frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 18 September 2024
DOI 10.3389/feduc.2024.1405121

OPEN ACCESS

EDITED BY
Analía Arévalo,
University of São Paulo Medical School, Brazil

REVIEWED BY
Martín-Lobo Pilar,
International University of La Rioja, Spain
Marc S. Schwartz,
University of Texas at Arlington, United States

*CORRESPONDENCE
Efrat Luzzatto
✉ efratluz@gmail.com

RECEIVED 22 March 2024
ACCEPTED 23 August 2024
PUBLISHED 18 September 2024

CITATION
Luzzatto E, Shalom M and Rusu AS (2024) Perceptions of special education pre-service teachers regarding the implementation of a neuroscience motifs-based teacher training program.
Front. Educ. 9:1405121.
doi: 10.3389/feduc.2024.1405121

Perceptions of special education pre-service teachers regarding the implementation of a neuroscience motifs-based teacher training program

Efrat Luzzatto[1]*, Maya Shalom[2] and Alina S. Rusu[3]

[1]Levinsky-Wingate Academic Center, Tel Aviv, Israel, [2]Beit Berl College, Kfar Saba, Israel, [3]Faculty of Animal Science and Biotechnologies, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania

While the interest in the connection between neuroscience and education continues to increase, there is a gap between the declarative statements regarding its importance and the small number of programs that put it into practice. The perceptions of the participants in these programs might offer valuable insights regarding the applied values of this connection. This study seeks to contribute to the accumulated research knowledge by using a qualitative analysis approach regarding the perceptions of pre-service teachers (PSTs) in a special education track program. The PSTs participated in a unique training program called the "Neuroscience Motifs-based Teacher Training Program" (NMTTP) that was presented as part of a reading course. Findings reveal mostly positive perceptions of the PSTs regarding the importance, relevance and contribution of neuroeducation to education, from a professional & personal perspective. In addition, the findings expand the current literature in two aspects: (1) the potential benefits that neuroscience can grant to education in general, and to special education in particular; (2) the contribution of knowledge on neural basis for PSTs to a sense of perspective, patience and empathy toward challenging students, by understanding some of the ongoing processes in their students' brains.

KEYWORDS

neuroeducation, educational neuroscience, pre-service teachers, training program, special-education

1 Introduction

Research in the field of neuroeducation (NE) is flourishing among researchers from various fields who seek to connect the dots between neuroscience, cognitive science, psychology and education. Neuroeducation shares commonalities with the science of learning that recognizes the value and importance of cross-fertilization across traditional fields of study, drawing on many different methods and techniques to understand how learning occurs—with the ultimate goal of optimizing learning for all (Sawyer, 2006). Neuroeducation aims to support the dialogue between researchers and practitioners in the fields of neuroscience and education, and to encourage transdisciplinary partnerships (Sigman et al., 2014). Such partnerships have the potential to improve educational outcomes by integrating teachers' practical experience with scientific insights into the mechanisms of attention, motivation, executive functions, and memory and their relations to learning. Integrating neuroscience into teaching training programs may lead to a better quality of teaching by sharing evidence-based knowledge to provide another perspective on the teaching-learning process (Gola et al., 2022). According to Jolles and Jolles (2021), educators can create the conditions for the acquisition of knowledge and experiences that are to be stored by the learning brain and they inspire and direct the process of curiosity and information processing by the student. With this in mind, approaching learning from a scientific perspective may encourage teachers to think more about the process of learning, leading to pedagogical change and improved educational outcomes. Specifically, neuroscience training is thought to benefit education by increasing the use of pedagogical and didactic strategies associated with active learning or providing teachers with a wider toolkit of resources to support diverse learners with major individual differences. Together, these goals provide sufficient justification for the inclusion of neuroscience in teacher training (Privitera, 2021).

Furthermore, and this is especially important among special education teachers, NE can provide a sense of perspective, patience and empathy toward challenging students, by understanding some of the unique processes in their students' brains (Achva Model of Neuropedagogy, 2016; Hook and Farah, 2013). Recognizing learner differences remains a critical skill that teachers must develop. Not only should teachers recognize individual learner differences, but they need the skills and materials necessary to provide alternative instructional strategies to meet wide-ranging student needs. Developing formal training programs for teachers to help them understand the latest developments in neuroscience and how they apply to education will only help make educational systems stronger, allowing teachers to recognize how individual learner differences intersect with curricular goals and objectives, ensuring our diverse student body is optimally prepared for success (Walker et al., 2019).

In Israel, the field of NE is still in its initial stages. There are only few programs that incorporate NE, usually for in-service teachers (Achva Model of Neuropedagogy, 2016) and also newly created, non-mandatory courses in a few Colleges of Education. Last year, in 2023, the first MA program in neuroeducation took place in a teacher training college in the south of Israel. The first internship in NE was developed for teacher educators in Israel in 2021–2022 and is now running for the fourth time. Moreover, none of the existing courses are specifically targeting the category of special education PSTs. The findings from this study might provide an example of good practices and research-informed motivation for including NE in both general and special education teacher training programs.

Teachers who participated in NE programs indicated a positive attitude and influence on their professional practice (Dubinsky et al., 2019). Furthermore, they described improved teaching abilities by suggesting innovative methods, productive learning, and improved teacher-student relationships (Friedman et al., 2019). Even though these findings are promising, they are based on limited data and programs in the nascent field of NE. This research aims to expand the knowledge base by exploring the individual perceptions of Israeli pre-service teachers (PSTs) in the field of special education, after taking part in a Neuroscience Motifs-based Teacher Training Program (NMTTP).

2 Theoretical background

2.1 Neuroeducation

Neuroeducation (NE) links neuroscience, cognitive science, psychology and education. Over recent years, the field of NE has grown, with neuroscientific findings leading new insights, different points of view and a deeper understanding of the teaching-learning processes (Ansari et al., 2012; Gola et al., 2022; Tokuhama-Espinosa, 2017). The neurobiology of learning, and in particular the core concept of plasticity, have the potential to directly transform teacher preparation and professional development, and ultimately to affect how students think about their own learning (Dubinsky et al., 2013). Interest into implementing neuroscience knowledge and research findings into pedagogy and classroom teaching for advancing teaching and learning is also growing (Chang et al., 2021; Friedman et al., 2019). According to Dresler et al. (2018), the combination of neuroscientific methods and educational practice may explain conditions that hamper learning success, such as learning disorders. The potential of neuroeducation to elucidate the core cognitive and neural deficits and the efficacy of training and intervention program, seems apparent (Gabrieli, 2016). Tailoring instruction based on an understanding of cognitive diversity not only maximizes student learning and behavior, but it has also shown the potential to mitigate learning or behavioral difficulties from becoming a lifelong disability that is highly resistant to intervention (Koziol et al., 2013; Walker et al., 2019).

