

## Review article

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# Misconceptions about neuroscience – prevalence and persistence of neuromyths in education

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**Abstract:** *Brain-friendly learning* is a new catchphrase in school and university instructional practice. However, it often escapes the notice of the teachers and learners involved that *neurodidactics* is not simply a plausible concept – it can also be a myth if applied incorrectly. Numerous international studies show that both pre-service and in-service teachers as well as university educators endorse misconceptions on the topic of learning and the brain and orient their didactic conception on so-called neuromyths. This paper presents nine neuromyths on the topic of learning and memory. Based on a review of the current research, we discuss what determines their emergence and prevalence, to what extent neuromyths pose a problem for practice, and why and how both neurodidactics and neuromyths should be made an object of university instruction.

**Keywords:** brain-friendly learning; neurodidactics; neuromyths; (pre-service) teachers; university educators

**Zusammenfassung:** *Gehirngerechtes Lernen* gilt als neues Schlagwort in der schulischen und hochschuldidaktischen Praxis. Was dabei häufig aus dem Blick der engagierten Lehrenden und Lernenden gerät, ist, dass *Neurodidaktik* nicht nur ein plausibles Konzept, sondern falsch angewendet auch ein Mythos sein kann. Zahlreiche internationale Studien zeigen, dass sowohl angehende und praktizierende Lehrkräfte als auch Hochschullehrende Fehlvorstellungen zum Thema Gehirn und Lernen glauben schenken und ihre didaktische Konzeption an sogenannten Neuromythen ausrichten. In diesem Beitrag werden neun

Neuromythen zum Thema Lernen und Gedächtnis vorgestellt. Auf Basis einer Darstellung des aktuellen Forschungsstands wird erläutert, was ihre Entstehung und Verbreitung bedingt, inwiefern Neuromythen ein Problem für die Praxis darstellen und warum bzw. wie sowohl Neurodidaktik als auch Neuromythen zum Gegenstand universitärer Lehre gemacht werden sollten.

**Schlüsselwörter:** (angehende) Lehrkräfte; Gehirngerechtes Lernen; Hochschullehrende; Neurodidaktik; Neuromythen

## Introduction and objectives

In recent years, insights from the field of brain research have launched a downright *neuro-boom* reflected not only in numerous publications but also in transfer attempts such as *neuromarketing*, *neuroarchitecture*, *neuromanagement*, and *neurodidactics* (cf. e. g., Häusel, 2008; Herreros, 2012; Herrmann, 2009; Metzger, 2018). Teachers especially show great interest in neuroscientific research findings and consider it useful to incorporate them when designing their instruction (Dekker et al., 2012). *Brain-friendly learning*<sup>1</sup> is seen as a new magic spell, not only in schools but also in university instruction (Folta-Schoofs and Ostermann, 2019). Nevertheless, (pre-service) teachers and university instructors, the alleged experts on learning, still endorse numerous neuroscientific misconceptions and partially orient their instructional practice on so-called neuromyths (e. g., Dekker et al., 2012; Gleichgerricht et al., 2015). The term *neuromyths* can be traced back to the neurosurgeon Alan Crockard, who used it in the 1980s to refer to scientifically inappropriate understandings of the brain in medical

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<sup>1</sup> The terms *brain-friendly* or *brain-based* learning are used in education science as synonyms for neurodidactics. The authors note that these terms are not neuroscientifically justifiable, because all learning is based on neural changes in the brain and can never be *non-brain-friendly* or *non-brain-based*. The authors recommend using the term “neuro-didactics” in future discourse.

culture (Howard-Jones, 2010). The Organization for Economic Co-operation and Development (OECD, 2002) defines neuromyths as “misconception[s] generated by a misunderstanding, a misreading, or a misquoting of facts scientifically established (by brain research) to make a case for use of brain research in education and other contexts” (p. 111). Neuromyths have been identified with respect to numerous topics, including indications of specific learning difficulties such as dyslexia (Macdonald et al., 2017) or the influence of nutrition (Dekker et al., 2012) and music (Düvel et al., 2017) on the brain. This paper focuses on neuromyths concerning the topic of learning and memory. We discuss what research findings on neuromyths currently exist and what problems and objects for university instruction result from them.

