as often as newer staff. This may indicate staff working within a school who had received the initial school-based professional development on brain-based learning have a greater likelihood to identify evidence-based knowledge from some myths. However, Statement 2 concerning the left/right brain reveals that 80% of long-serving teachers inaccurately believe this neuromyth. This suggests that while professional learning may initially act as a protective factor against believing some neuromyths, ongoing opportunities to update knowledge is necessary to maintain currency of knowledge (Australian Institute for Teaching and School Leadership, 2012; Boeskens et al., 2020; Larsen & Allen, 2021; Queensland College of Teachers, 2017).

Years of experience in the profession overall appeared to make minimal difference to the types of neuromyths endorsed. As seen in Table 6, there was no significant difference in the presentation of neuromyths between those in the early stages of their careers and their more experienced counterparts. In the instance of Statement 2 (left brain/right brain learners) where teachers with 5-10yrs experience were less likely to report this myth as accurate, they were concurrently unlikely to refute it, instead remaining undecided about its accuracy. Either instance raises concerns that there are teachers at all career stages that may be basing their pedagogical decisions on misinformation and myth.

	accurate	**not accurate**	**unsure**
1. Academic achievement can be affected by skipping breakfast. TRUE			
0-5yrs	**3**	**1**	**0**
5-10yrs	**3**		**1**
10-15yrs	**3**		**1**
15yrs+	**1**		**1**
2. Differences in the left brain/right brain can help explain individual differences among learners. FALSE			
0-5yrs	**3**	**0**	**1**
5-10yrs	**1**	**0**	**3**
10-15yrs	**4**	**0**	**0**
15yrs+	**2**	**0**	**0**
3. Children are less attentive after consuming sugary drinks/snacks. FALSE			
0-5yrs	**4**		
5-10yrs	**3**		**1**
10-15yrs	**3**	**1**	**1**
15yrs+	**1**		
4. Individuals learn better when they receive information in their preferred learning style. FALSE			
0-5yrs	**4**		
5-10yrs	**4**		
10-15yrs	**4**		
15yrs+	**1**		
5. Regular moderate exercise can improve mental function. TRUE			
0-5yrs	**4**		
5-10yrs	**4**		
10-15yrs	**4**		
15yrs+	**1**		

Table 6: Years of teaching experience and beliefs

Teachers' Beliefs Informing Pedagogy

Teachers in this study implemented brain-based strategies as part of their pedagogical approach in ways that reflected their personal beliefs regardless of accuracy. As would be expected, if teachers believed the statement, it was more likely to influence classroom practice than if they deemed it inaccurate (Figure 1).

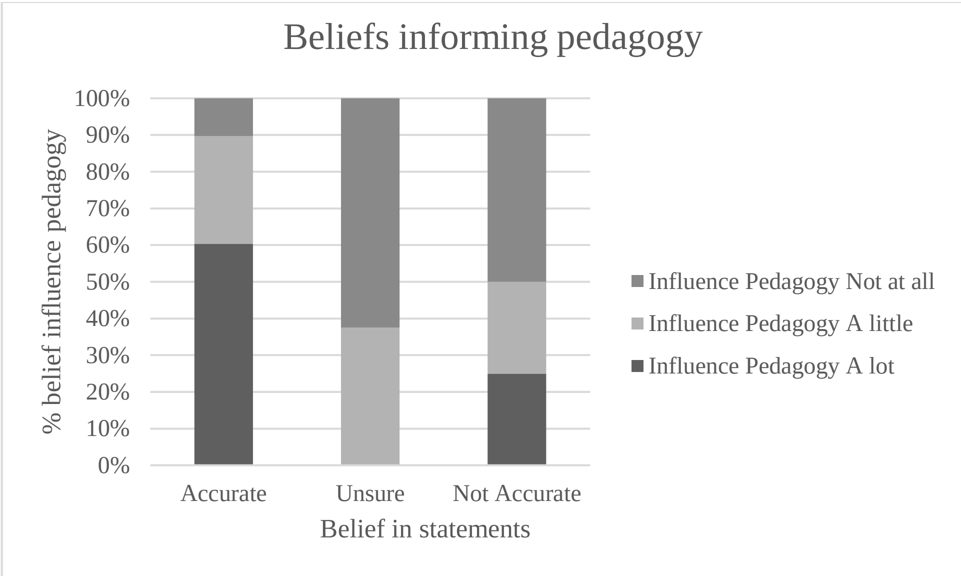

Figure 1: Level of belief compared to degree of influence of practice

For example, out of the 58 statements that were rated as accurate, 52 were positively correlated with influence on classroom practice to varying degrees (Table 7).