However, it seems there is a gap between the declarative statements about the importance of implementation of neuroscience in education (Curtis and Fallin, 2014; Gabrieli, 2016; Stern et al., 2016) and the small number of suggested programs that actually put it into practice (BrainU, in: Dubinsky et al., 2019; NAP, in: Friedman et al., 2019; Tan and Amiel, 2022). One such program is BrainU that aimed at teaching fundamental principles of neuroscience including the Neuroscience Learning Concepts, to improve both teachers' and consequently, students' knowledge of both neuroscience and how this knowledge translates to learning (Dubinsky et al., 2013). BrainU's neuroscience content was intended to be incorporated into the training of in-service middle school science teachers. The authors strongly recommended that their principles would be implemented in PSTs frameworks (Dubinsky et al., 2013, 2019).

While there have been positive results and enthusiasm from the participants in existing programs regarding the integration of neuroscience insights into their work, what appears to be lacking, however, is a single specific curriculum to guide this implementation, and more importantly, literature that presents educators' perceptions of the assimilation process and its implications (Jolles and Jolles, 2021). Privitera (2021) noted that there are relatively few research papers with sufficient detail and quality to enable a comprehensive evaluation of the current neuroscience training for teachers. Only one of these studies dealt with PSTs.

The Neuroscience Motifs-based Teacher Training Program (NMTTP) attempts to address this void. The program was designed as a part of a larger doctoral research project, in which the perceptions of Israeli PSTs in their 2nd year of training in the field of special education after participating in the program were evaluated. The NMTTP was built as part of a unique platform that combined a reading course named: "*Reading Disabilities—Theories and Intervention Programs*" for PSTs with the application of motifs from neuroscience. It was aimed to consider the different needs of pupils with reading difficulties with regard to concepts and methods from the neuroscience field. The word "motifs" in this study refers to specific, recurring elements or themes identified within the neuroeducational approach. The literature presents parallel phrases such as "neuroscience topics," "neuroscience terms" (Kerchner et al., 2012), "Educational neuroconcepts" (Chang et al., 2021), and "neuroscience knowledge" (Dubinsky et al., 2019). In our study "motifs" highlight recurring themes within the neuroeducational approach, focusing on practical application in educational programs.

Three lecturers taught this course: all three are experts in special education and teaching reading, and one of them (the developer of the NMTTP and the author) is also an expert in neuroscience and psychology. This lecturer developed the various lessons included in the program, including the required knowledge, preparation of different materials, and creating the connection between them and the reading course. The other lecturers received prepared lesson plans and provided their opinions on them before and after each lesson, including sharing dilemmas and challenges that arose during the lesson. The NMTTP is based on three main components: Brain Targeted Teaching Model (BTT) (Hardiman, 2012a, 2012b); Guide to brain-based teaching (Tokuhama-Espinosa, 2011); and several original lessons developed by the author (EL) in the spirit of the components we presented above to adapt them to the reading course.

In an attempt to adapt NMTTP to the reading course, the author (EL) planned 10 lessons throughout the academic year of 2017–2018, which implemented motifs from neuroscience into the current reading class issues. The program incorporated innovative topics: learning in context, neuroplasticity, neuromyths, brain and reading, mirror neurons, and metacognition. Each 90-min lesson was defined by a specific purpose, key concepts and teaching methods. and contained the following components: (a) a short review of the status of the reading course and the specific unit currently being studied; (b) important neuro-educational concepts; (c) evidence-based teaching methods aimed at encouraging active learning; (d) implications for teacher training: a discussion with the PSTs about the implications of the lesson to their work and their professional identity development.

The units of neuroscience in the reading class were presented at the beginning of each lesson, but, if needed, the neuroscience elements were discussed in a flexible manner throughout the whole lesson. Each lesson began with a rehearsal on the previous lesson in different ways (such as: playing with a ball, fun-quiz, role play, case studies etc.) with continuous rehearsals about the importance of synaptic connections in learning concepts. To enhance the understanding of brain functions, metacognitive discussions with the PSTs were engaged in about the possible implementations of the new concepts in practice, critical thinking about the advantages and disadvantages of each teaching method chosen to teach the concept, etc. One possible metacognitive question, for instance, was: "Is the conclusion from this experiment well-founded? Could you think differently about the implementation of this concept in your lessons?" (for more information about the development of the program, see Luzzatto and Rusu, 2020).

One significant feature of the program was its interdisciplinary approach, that sets it apart from other programs such NAP or BrainU, which focus on teaching PSTs neuroscience or NE in a separate, stand-alone course (Friedman et al., 2019). The choice to take this approach was based on the advantages of multidimensional interdisciplinarity courses that Rooks and Winkler (2012) described including: knowledge that is not compartmentalized but transferable such as it is in the real world; allowing students to understand how to marshal a wide range of skills and knowledge bases to solve pressing social, economic, and technological problems; and encouraging different ways of learning, specifically more collaborative approaches that promote dialogue and problem-solving capacities.

2.2 Challenges and contributions in implementing pedagogical change

While teacher training institutions, and the organizations that accredit those institutions, have not yet widely embraced the idea of providing neuroscience training for teachers (Dubinsky et al., 2019; Jolles and Jolles, 2021; Privitera, 2021), there are voices calling for innovative, interdisciplinary and active learning. Introducing and implementing innovative pedagogical changes is a difficult process, in which teachers play an essential role, widely recognized by researchers and educators alike (Wu et al., 2015). Moreover, the ability of teachers to play an active role in the process of implementing new practices is crucial for radical and long-lasting change and reform throughout the entire educational system (Fullan, 2007; Mariage and Garmon, 2003). At the same time, the characteristics of teachers, together with the characteristics of the innovation and features of environmental context all influence the outcome of the diffusion of an innovation, determining whether it is successfully adopted and spread within an educational setting (Rogers, 2003; Sherry, 2000). According to Wu et al. (2015), teachers need to understand the innovation and reduce uncertainty about their advantages and disadvantages. For this reason, there is a great importance to exploring the perceptions of those who are involved in the implementation of innovation, and observing the process from their point of view. Exploring the perceptions of special education teachers may have even greater applied value in terms of individual functioning, as knowledge of the neural basis of learning can increase patience and empathy toward challenging students by increasing understanding of some of the unique processes in their students' brain (Baker et al., 2014; Hook and Farah, 2013; Kosaraju et al., 2014).

Findings from quantitative data collected as part of a larger research project for one of the author's doctoral thesis showed positive attitudes to neuroeducation since the inception of the NMTTP program and a notable contribution to the participants' sense of competence (Luzzatto and Rusu, 2019). What needs to be clarified, however, is how the participants felt about the process itself. This knowledge gap motivated the following research question: What are the perceptions of PSTs preparing to work in special needs schools regarding the implementation of motifs from neuroscience in education and teaching, and specifically regarding the NMTTP?

3 Methodology

3.1 Research paradigm

Individuals develop subjective meanings of their experiences, which are directed toward certain objects or things (Guba et al., 1998). To explore the PSTs perceptions of NE and the NMTTP from an authentic point of view, a qualitative paradigm based on research questions and on thematic content analysis was chosen for this study.