## Neuromyths on the topic of learning and memory

Grospietsch and Mayer (2019) identified 11 neuromyths on the topic of learning and memory. The study’s scientific content analysis showed that each of these misconceptions is based on a *kernel of truth* (= scientific term/research finding) and morphs over a chain of erroneous conclusions into a no-longer-scientifically-correct implication for teaching and learning (= neuromyth). Insights from neuroscience and cognitive psychology form the starting points for each fallacious line of argument. Table 1 compares the kernel of *truth* and neuromyth for the nine

**Table 1:** Scientific *kernels of truth* and the neuromyths resulting from them.

Scientific <i>kernel of truth</i>	Neuromyth
<i>Perception preferences</i> Learners exhibit preferences for receiving information in a specific mode.	<i>Existence of learning styles</i> Individuals learn better when they receive information corresponding to their learning style (e. g., auditory, visual, haptic, or intellectual).
<i>Crossover in neural pathways</i> Neural pathways link the left brain hemisphere to the right side of the body and vice versa.	<i>Effectiveness of Brain Gym</i> Coordination exercises (e. g., cross-body movements) can improve the interaction between the left and right brain hemispheres and thus learning and/or intelligence.
<i>Existence of cortical regions</i> The cerebrum is made up of different cortical regions subject to a functional division of labor.	<i>Specific storage locations (hard drive)</i> The brain works like a hard drive. Information is stored in specific locations (e. g., in the center for math).
<i>Hemispheric dominance</i> One brain hemisphere is more strongly involved in a certain cognitive process than the other.	<i>Differences due to hemispheric use</i> Each person uses their left and right brain hemispheres to different degrees, which explains differences between learners. This hemispheric dominance needs to be taken into account.
<i>Brain development</i> Neural cell connections enormously increase in the first years of life.	<i>Best learning before age 3</i> Learners are most receptive to learning processes from birth until age 3.
<i>Hemispheric asymmetry</i> Two cerebral hemispheres exist that are not completely identical, both anatomically and functionally.	<i>Logic on the left/creativity on the right</i> Creative thought processes engage the right brain hemisphere, while logical thought processes engage the left. Deliberate effort must be made to equally engage both brain hemispheres.
<i>Sensitive phases in child development</i> There are sensitive phases in childhood during which certain things can be learned more easily and in which isolation from stimuli can lead to irreversible damage (e. g., language acquisition).	<i>Critical time periods for learning</i> Children must be presented with as many <i>good</i> stimuli as possible during this time window that then closes irrevocably so that their learning will not be impaired throughout their life, as this cannot be corrected through education.
<i>Brain activity</i> Imaging techniques make it possible to measure which brain regions are involved in a mental or physical activity.	<i>Only use 10% of the brain</i> We only use the 10% of our brain regions highlighted in images (e. g., fMRI) and thus only a fraction of our mental capacity.
<i>Consolidation</i> Nighttime restructuring processes can lead to the gaining of new insights during sleep.	<i>Learning while you sleep</i> Completely new content can be learned during sleep via the acoustic channel (e. g., audio recordings of vocabulary lists).

*Note:* This table was created based on a summary of the current state of theory on neuromyths as well as supplementary literature research: Bear et al. (2018), Biswal et al. (2010), Carter (2014), Dekker et al. (2012), de Lussanet and Osse (2012), Gais and Born (2004), Grospietsch and Mayer (2019); Höffler et al. (2017), Jäncke (2013), OECD (2002).

neuromyths addressed in this paper to provide an overview of the problem of neuroscientific research findings being inaccurately transferred to teaching and learning. Three concrete examples of the individual errors in transfer involved as well as the scientific refutation of the neuromyths *learning while you sleep*, *logic in the left hemisphere/creativity in the right*, and *that we only use 10% of the brain* can be found in Grospietsch and Mayer (2019).