		Level of belief in statement		
		Not accurate	**Unsure**	**A lot**
Influence on pedagogy	**Not at all**	**2**	**5**	**6**
	A little	**1**	**3**	**17**
	A lot	**1**	**0**	**35**

Table 7: Level of implementation compared to level of belief

Concerningly, of the 58 statements believed to be accurate by teachers, 34 were in fact inaccurate. From those 34 inaccurate statements, 30 were reported to influence classroom practice, with 18 influencing pedagogy a lot and 12 a little (Figure 2). This indicates that classroom-based practices are significantly influenced by misinformation. Similarly, Newton and Miah (2017) found teachers' beliefs to be a strong driver of their pedagogy with 32% of 114 teachers in their UK study, despite being shown evidence-based research contradicting their beliefs, stating they would continue to implement learning style pedagogy citing experience as their rationale.

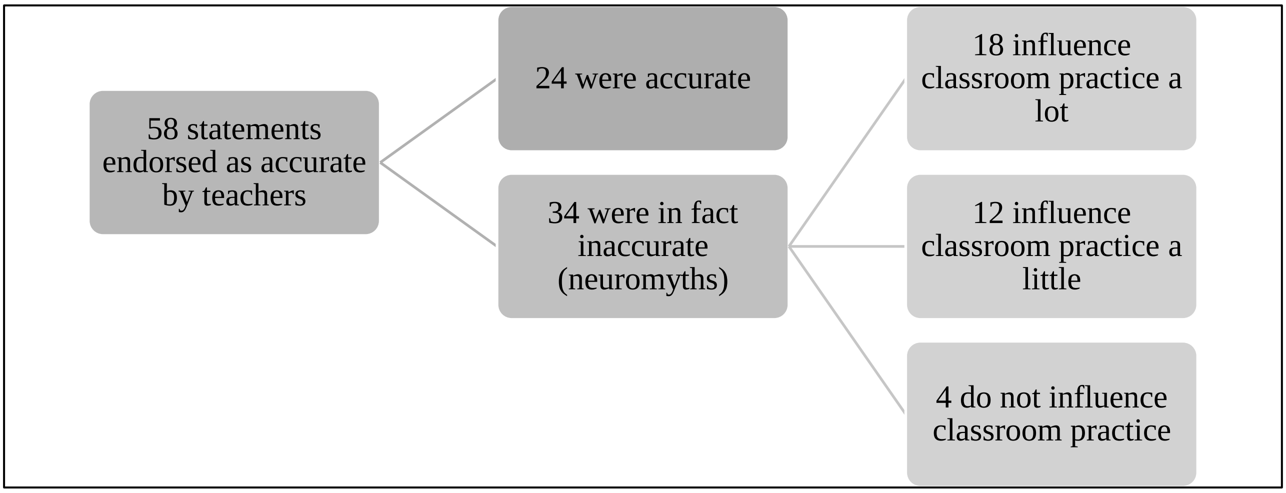

Figure 2: Inaccurate information informing classroom practice

To illustrate, one teacher with over 15 years of teaching experience and new to the school setting inaccurately believed that the left and right brain can account for differences in learners. They went on to report that this belief informed their practice a lot, stating,

> *I encourage the use of meditation for a short time at the beginning of each session to help calm the right brain and open up opportunities for the left brain.*

Similarly, another experienced teacher with over ten years of teaching experience who has been at the school for more than six years not only reported learning styles influenced their pedagogy a lot, but also understood themselves to fall into a specific learning modality. They stated,

> *I need to consider children's learning styles to be able to adapt/change lessons to support students learning. I am a visual learner, not auditory or kinaesthetic.*

One teacher, with less than five years of experience and also new to the school, inaccurately reported that children are less attentive after consuming sugar. They reported it influenced pedagogy a little and gave an example of how they structure learning activities accordingly. They went on to report that they “offer less cognitively demanding tasks or more movement breaks” throughout the day to counter the effects of unhealthy food consumption during morning tea and lunch breaks.

The findings demonstrate that teachers’ beliefs are not benign ideals but translate into practical application in the classroom which Nancekivell et al. (2020) contest has an “effect on life and learning” (p. 12). Critical consequences may result in inappropriate labelling of learners, inappropriate instruction (Scott & Curran, 2010), and wasted time, resources, and money (Dekker et al., 2012). The example given by one of the participants of adjusting the cognitive demands on students based on inaccurate information may be an example of the omission of learning time dedicated to higher-order thinking opportunities and the implementation of low-order 'busy work'.