3.2 Research population and sampling

The research included 11 PSTs who studied in a teacher training college in the centre of Israel. The 11 PSTs were chosen from 90 PSTs who participated in the NMTTP. The 11 PSTs were chosen directly by the lecturers, selecting those who were particularly active in class discussions, and appeared to have the most to discuss and analyze in terms of findings. This decision suits the outline suggested by Etikan et al. (2016), Seidman (2006), and Creswell (2009), according to which purposive sampling is often used in qualitative research to select participants who can provide insightful data. The research approach used here is an exploratory multiple case study, which enables the researcher to gather data from a variety of sources and to converge the data to illuminate the case (Baxter and Jack, 2008). According to this method, each of the 11 PSTs serves as a window into the course and the impact of the NMTTP. All the PSTs that year and therefore the PSTs that were interviewed were female. The gender bias, reflected in the chosen participants in the study, is due to the general characteristics of the educational system in Israel, i.e., most of the PSTs in education in general, and special education in particular, are women (over 80%, according to the Israel Central Bureau of Statistics, 2019). Their ages ranged from 24 to 29 years old (mean age 23.6). They were all enrolled in the special education track. Five of the PSTs studied in parallel with another track such as math, biblical studies, English or literature. Table 1 presents the demographic characteristics of the participants in the study.

3.3 Research tools

Two research tools were used in the research: (1) semi-structured interviews and (2) open-ended questionnaires.

3.3.1 Semi-structured interviews

Semi-structured interviews took place at the end of the academic year 2017–2018 (June to July 2018) with the 11 PSTs. Two examples from the PSTs' interview questions (out of six) are presented: (1) "*Which of the topics from neuroscience that were integrated into the reading course do you remember or were meaningful to you in particular?*" (2) "*How would you describe your experience taking part in the NMTTP program that was integrated into the reading course*?"

TABLE 1 Demographic characteristics of the participants in the interviews following participation in the NMTTP program.

	Participant	Gender	Age	Field of Study
1	M.B.	F	29	SE
2	Y.Z.	F	26	SE + Literature
3	H.Y.	F	24	SE + English
4	M.S	F	28	SE
5	D.S.	F	24	SE
6	C.M.	F	25	SE + Math
7	R.R.	F	27	SE + Math
8	N.T.	F	27	SE
9	G.A.	F	24	SE + Biblical studies
10	L.S.	F	26	SE
11	M.V.	F	24	SE

3.3.2 Open-ended questions

Open-ended questions were presented to all the PSTs as non-mandatory questions in a mid-year and final year questionnaire. The questions asked were: (1) "*List 3 to 4 neuroscience concepts mentioned in the lesson that should be integrated, in your opinion, into the teaching process*"; (2) "*Describe whether and how content from the neuroscience mentioned in the course will benefit you during this year's experience in class and later in your role as a teacher*." Ninety PSTs filled in the questionnaires, 31% of them submitted the open-ended questions. The questions were made non-mandatory to ensure ethical compliance and voluntary participation.

3.4 Data analysis

Content analysis method is applied in this study, using text segments to create theme categories. According to this method, major categories are identified regarding the research perception, with reference to the research questions. The categorization process means deviation and organizing the data in an analytic order. This is a process that combines some information units such as words, phrases, expressions or statements that are considered by the researchers to reflect the domain of interest of the research question (Shkedi, 2011; Tashakkori and Teddlie, 2003). The categories are used by researchers to sort out the raw data of the study, distinguishing and separating them to indicate their significance (Shkedi, 2011). According to Erlingsson and Brysiewicz (2017), the objective of qualitative content analysis is to systematically transform a large amount of text, which is considered the raw data, into a concise and organized summary of the key results. The following steps were performed: (1) reading the written materials to gain a general understanding of what the participants are expressing; (2) condensation of the text by division into meaning units (codes, for example: special education teachers); (3) grouping the codes into categories (i.e., a category is formed by grouping together those codes that are related to each other through their content or context. For example, in this study, NE importance, relevance and contribution) and themes (i.e., a theme can be seen as expressing an underlying meaning found in two or more categories, for example, attitudes). This framework is in line with other researches in the field of neuroeducation, such as in the research of Peregrina Nievas and Gallardo-Montes (2023). In the current study, a systematic content analysis was conducted on the PSTs interviews transcriptions and the PSTs written answers to the open-ended questions, by identifying categories that were categorized into groups. In addition, an analytical analysis was performed on the open-ended questionnaires to identify the frequency of use of NE terms and concepts. This involved systematically reviewing the responses to uncover patterns, counting occurrences of specific terms, and interpreting how these terms reflected the participants' understanding of NE concepts.

3.5 Reliability and validity

In order to ensure and improve the research quality, there was an attempt to meet the criteria of the qualitative research quality presented by Lincoln and Guba (1985): reliability, transferability, trustworthiness and applicability. In order to meet these criteria, rich descriptions and many direct quotes were used; transparency of the research process was maintained by documenting the process and keeping the original records and the data analysis was conducted with a co-researcher or an external judge, and their analyses were found suitable to the research aims. Disagreements and misconceptions were discussed until appropriate resolution was reached. The professional record of the main researcher helped in analyzing the content and in distinguishing the relativeness of what was presented in the different research tools; the co-researcher and the external judge provided a critical perspective on the interpretations, which enhanced the reliability of the data analysis by ensuring a non-biased evaluation. These decisions also met Tracy's (2010) eight "Big-Tent" criteria which were used as a guiding framework. This included *rigorous* data collection and analysis; *credibility* established through triangulation of data sources, *sincerity* by self-reflection were shared with others and discussed to address potential biases; and *resonance* was met by providing rich descriptions of the data and illustrative examples.

3.6 Ethical considerations

All ethical guidelines and behaviour were adhered to in this research, in accordance with the national and international legislative frames regarding ethics in academic research. The study was reviewed and approved by the research ethics committees from the teacher training college, ensuring that ethical research practices were followed. In addition, the PSTs were not required to provide their names or any other indication of their identity.

4 Findings

The data analysis revealed two main themes: attitudes and knowledge. The first theme, attitude, contains four main categories: (1) NE importance, relevance and contribution (Figure 1); (2) attitudes toward the structure of the NMTTP (Figure 2); (3) the affective component of the attitudes (Figure 3); and (4) PSTs' attitudes toward obligations of the role as teacher. The knowledge theme (Figure 4) contains three codes of categories: (1) perceptions of knowledge related to teaching methods; (2) perceptions of knowledge related to the process of implementation of neuroscience in teaching; and (3) perceptions of knowledge related to specific motifs and concepts from neuroscience. The findings also reveal the frequency of use of neuroscience terms and the category to which they belong (Table 2 and Figure 5).

4.1 Theme attitudes

4.1.1 Category attitudes toward NE importance, relevance and contribution

In the interviews, the PSTs presented generally positive attitudes toward NE, as reflected in the presentation of its importance, relevance, and contribution to all teachers (Figure 1). Similar attitudes were also reflected in the answers to the open-ended questions. For example, "*We have the opportunity to influence students, even at the level of their brain structure.*" Or, "*We can influence the way information is organized, which will help the student later in the retrieval phase.*"

Similarly, a positive attitude regarding the importance, relevance, and contribution of NE for special education teachers was also expressed. The PSTs related to the understanding of the behavior and needs of a child with special needs, after learning the biological basis of learning and disabilities. The open-ended questions in the questionnaires revealed similar sentiments, for example, "*In any case where the teacher has difficulty obtaining knowledge or accessing new material, he must find indirect ways to reach the information and the student, just as the synaptic connections in the brain do.*" Or, "*Knowledge of the brain provides additional tools for understanding the different needs, different functioning, different ways of thinking by students in the classroom.*"

In at least four cases of the references, the PSTs already referred to themselves as future teachers: "*Because we know a little about how the brain works, we know how to adapt teaching and learning. In fact, we can direct our teaching more precisely*"; "*I, as a teacher, need to prepare effective lessons for my students that are right for them and their abilities … to create situations where they will be free to learn in terms of creating synaptic connections.*" This interesting finding relates to the personal level, in particular to the professional development of the PSTs, while the other findings relate to the applied contribution of the program in improving the ways of teaching-learning (Figure 1).