Numerous studies (cf. Figure 1) show that pre-service and in-service teachers as well as university educators exhibit great interest in neuroscience but are simultaneously unable to differentiate between neuromyths and neurofacts. There is a general tendency to endorse neuroscientific statements about the topic of learning and memory – regardless of whether or not they are neuromyths (Grospietsch and Mayer, 2019). University professors and instructors who train future teachers endorse neuromyths at slightly lower rates than (pre-service) teachers (Gleichgerrcht et al., 2015; van Dijk and Lane, 2018). In-service teachers, in turn, endorse neuromyths a little less frequently than pre-service teachers (Canbulat and Kiriktas, 2017). However, Zhang et al. (2019) and Horvath et al. (2018) demonstrate that even headmasters and award-winning teachers endorse neuromyths at high levels.

Research on the prevalence of neuromyths can be summarized as mostly consistent, with the exception of a few cultural differences between countries. Many neuromyths on learning and memory are endorsed to a high degree. Myths concerning the *effectiveness of Brain Gym* and *existence of learning styles* are particularly widespread and have found their way into learning guides and educational programs (Grospietsch and Mayer, 2019; Pasquinelli, 2012). Research findings on the factors determining the endorsement of neuromyths are more diverse. Ferrero et al. (2016) conclude that reading educational magazines increases beliefs in neuromyths. Conversely, Düvel et al. (2017) show that reading a large number of educational books, magazines, and websites reduces endorsement of neuromyths. Research by Macdonald et al. (2017) and Ferrero et al. (2016) indicates that reading scientific journals reduces beliefs in neuromyths. In contrast, Gleichgerrcht et al. (2015) determine that neither neuroscientific nor popular science articles sufficiently reduce endorsement of neuromyths. Macdonald et al. (2017) could show that people with high levels of neuroscientific knowledge endorse neuromyths to a lesser degree than teachers and the general public. Papadatou-Pastou et al. (2017) emphasize that general knowledge about the brain is the best “safeguard against believing in neuromyths” (p. 1). This result is corroborated by van Dijk and Lane (2018). However, in numerous studies, teachers with high levels of