Even in some instances where teachers recognise neuromyths or report a lack of surety as to accuracy, they may still indicate that it informs classroom practices (Figure 2). In one case, a new teacher with less than five years of experience and new to the school inaccurately reported they do not believe skipping breakfast affects student achievement but stated it does influence pedagogy a little. The example of classroom implementation given was providing a Brain Break/Fruit Break early in the day. In this school setting, providing students with breakfast or fruit in the morning is a whole school directive is a whole school policy and daily practice and therefore is expected to influence teachers’ practice (Mayer, 2021). While in this particular instance the teacher’s implementation of this practice, despite their lack of belief in its scientific grounding, is positive for the students, there is a concern that practice driven by compliance rather than intrinsically driven motivation may lack commitment (Larsen & Allen, 2021). In a case where school policy may be based on inaccurate understandings of neuroscience, compliant adherence to mandated practice may have detrimental effects on student learning (Dekker et al., 2012; Pashler et al., 2008). It is therefore imperative to ensure that teachers, and school leaders, access accurate and up-to-date sources of information about brain-based teaching and learning practice.

Sources of Information

The study indicates that in this neuroscience school setting, all teachers hold some accurate, evidence-based information alongside common inaccurate beliefs about brain-based learning. Current processes of keeping teachers up to date with rapidly evolving scientific findings have been extensively reviewed as problematic for almost 20 years internationally (Bassett et al., 2020; Bruer, 2016; Dekker et al., 2012; Grospietsch & Lins, 2021; Hughes et al., 2020; Macdonald et al., 2017; Pasquinelli, 2012), and the findings from this study demonstrate that school settings, despite a strong commitment to a neuroscience framework of teaching and learning, are not immune from this challenge.

School-Based Professional Learning

This current study found school-based professional development to be the main source of teachers' information, followed by research journals and university programs (Figure 3). This finding mirrors the only other study conducted in Australia amongst 228 qualified teachers where Hughes et al. (2020) found the most common listed source of teachers' information about brain-based learning was also school-based professional development. Of note, nine out of 14 participants reported school-based professional development as the main source of information, yet the majority of teachers demonstrate a belief in inaccurate information, albeit to varying extents. It should be pointed out, however, the last substantial school-based professional learning on neuroscience provided by the school was held approximately three years ago.

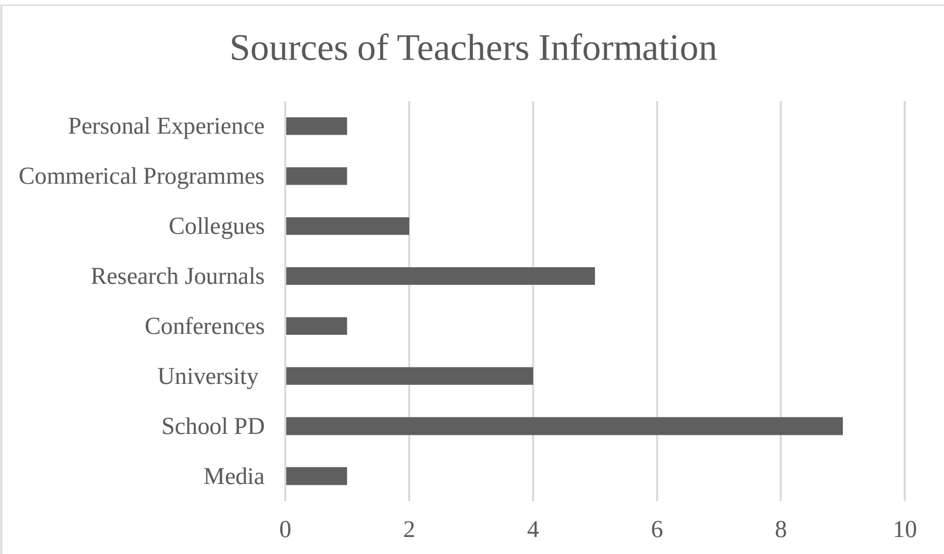

Figure 3: Sources of information

Of concern for teachers reliant on school-based professional learning is both the quality and reliability of the disseminated content. Ansari and Coch (2006) and Goswami (2006) both identify a lack of trained professionals and professional organisations who can bridge the disciplinary gap between education and neuroscience. Teachers can innocently make untenable and unquestioned connections as they may be getting information second and third-hand from a presenter who may have a self-purported interest in neuroscience but lack accurate, current, evidence-based knowledge (Zadina, 2015). This issue is further problematised where out-of-date programmes, supported by obsolete neuroscience, serve as a source of learning for teachers.