4.1.2 Category attitudes towards the structure of the NMTTP

Based on the findings, the attitudes regarding the structure of the NMTTP were mostly positive. The general perception, in about 60% of the interviews, was that the integration of neuroscience motifs into the reading course was well executed (Figure 2). However, while most of the attitudes toward the integration were positive, some were less so. For example, "*I do not remember incorporating neuroscience into a lesson as something very major and significant… it wasn't connected enough*"; or regarding the connection between neuroscience and reading: "*Personally, this connection is less important to me… I needed to make the connection by myself and I have not always done it… it's not related*"; "*I cannot tell you that I was told in the courses 'now we are learning something about neuroscience'… I cannot really link it… maybe a direct reference to the topic would have helped.*" Therefore, it seems the picture of the attitudes toward integration is complex. While some PSTs perceived the integration as working well, others found it not relevant or related to the reading course (Figure 2).

Regarding the quantity of neuroscience in the reading class, the PSTs attitudes were varied, with several sharing that the quantity of neuroscience elements was not enough, mostly due to time constraints (Figure 2). While some of the participants voiced a request for more knowledge on neuroscience and the influence of it, others expressed the elements of neuroscience in the course as not significant: "*During the course I felt it was less relevant… it was vague… I cannot say these motifs are from neuroscience… although I was happy to… I do not feel it has any added value for me.*"

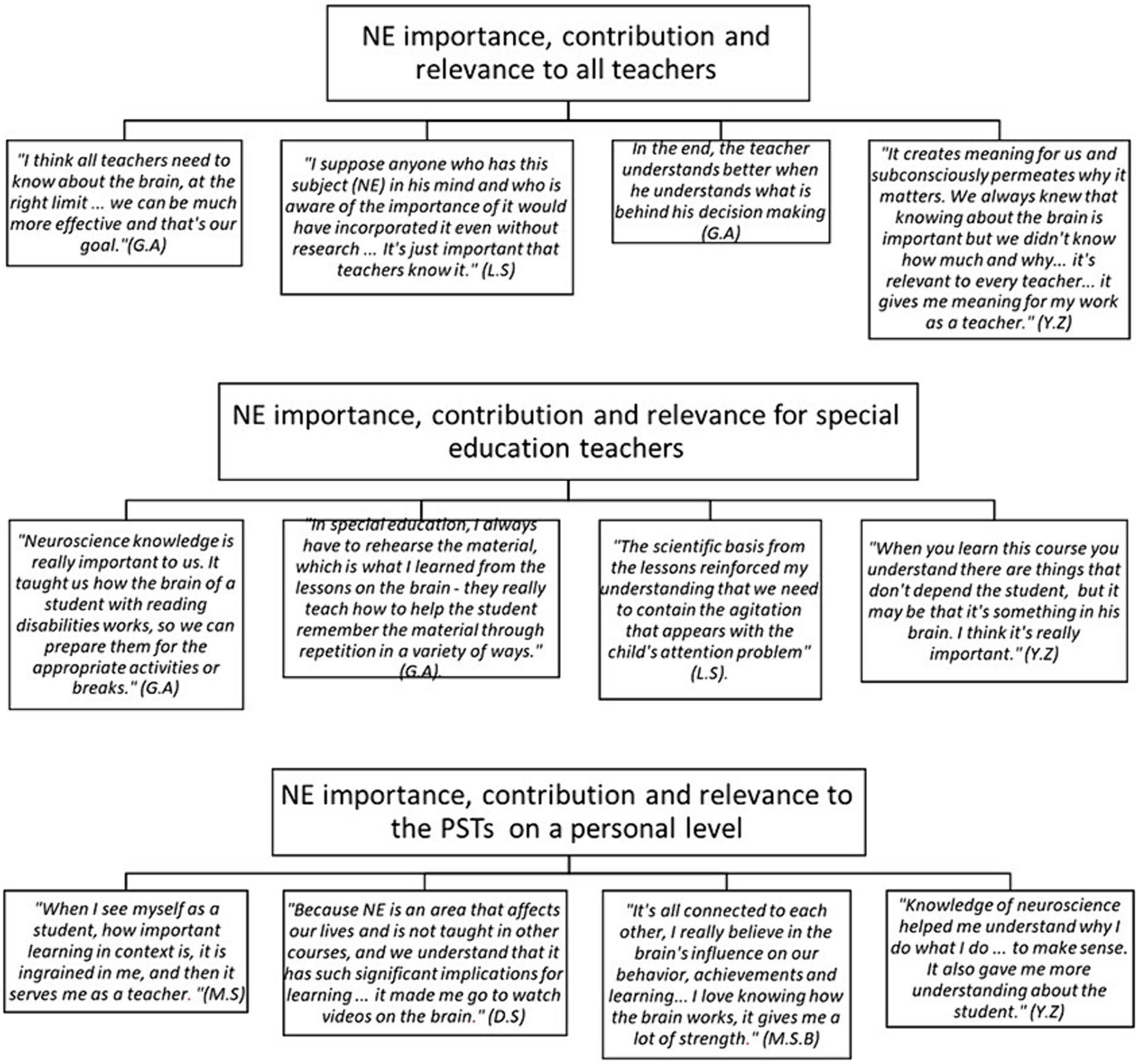

FIGURE 1
Codes within the category of NE importance, contribution, and relevance, i.e., to all teachers, to special education teachers, and to the PSTS on a personal level.

4.1.3 Category affective component of the PSTs' attitudes towards the NMTTP

The affective component of some of the PSTs' attitudes revealed their initial concerns about neuroscience in general or the NMTTP. The reflections they shared indicate a feeling of apprehension, stress and fear, especially in the beginning of the course, when a lot was unknown. Some also presented doubts of the ability to succeed in learning neuroscience motifs (Figure 3).

4.1.4 Category attitudes toward obligations of the role as teacher

Another identified theme was the attitudes toward obligations of the teacher role. The decisive wording appeared in the open-ended questionnaires and referred to the PSTs' attitudes toward the obligation for all teachers to learn about the brain: "*The content learned from neuroscience contributes to understanding how the brain works … which impacts on learning and the ways of instruction to be taken. In my opinion, we, as learning intermediaries and educators, are obliged to learn these contents to help students reach full realization of their learning potential*"; "*A teacher must be aware of the cognitive processes that take place in each student's mind, to make learning meaningful and experiential.*" The decisive style expressed in this theme may indicate a high commitment to the process of assimilation of neuroscience into the teaching-learning process and emphasis on its importance.