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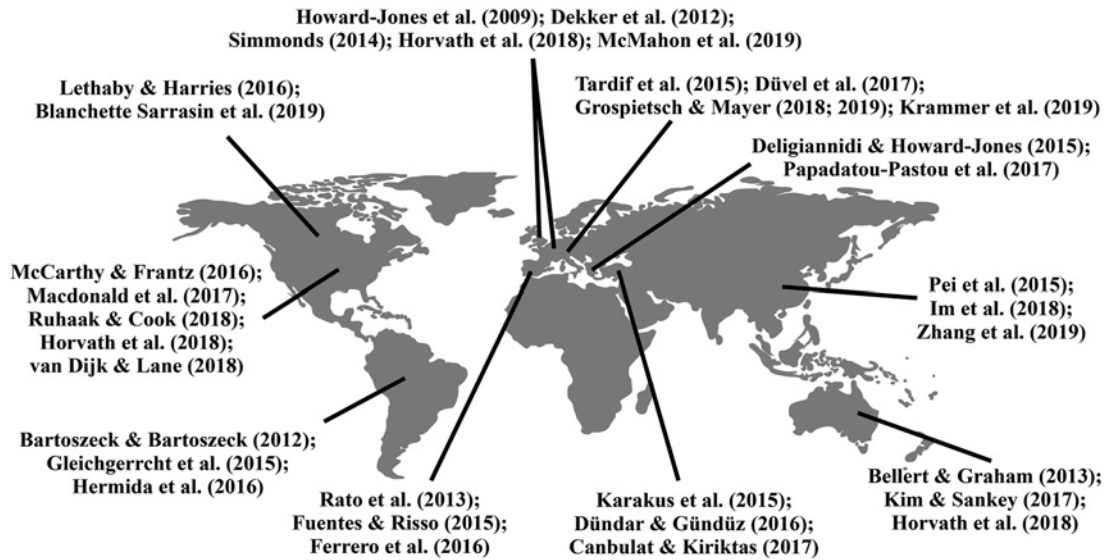
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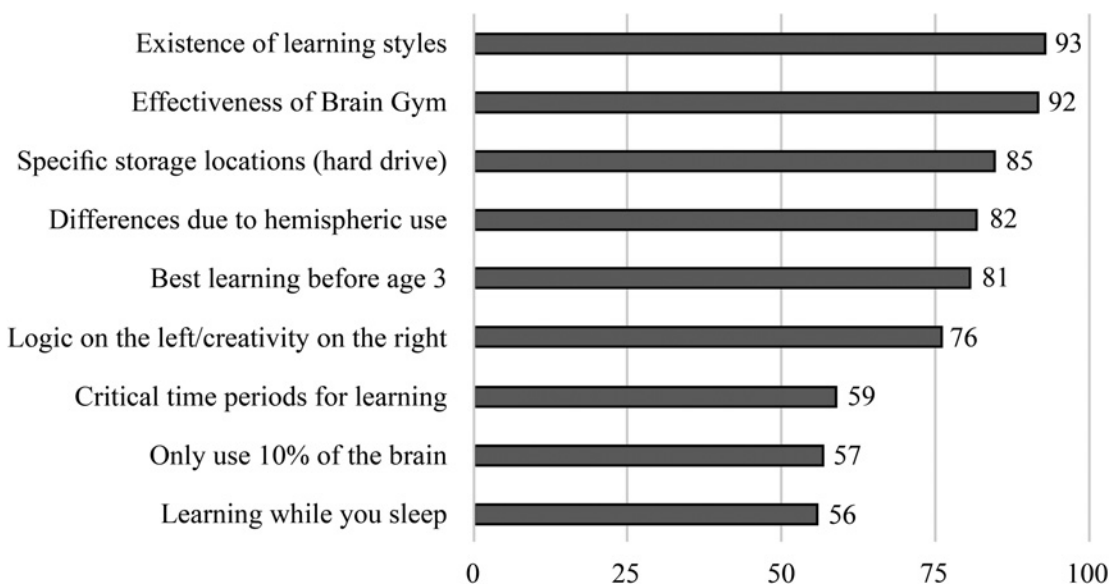
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**Figure 1:** Overview of existing studies on neuromyths among pre-service teachers, in-service teachers, and university educators.

scientifically appropriate conceptions of the brain prove to be more susceptible to neuromyths (e. g., Dekker et al., 2012; Ferrero et al., 2016; Papadatou-Pastou et al., 2017). Research findings concerning personal characteristics are also inconsistent. The majority of studies show that age, gender, professional experience, teaching subject, school type, school location (urban/rural) and participation in professional development courses are not correlated with the endorsement of either neuromyths or scientifically appropriate conceptions about the brain (e. g., Dekker et al., 2012; Karakus et al., 2015; Papadatou-Pastou et al., 2017; Rato et al., 2013). Macdonald et al. (2017) conclude

that being younger, having a university degree, and attending neuroscience courses reduce but do not eliminate endorsement of neuromyths. The latter result is corroborated by Canbulat and Kiriktas (2017) as well as Ruhaak and Cook (2018). Four studies have found an association between endorsement of neuromyths and gender. In two studies, female teachers are more likely to endorse neuromyths (Dündar and Gündüz, 2016; Ferrero et al., 2016), but they outperform male subjects in two other studies (Canbulat and Kiriktas, 2017; Macdonald et al., 2017). In sum, we primarily know one thing: pre-service and in-service teachers as well as university educators endorse numerous



**Figure 2:** Pre-service biology teachers' ( $N = 550$ ) endorsement of nine neuromyths on the topic of learning and memory (Grospietsch and Mayer, 2019).

neuromyths on the topic of learning and memory. The leading determinants of these beliefs and how they can be effectively reduced still remain open questions.