One case in point is one commercial programme based on right/left differences in the brain which became a highly influential commercial programme in Australia from around 2010, receiving government endorsement and accolades (Han, 2013; Stephenson, 2009). This may account for belief levels in the more experienced teachers who may not have been informed this myth has been extensively debunked by the scientific community since 2004 (Centre for Educational Research Innovation; Organisation for Economic Co-operation Development, 2007; Geake, 2008; Goswami, 2006). Furthermore, this finding may indicate a wider systematic failure between the science and education communities (Dekker et al., 2012; Hardiman et al., 2012; Pasquinelli, 2012; Tham et al., 2019; Zadina, 2015) whereby the dissemination of contemporary neuroscientific understandings is so delayed that teachers, and professional learning providers, may be operating on outdated scientist beliefs.

Access to ongoing professional learning is also necessary where schools choose to frame their teaching and learning approaches in neuroscience, a pedagogy based on a rapidly evolving scientific field where research is ongoing and new understandings are published regularly. Literature on the delivery of professional learning suggests a move away from stand-alone, one-off, homogeneous delivery to staff who are passive recipients in the process (Australian Institute for Teaching and School Leadership, 2012; Larsen & Allen, 2021; Thompson et al., 2020) and recommends a more collaborative, social constructivist process of ongoing delivery (Tham et al., 2019). Brain-based learning is a pedagogical approach that requires continual professional learning that can provide teachers with accurate, timely and evidence-based understandings and delivered in such a way as to challenge long-held beliefs that may compromise shifts in practice (Newton and Miah, 2017).

Research Literature

The second common source of information, reported in the study by five out of 14 teachers, was through engagement with research journals. Problems accessing quality research journals have been extensively documented in the literature due to financial costs (Ansari & Coch, 2006), and scientific literacy which Pasquinelli (2012) argues makes it difficult for teachers to accurately interpret and understand empirical research. Hardiman et al. (2012) note that “there is a scarcity of rigorous research from the neuroscience community that is readily translatable” (p.137), into educational practice. The high level of inaccurate responses reported by those five participants goes some way to support these concerns (Table 8, where a tick indicates an accurate response).

Survey	1. Breakfast	2. Left brain/right brain	3. Sugary drinks/snacks	4. Learning styles	5. Exercise
11	✓				✓
12	✓				✓
13					✓
16	✓		✓		✓
17					✓

Table 8: Responses from participants who source information from research journals

Initially, it may seem that a process of translation from scientific literacy to educational literacy may be a useful solution; however, there is a lack of credible data to support this view (Tham et al., 2019). Larger systemic differences between the fields of education and science are an ongoing, underlying issue and remain a difficult gap to bridge (Bruer, 2016). Rather, genuine transdisciplinary collaboration (Castro-Kemp & Samuels, 2022; Centre for Educational Research Innovation; Organisation for Economic Co-operation Development, 2007; Dekker et al., 2012; Hughes et al., 2020) has been suggested as a more authentic starting point to bridge the gap, with Zadina (2015) proposing neuro-educators with the skills to bridge the disciplinary gap (Sanchez, 2017), as an essential means to support interdisciplinary confluence.

The Role of Universities

The third source of information nominated by participants as informing their understanding of neuroscience relevant to their work is their university learning, with four out of 14 teachers naming this as a top source of information. Further analysis found that of these four teachers, two teachers were in the first five years of the profession. While Carter et al. (2020) found that the provision of specific neuroscience courses in teacher education went some way to reducing the prevalence of neuromyths among preservice teachers, an internet search for specific neuroscience courses in Australian universities within teacher education programs revealed that while such courses exist, they more often sit outside of teacher education programs, instead more likely located in pharmaceutical, biological, science and mathematics programs. With this in mind, these teachers may not have had the benefit of specific neuroscience courses during their teacher education.

While previous studies have identified preservice teachers may leave universities believing neuromyths, Torrijos-Muelas et al. (2021) still position universities to be best placed in the battle against neuromyths. The inclusion of specific neuroscience modules in initial teacher education course content is advocated by Horvath et al. (2018) to address and rectify these misconceptions and support evidence-based practice in classrooms. Further to this, some literature suggests the most beneficial skill for preservice teachers to develop at university is that of critical analysis which early studies have shown acts as a protective factor against neuromyths (Bensley & Lilienfeld, 2017; Pasquinelli, 2012).