4.2 Theme knowledge

The knowledge theme presents the way that neuroscience content from the course benefits the PSTs during their practical experience as part of the teacher training as well as their perceptions as future teachers. The knowledge theme that emerged from the findings contains three categories: perceptions of knowledge related to teaching methods, to the process of implementation of neuroscience in teaching, and to specific motifs and concepts from neuroscience (Figure 4). In addition, we reveal the level of frequency of neuroscience

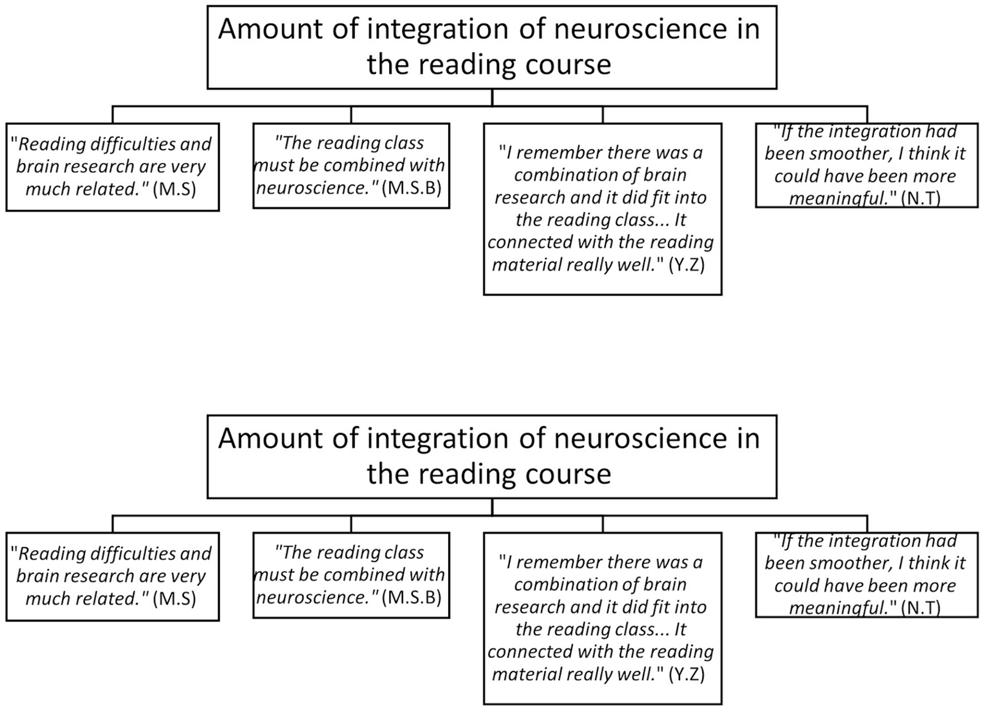

FIGURE 2
Codes within the category attitudes toward the structure of the NMTTP, i.e., quantity of NE material presented in the reading course and the PSTs' attitudes toward the amount of integration of neuroscience.

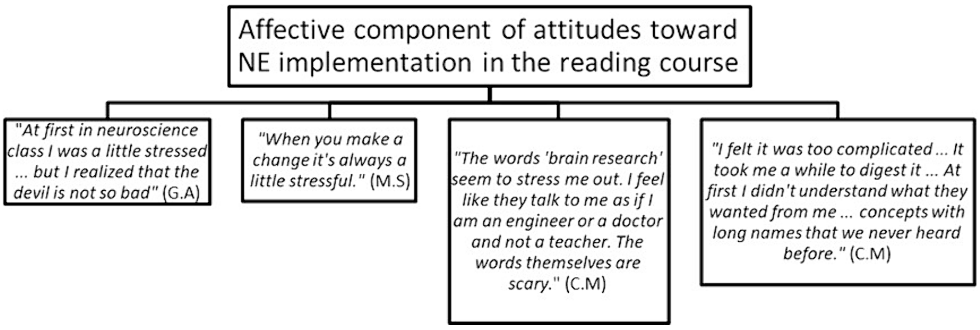

FIGURE 3
Affective component of the PSTs' attitudes regarding towards the NMTTP.

terms and their level of categorization by topics the PSTs used in the open-ended questionnaires (Table 2 and Figure 5). These findings may shed light on the understanding and assimilation of knowledge in the context of learning and teaching processes.

4.2.1 Category: knowledge related to teaching methods, process of implementation, and neuroscience motifs

The findings from the semi-structured interviews and the open-ended questionnaires reflect the PSTs' level of knowledge of the neuroscientific concepts presented in class and how they connect to different teaching methods. Findings show that PSTs who participated in the NMTTP demonstrated an understanding of a variety of neuroeducation concepts acquired in the training program, as well as their understanding of how these concepts affect the learning process, for example, the PSTs cited the importance of multi-sensory activities in learning; how spaced learning can improve memory; as well as the importance of combining physical activity during the lesson (Figure 4).

Regarding the process of implementation of neuroscience concepts into the reading component of the course, the perceptions expressed by the PSTs were positive. Some comments by the PSTs suggested they felt a level of fluidity to the process of integrating neuroscience and education, that it became natural to them (Figure 4).

4.2.2 Category frequency of the neuroscience terms

The next section describes the frequency of the use of motifs, in an attempt to show understanding and assimilation among the PSTs.