## Neuromyths' resistance as a problem of university instruction

Although the current research literature on neuromyths calls for integrating more neuroscience into teacher training (e. g., Howard-Jones, 2014), this alone does not seem to be sufficient to professionalize pre-service teachers' misconceptions on the topic of learning and memory. According to Dündar and Gündüz (2016), pre-service science teachers significantly outperform pre-service teachers of other subjects, whereas studies by Macdonald et al. (2017) and Im et al. (2018) indicate that mere enrollment in neuroscience or psychology courses at university does not sufficiently reduce endorsement of neuromyths. A study by Grospietsch and Mayer (2019) showed that even pre-service biology teachers, who receive instruction in neuroscientific content during their studies (e. g., courses in human biology and animal physiology), endorse neuromyths to a great extent. As shown in Figure 2, all nine misconceptions on the topic of learning and memory were endorsed by more than half of pre-service biology teachers. Participants at different stages of their training (first-year students, more advanced students, and graduates enrolled in practical teacher preparation) differed only with respect to their endorsement of scientifically appropriate conceptions, but not in their endorsement of neuromyths (Grospietsch and Mayer, 2019).

Given that biology teachers need to not only address the topic of learning and the brain as instructional content but also use it to guide their students' learning processes, the conceptions of pre-service biology teachers – up until the end of their practical training phase – must be described as deficient. The results of another study (Grospietsch and Mayer, 2018) show that even a university course conveying and closely interlinking professional knowledge from the fields of cognitive psychology, neuroscience, and biology didactics on the topic of learning and the brain is insufficient for students to critically engage with neuromyths. The results of Grospietsch and Mayer's (2019) study indicate that neuromyths exist in parallel to accurate professional knowledge and beliefs about neuroscience and learning and can prove to be resistant to conventional teacher education. This means that even after acquiring professional knowledge, university students are released into practice with misconceptions. According to Horvath et al. (2018), there is still a lack of studies proving that endorsement of neuromyths negatively

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affects teachers' effectiveness, students' learning performance or their perceived self-efficacy. However, Lethaby and Harries (2016) and Blanchette Sarrasin et al. (2019) highlight that many teachers who endorse neuromyths employ practices linked to these misconceptions in their instruction (with pre-school teachers doing so most frequently, followed by primary school teachers and then secondary school teachers). This is problematic on the one hand because it could lead teachers to pass on incorrect cognitive psychology/neuroscience content and/or ineffective learning strategies to their students. On the other hand, the education system's "money, time and effort" (Dekker et al., 2012, p. 1) could be wasted and both teachers and learners are deprived of the opportunity to expend these resources on more effective theories and methods (e. g., teaching learning strategies or cognitive activation) (Grospietsch and Mayer, 2019). Ruhaak and Cook (2018) show that accurate beliefs about neuromyths are associated with a higher probability of employing effective, rather than ineffective, neuromyth-based instructional practices. Hence, developing university instruction programs for pre-service teachers as well as professional development opportunities for in-service teachers that clarify neuromyths scientifically and professionalize them sustainably is of great relevance.

## **Brain-friendly learning and neuromyths as an object of university instruction**

Related to the goal of lifelong learning in a rapidly developing society, a professional understanding of learning is important for both teachers and learners. University education should be capable of providing students with an appropriate conception of learning. Langfeldt and Nieder (2004) summarize, with respect to teacher education, that around one-third of students' learning concepts prove to be resistant to change over the course of their studies and cannot be sufficiently professionalized into more pedagogically-desirable concepts. Studies on neuromyths show that (pre-service) teachers encounter neuromyths and related practices in their academic and practical training and professional development (Blanchette Sarrasin et al., 2019; Howard-Jones et al., 2009; Lethaby and Harries, 2016; Ruhaak and Cook, 2018; Tardif et al., 2015). Although (pre-service) teachers primarily refer to TV, the internet and popular science magazines in their research (Ferrero et al., 2016; Rato et al., 2013), university instructors should view their teaching as a significant opportunity to build up accurate neuroscientific knowledge, a well-founded