Of note, the other two teachers referencing university as a main source of information were between five to ten years of teaching experience; as such, they may potentially be drawing on outdated information about brain-based learning. Additionally, these teachers were also identified as new staff to the school site. Such circumstances draw our attention to the importance of pedagogical induction programs for teachers arriving in schools to ensure that their knowledge about specific school pedagogical frameworks is sufficient. Where barriers to accessing professional learning exists, such as time, competing priorities and financial cost (Krille, 2020), new teachers on staff may default to outdated understandings to inform their practice.

In sum, this study underscores the need for schools to be vigilant about ongoing professional learning in support of specific pedagogical frameworks, in particular those underpinned by brain-based approaches that are connected to rapidly evolving science. Findings highlight how initial processes implemented to promote a whole school approach to teaching and learning require an address of the unavoidable changes in staff, and the diverse beliefs among staff working within the school. Whether misconceptions or neuromyths are a consequence of university experience, engagement with research that is challenging to interpret or limitations with accessing the most recent research, a lack of professional learning intervention at a number of touchpoints may result in practices that are in tension with the most contemporary research about, in this instance, neuroeducation. These beliefs and practices can serve to undermine the school's ability to make claim to its pedagogical foundations.

Limitations

Findings notwithstanding, a key limitation of this study is the sample size and specificity of context. The small number of participants may serve to magnify findings (Hackshaw, 2008). While appropriate to the intention of this study to explore the phenomenon of neuromyths in a very specific setting, such a delimitation may make the findings non-representative of the general teaching population (Cohen et al., 2017). That said, findings make clear the pervasiveness of neuromyths and facilitate a further conversation around this significant issue in education and make suggestions for how these may be addressed moving forward in schools and universities. The authors encourage future research that investigates the presentation and development of neuromyths among educators across a range of diverse contexts, particularly using methodologies that allow for rich, qualitative understandings that may not be available through survey approaches.

Conclusion

Whilst there is extensive literature regarding teachers' knowledge of brain-based learning, most studies are large-scale in non-specific school settings. In contrast, this small-scale study sought to explore teachers' beliefs from a highly contextualised school setting where neuroscience is written into school policy. This nuanced study explored the accuracy of the teachers' neuroscience-based beliefs and the extent to which teacher beliefs in brain-based learning influenced classroom practice. The study also provided context-based insights into the main sources of information that these teachers turned to for professional learning using a small, mixed-method survey. While this paper reports on a study in one specific context, the work has potential implications for consideration more broadly.

First, while neuroscience continues to offer a useful approach to education that leverages an understanding of the brain and how learning and brain development occur, the rapidity with which this disciplinary field evolves has implications for any interdisciplinary application, as is the case in brain-based or neuroeducation. The range of understandings of brain-based learning, and the evidence of neuromyths among teachers in this study context serve as a reminder that learning and teaching methods grounded in science are in constant motion (Bassett et al., 2020; Bruer, 2016; Dekker et al., 2012; Grospietsch & Lins, 2021; Hughes et al., 2020; Macdonald et al., 2017; Pasquinelli, 2012). If education intends to intersect with other disciplines such as science to enhance and inform contemporary practice, there will need to be mechanisms developed whereby education can respond to changes and advances in scientific understandings in ways that are more expeditious than is currently the case. This will, of course, include timely responses within universities (Torrijos-Muelas et al., 2021) and from other professional learning providers, alongside school contexts.

Second, and somewhat related, this study underscores the potential challenge for schools to maintain fidelity and currency of implementation to specific pedagogical frameworks, such as a brain-based teaching and learning framework. The cost and resources required to access up-to-date professional learning cost (Krille, 2020), and disruption to the whole school approach due to teacher turnover and new staffing arrangements make ensuring that teacher beliefs and practice remain aligned with contemporary research related to the school's intended pedagogical framework. We suggest that schools develop a professional learning and induction plan concurrent to their pedagogical framework that can support the longevity and currency of their brain-based approach. This study has demonstrated that school branding as a neuroscience school may be insufficient to counter the presentation of neuromyths among teaching staff without a clear process for ongoing professional learning.

As previous research has indicated, the prevalence of neuromyths is not specific to the Australian context (Newton and Salvi, 2020). As such, these findings, though generated within a small study, serve to contribute contextual insights to the much larger national and global conversation that seeks to understand how to leverage the potential of brain-based learning in schools in ways that also minimise the emergence and proliferation of neuromyths in teachers' practice. In doing so, teachers may be better positioned to work productively over time with brain-based learning.

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