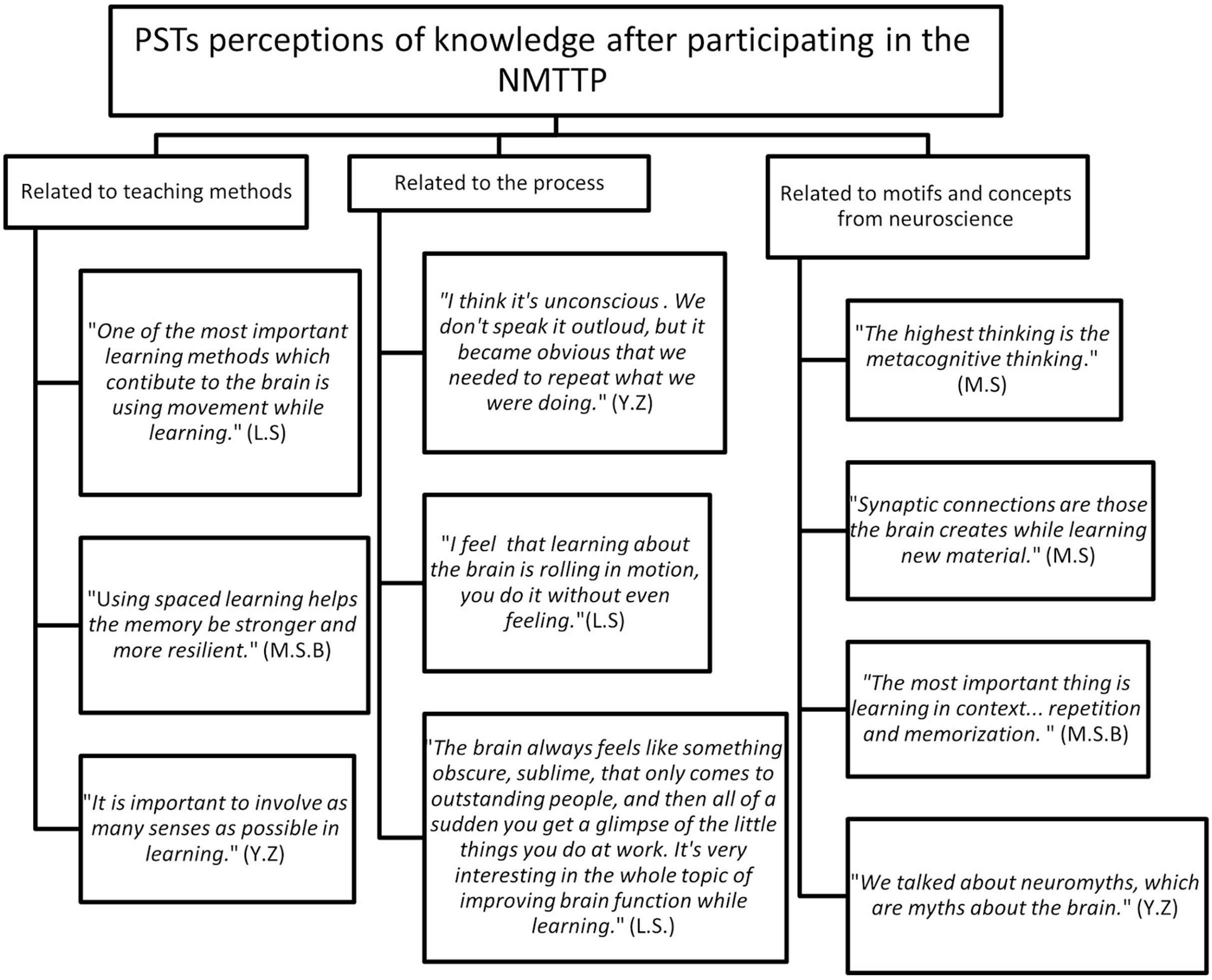

FIGURE 4
Codes within the category PSTs perceptions of knowledge after participating in the NMTTP, i.e., related to the teaching process, related to the process and related to the motifs and concepts from neuroscience.

Quantification of the findings of the qualitative analysis yielded a frequency table of the neuroscience concepts raised from the PSTs' answers (Table 2). The answers were content analyzed in order to produce neuroscience (NS) terms related to teaching and learning and to divide the terms and classify them (Table 2 and Figure 5).

A total of 140 terms were produced, which were categorized into four main categories (Table 2): "physiological terms" (f = 80, 57%), "teaching/learning processes" (f = 26, 19%), "combined—physiological terms and teaching/learning processes" category (f = 23, 16%), and "cognitive physiological/psychological processes" (f = 11, 8%). The frequencies (Table 2 and Figure 5) reflect the diversity of answers raised from the PSTs, which reflect the vast range of concepts they were exposed to. Some concepts were only mentioned once in the course, but it seems they left a great impression, such as mirror neurons or neuromyths.

In the explanations of the concepts, there was an emphasis of the importance of neuroscience in teaching, which affected the operative level as reflected in learning-teaching methods.

The largest category included "Physiological terms" (f = 80, 57%), e.g., "*Neuroplasticity means change between the neurons' connections in the brain. The stronger the neurons work and cooperate, the stronger the synaptic connections*" (neuroplasticity). The other categories included (in descending order): "Teaching/learning processes" (f = 26, 19%), e.g., "*It is very important for us to know as teachers that repeating a previous lesson at the beginning of the lesson is important for strengthening the relationship between brain synapses, enhancing learning efficiency and having evidence from brain research studies* (learning in context). The constant rehearsal of those concepts is reflected in the frequency table.

"Combined—physiological terms and teaching/learning processes" category (f = 23, 16%), e.g., "*The educator must be critical with relation to content in the pedagogical-educational context while examining it. Sometimes, neuromyths can harm our students in choosing unsuitable teaching strategies or giving up ones that could benefit from mistaken beliefs in neuromyths*" (neuromyths).

These two categories together (35%) may indicate that the learned neuroscience concepts have been assimilated in the PSTs' understanding and comprehension of the relationship of these concepts to education, teaching and learning. For example: "*All our learning takes place through synaptic connections. If I, as a teacher strengthen these connections—there may be faster progress in learning.*" The smallest category included "Cognitive physiological/

TABLE 2 Frequency (number and percentage of occurrences) of the neuroscience terms in the PSTs' open-ended questionnaires.

Categories and concepts	Frequency (number of occurrences)	Percent of frequency total	Percent of category
Total	140	100%	
Physiological terms	80	57%	100%
Neuroplasticity	27		34%
Synaptic connections	20		25%
Neuron	14		18%
Synapse	9		11%
Mirror neurons	4		5%
Gray matter	4		5%
Hemispheres	2		3%
Teaching/learning processes	26	19%	100%
Learning in context	9		35%
Spaced learning	7		27%
Rehearsals in teaching	4		15%
Diverse teaching methods and neuronal activity	4		15%
Attention and the brain	2		7%
Combined—physiological terms and teaching/learning processes	23	16%	100%
Neuromyths	7		30%
Neurological deficit and dyslexia	5		22%
The limbic system and learning	3		13%
Imaging studies	4		17%
Neuropsychology	2		9%
NE	2		9%
Cognitive physiological/psychological processes	11	8%	100%
Metacognition	5		45%
Memory	3		27%
Physical activity and the brain	1		9%
Information processing	1		9%
Morphological changes	1		9%

psychological processes" ($f = 11$, 8%), e.g., "*Metacognition is important for reading comprehension, since many of the strategies we teach in order to improve understanding of text are based on metacognition.*" However, this code was identified in the open-ended question from the questionnaire and reflects the positive attitudes towards NE regarding its connection to high thinking and metacognition, "*Learning about NE aligns with the spirit of global education … developing higher-order thought processes*"; "*The educator must be critical of the content and information in the pedagogical-educational context, apply logic and examine the content.*"

5 Discussion

The aim of this study was to explore the perceptions of the PSTs preparing to work in special needs schools, regarding the implementation of motifs from neuroscience in education and teaching, and specifically regarding the NMTTP. The two main themes that emerged from the research findings, attitudes and knowledge, were evident in the PSTs' interviews and open-ended questionnaires. In general, the findings indicate a positive attitude toward the implementation of neuroscience in education from the PSTs perspective and recognized the significance of its contribution to their existing knowledge base. Overall, most of the PSTs agreed that introducing neuroscience into education and teaching is important, relevant and contributes to the classroom decision-making process as well as to the choice of teaching methods. Some of the PSTs presented this knowledge as crucial for their learning and professional development. For example, one PST wrote "*I truly believe that neuroscience and education are interdependent. What I do not understand is how something so obvious was not part of my knowledge base until this course.*"

The generally positive reception of the course could be attributed, in part, to the transformation of the PSTs' initial feelings of stress and overwhelm about learning something unfamiliar into the sense of