conception of neurodidactic, and an evidence-based understanding of learning (Grospietsch and Mayer, 2019). Thus, in light of the reported research findings, it seems necessary for the disciplines involved (neurobiology, cognitive psychology, education science, and subject and university didactics) not to leave the field to pop science but rather to actively counter the misunderstanding, misreading, or misquoting of facts scientifically established by brain research to make a case for use of brain research in education and other contexts (OECD, 2002, p. 111). Pithy yet empty promises, such as *learn vocabulary while you sleep* or *Brain Gym exercises make you smarter*, are becoming more and more common in everyday life. Advertised by companies as "low-cost and easily implemented classroom approaches" (Howard-Jones, 2014, p. 819) promising to improve learning and/or memory performance, neuromyths find their way into teachers' methodological repertoires, which they pass on to their students with the best of intentions (Simmonds, 2014). These findings suggest that the prevalence of neuromyths should be responded to not only with criticism but also by constructively addressing the problem. Previous studies on neuromyths (cf. Figure 1) all indicate that teachers and university students are highly interested in neuroscience but need help to correctly relate elements of knowledge from cognitive psychology, neuroscience, and subject didactics and to critically engage with information lacking a grounding in proper evidence. Grospietsch and Mayer (2018) developed a neurodidactic concept for times in which the catchphrase *brain-friendly learning* enjoys persistent popularity to clarify for (pre-service) teachers and university educators that although neurodidactics is certainly a plausible concept, it can become a myth when applied incorrectly. Moreover, Papadatou-Pastou et al. (2017) emphasize the importance of developing an understanding among (pre-service) teachers of how neuroscience research is conducted and presented (e. g., understanding images which show increased brain activity). Consequently, both neuroscience content/methods and an accurate foundation for neurodidactics approaches should be incorporated into teacher education and university didactics. A corresponding curriculum would be quite helpful.

One aspect that university instructors need to be aware of when addressing neuromyths is that these misconceptions can be deeply biographically anchored and difficult to change (Grospietsch and Mayer, 2019). Grospietsch and Mayer (2018) show that students argue not only scientifically in support of neuromyths (e. g., based on neuroscience and cognitive psychology) but also use biographical arguments (e. g., referring to personal experiences) and that refutation can even reinforce their

misconceptions (= backfire effect; cf. Cook and Lewandowsky, 2011). Work by Pettito and Dunbar (2004) has highlighted that students can stubbornly cling to their original beliefs despite empirical demonstrations and theoretical representations. Newton and Miah (2017) demonstrate this specifically for the neuromyth concerning the *existence of learning styles*. Moreover, based on a study by Kim and Sankey (2017), it must be acknowledged that pre-service teachers may have already learned neuromyths before beginning their university studies, that is, during their own school years. They can also be deeply convinced of their misconceptions due to their practical experiences or intuitively believe them to be true (cf. Blanchette Sarrasin et al., 2019). These are all potential reasons why few effective intervention approaches to combat neuromyths currently exist (Grospietsch and Mayer, 2018; McCarthy and Frantz, 2016; McMahan et al., 2019). Teaching strategies and methods that take up students' misconceptions, that deliberately bring them into a *cognitive conflict*, and that systematically expand them in the direction of scientifically appropriate conceptions have proven to be particularly effective at combating neuromyths (Grospietsch and Mayer, 2018). Based on this *conceptual change theory* (Vosniadou,

2013), a course was developed through an interdisciplinary collaboration at the University of Kassel (Grospietsch and Mayer, 2018). In contrast to merely imparting professional knowledge from cognitive psychology, neuroscience, and subject didactics, the instructional material used in this seminar, *conceptual change texts*, proved to be an effective and evidence-based means of translating neuroscientific content into the language of teachers. Moreover, both neuromyths and scientifically appropriate conceptions were sustainably professionalized with medium to large effect sizes (Grospietsch and Mayer, 2018). Based on our experiences, we can report that the quality of such learning programs can be improved by having neuroscientists and cognitive psychologists clear up neuromyths in a scientifically accurate way based on the most current research results. Precisely because disciplines have their unique methods and languages that are difficult to understand for experts in other areas, there is a need for cooperation among teacher educators, cognitive psychologists, and neuroscientists. Only by intensifying (existing) exchange networks can (pre-service) teachers' and university instructors' neuroscience literacy be improved and neuromyths related to *brain-friendly learning* be eliminated. In particular,



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neuroscientists interested in a content-based collaboration are warmly invited to contact us.

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