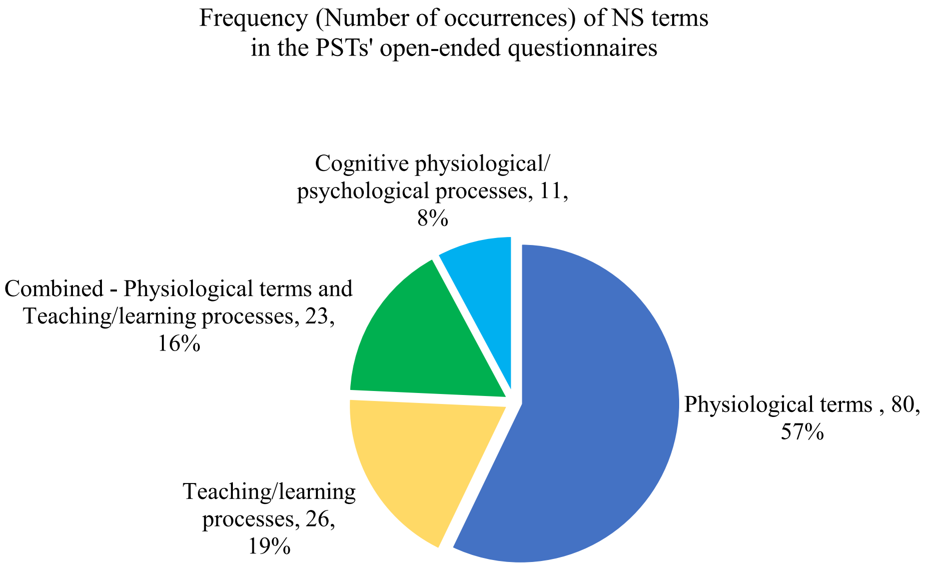

FIGURE 5
Frequency (number and percentage of occurrences) of the NS terms in the PSTs' open-ended questionnaire, by category.

confidence they felt at the conclusion of the course, in their ability to use neuroscientific concepts in planning lessons for students with special needs as well as in their classroom teaching.

Generally, the findings indicate that at a perceptual level based on the personal interviews and answers to the open- ended questions, the attitudes of the PSTs regarding the importance, relevance and contribution of NE and the NMTTP were mostly positive. These results of the qualitative research were in accordance with previous findings in the literature that report on teachers' enthusiasm for NE (Pickering and Howard-Jones, 2007; Serpati and Loughan, 2012; Ching et al., 2020). Tan et al. (2019) found that teachers reported better understanding of the relationship between brain function and pedagogy. This understanding may have provided teachers with a new perspective from which to evaluate instructional decisions made in the classroom. Hook and Farah (2013) discussed the question of whether and why NE should interest teachers and its relevance to them. In their research, they found that teachers are interested in intellectual triggers, evaluating and assessing their work as well as discovering new teaching methods. The research presented here builds on the current literature in two additional areas. Firstly, the study offers a research-informed support for the understanding of the effect of neuroscience infusion in special education teacher training in Israel. Secondly, it also sheds light on an interesting and unexpected point of the importance, relevance and contribution to the *PSTs on a personal level*, as perceived in their attitudes.

Research from the neuro- and cognitive sciences shows the potential to improve pedagogical practices and develop creative problem-solving abilities (Boomgard, 2013; Carew and Magsamen, 2010; Hassinger-Das et al., 2017; Kosaraju et al., 2014). Considering that neuroscience within the educational setting may have profound implications for individuals with reading, writing, and comprehension disabilities (Goswami, 2006; Martín-Lobo et al., 2018; Sigman et al., 2014), this qualitative analysis strives to support existing research that reflects the potential contribution NE can bring to the field of special education.

The extent of the relevance and contribution of the NMTTP on a personal level for the PSTs may be explained by the influence of the exposure to the way the brain learns and remembers. Fullan (2001) claimed that change in an organization has a practical impact on each of the partners in the process, in ways of responding and designing positions, in the development of the organization and in the growth and professional and practical development of those involved. The examples relating to importance, relevance and contribution on a personal level by the PSTs may indicate implementation of NE from another angle, as reflected specifically by Fullan (2001), which may indicate personal and professional growth. Walker et al. (2019) referred to this personal growth by focusing on brain literacy. According to the authors, brain literacy, like all literacy, requires exposure, explicit instruction, knowledge translation, practice, and continuing education. Developing brain literacy is helping educators realize how diverse thoughts and behaviors are governed by the brain, not only among their students, but also by their own brain functioning.

The interviews revealed that the PSTs had positive attitudes overall toward the structure of the NMTTP and its integration into the reading course, recognizing the contribution neuroscience can provide in this context, with one PST commenting that "*reading difficulties and brain research are very much related.*" Specifically, in relation to the integration of neuroscience in the reading class, one PST commented, "*I remember there was a combination of brain research and it did fit into the reading class… It connected with the reading material really well.*" Another PST shared this opinion: "*Neuroscience and education are two areas that are correlated. When a teacher engages in an in-depth study of brain studies, that is, understanding how the brain impairment affects the student's functioning and what is the origin of the difficulty, he has the ability to produce the best for his students.*" This comment could be interpreted further to suggest that brain research has a potential contribution to make beyond the bounds of its integration into this specific reading course, to a wider application in the field of education in general.

However, the integration was not received well by all PSTS with one commenting that if the "*integration had been smoother, I think it could* *have been more meaningful*." The decision to integrate the NMTTP into the teaching reading course was based on the researchers' experience, consideration and desire to apply neuroscience motifs in the context of specific content, in order to facilitate the transition of the theoretical concepts from neuroscience to a practical application. This decision transformed the course, to a certain extent, into an interdisciplinary one, in contrast to other NE courses, which are often taught separately from a specific content/context (e.g., Blake and Gardner, 2007; Warner and Templeton, 2010), even though required interdisciplinary courses have become an increasingly standard curriculum feature at many colleges and universities (Rhoten et al., 2006).

Interdisciplinary courses can have their difficulties and disadvantages. Goodman and Huckfeldt (2014) found mixed results regarding interdisciplinary courses: on the one hand, the course they investigated contributed to an increase in class participation and discussions based on evaluation, but on the other hand, the comments on the course claimed for too much material and requirements, untrained teaching team members, a too-high level of the material of the course and most important, students failed to implement the importance and relevance of the material and skills taught in the course. The mixed attitudes and feedback demonstrated in this research with regard to this integration of the NMTTP are therefore, not unexpected based on the research interdisciplinary courses to date.

5.1 Attitudes of PSTs to the NMTTP and NE—affective component

On the whole, the PSTs expressed positive attitudes toward NE, as reflected in the presentation of its importance, relevance and contribution to all teachers, including special education teachers, as well as positive attitudes of the PSTs toward NE and how it relates to their own experience. However, the qualitative analysis also revealed some initial feelings of stress and overwhelm being voiced on the part of some PSTs with regard to the NMTTP, as well as feelings of uncertainty in the face of unfamiliar concepts. The PSTs expressed these feelings in a retrospective point of view, relating to the beginning of the year. Change can elicit both skeptical and enthusiastic responses on a personal level: people who describe change processes use expressions of anxiety and fear, danger, loss and panic, along with expressions that indicate high energies, transcendence, risk-taking and great excitement (Fullan, 2007). Studies show that general education PSTs have concerns related to limited knowledge and preparation in many areas (Tillery et al., 2010). Sandholtz (2011) found that PSTs are concerned about teaching strategies, planning and organization, behavior management, collaboration, and working with diverse students and families.

5.2 Attitudes of PSTs to the NMTTP and NE—knowledge component

The qualitative findings show that the PSTs considered their participation in the NMTTP to have increased their knowledge in three areas: (1) knowledge related to teaching methods (2) knowledge related to the process of implementation of NE in teaching and education and (3) knowledge related to motifs and concepts from neuroscience. These findings are in line with the literature, for example, Coch (2018) claimed that knowledge about students' learning and learning environments might be included in pedagogical content relating to two components of the pedagogical content knowledge in PSTs: (1) knowledge about subject matter; (2) knowledge about students and learning. Research completed on brain literacy instruction demonstrates improved educator brain literacy knowledge, skills, and opinions regarding serving children with and without special needs in mainstream classrooms (Dubinsky et al., 2013; Walker et al., 2017). By empowering teachers with robust knowledge and skills in educational neuroscience, diverse student bodies can be better served through teaching practices designed to expand and grow their unique minds (Walker et al., 2019).

The findings show PSTs related to several teaching methods mentioned in the NMTTP such as multi-sensory teaching, spaced learning, involving movement in learning and learning in context. These findings are in line with the literature, describing the contribution of participating in neuroscience training to influence teachers' choice of instructional strategies (Dubinsky et al., 2019; Privitera, 2021). An interesting point arising from the findings dealt with the knowledge of neuroscientific motifs and concepts from neuroscience. The findings reveal a high assimilation of physiological terms, especially neuroplasticity and synaptic connections, which were concepts rehearsed in different lessons throughout the NMTTP in connection to learning in context. Furthermore, the findings indicate a low assimilation of concepts of cognitive physiological/psychological processes, and in particular, metacognition. However, the relatively low frequency of concept occurrences in this category may imply that they are an inherent component in the PSTs' knowledge, yet still need to be related to teaching and learning process. According to Im et al. (2018), educators' knowledge of the brain often fails to match their enthusiasm for the brain, and they lack neuroscience literacy. It might be that lack in knowledge contributed to the low retrieval of some of the concepts. Another option for explaining the low frequency of these concepts may be because the PSTs were asked to retrieve concepts from neuroscience mentioned in the course, and those concepts belong to the field of cognitive psychology.

It should be noted that special effort was taken in order to prevent the creation of neuromyths among the PSTs, and to create a "risk prevention strategy" so that the PSTs would not misinterpret the neuroscientific knowledge they had received. This was made by presenting accurate terms and definitions dealing specifically with neuromyths and conducting discussions in which the retrieved knowledge was corrected and explained. However, the literature shows that teachers' simultaneous interest and lack of training in neuroscience may, in part, support the perpetuation of neuromyths in the field of education (Goswami, 2006; Howard-Jones, 2014; Ruhaak and Cook, 2018). Surprisingly, Dekker et al. (2012) found that a significant predictor of belief in neuromyths was a teacher's general knowledge about the brain. Thus, teachers who knew more about the brain were more likely to believe myths about the brain. From another perspective, Im et al. (2018) found that participating in an educational psychology course that included neuroscience topics reduced but did not eliminate belief in neuromyths in pre-service teachers from South Korea. However, we consider that it is an unrealistic expectation that a single course of study in neuroscience could address all neuromyths. Although by no means a "magic bullet" against neuromyths, neuroscience training has the potential to reduce the pervasiveness of these misconceptions among teachers while simultaneously increasing neuroscience content knowledge and confidence in the ability to teach neuroscience (Privitera, 2021). Therefore, special care must be taking in developing and delivering NE courses.

Overall, the study showed that PSTs who participated in the NMTTP demonstrated a variety of concepts acquired in the training program, and they also knew how to explain them and their applications in teaching. Apparently, it seems that there is a great importance of acquiring knowledge on the shaping of the PSTs attitudes toward NE and the NMTTP. van der Linden et al. (2015) concluded that it appeared possible to positively change PSTs' beliefs and attitudes toward research, while developing their research knowledge in the second year of their education. Also, according to Friedman et al. (2019), it is important that teachers and educators be equipped with basic knowledge of neuroscience and familiarity with brain structure and function, abilities and limitations. This is so that they can understand, appreciate and apply the principles of learning and its methods. With this knowledge, they will be able to recognize the emerging innovations in the field of learning research, improve their teaching ability, raise their students' achievements, increase their own enjoyment of teaching, and enhance their students' enjoyment and engagement in present and future learning.

Neuroscientific insights from the field of brain research may have the potential to contribute to the advancement/development/ of the teaching-learning process. Although the research literature generally agrees with the possible contribution of neuroscience to education, research into ways to bridge the gap between scientific research in the field of neuroscience and educational practice is scarce. By tackling the challenge of how to apply NE in a practical setting, the research presented here may in some way refute the arguments voiced about the lack of need or the futility of applying brain research findings to pedagogy (e.g., De Vos, 2015). However, when considering the process of bridging the gap between neuroscience and education, one must notice that a causal chain of reasoning from a basic neuroscience fact to a teaching method is often weak, because of the variance between peoples' brains (Coch, 2018). Therefore, it is important to be aware that behavioral and neuroscientific laboratory findings require accurate translation and appropriate application in the classroom in order to avoid potentially harmful overgeneralizations.

6 Conclusion

The current findings provide insights into the contribution of neuroscience in education at both the theoretical and the applied level. At the theoretical level, the qualitative analysis could potentially contribute to understanding the role of NE in enhancing pedagogical practices. At the practical level the participants increased their knowledge in three areas: knowledge related to teaching methods; knowledge related to the process of implementation of NE in teaching and learning; knowledge related to motifs and concepts from neuroscience. Moreover, the PSTS presented positive attitudes toward the assimilation of neuroscience in education in general and special education, in particular.

Integrating neuroscience into teacher education programs provided another perspective on learning and teaching and played a modest but important role in building an evidence-based learning education culture. The contribution was perceived as important to an extent that some of the PSTs declared knowing NE principles as an imperative for teachers.

The findings revealed that the PSTs were able to successfully comprehend the theoretical integration of knowledge from the NMTTP. With regard to the majority of the core neuroscience motifs, it was evident that, despite being exposed to some concepts only once, these concepts left a significant impression in terms of utility. However, the practical implementation of these concepts is not clear yet, and an additional time is needed to fully understand the integration of these ideas into practice.

The interdisciplinary structure of the NMTTP allowed practical application of NE principles in a teaching reading course. However, it also had its disadvantages such as time constraints. Further research and planning of the courses should be considered as to the most efficient way of integrating NE content into existing courses. The PSTs' attitudes regarding the structure of the NMTTP were mostly positive, though the current research raises questions about the way the integration with the reading course occurred. Im et al. (2018) pointed out the difficulties of implementation of neuroscience in education and suggested educational psychology as a mediator between the two fields, and suggested that one approach to improve the neuroscience literacy is to increase the neuroscience content of pre-service teacher training. A two-year course, which will allow more in-depth treatment of relevant neuroscience motifs, cognitive psychology, educational psychology, and their connections to reading, might allow for a better implementation and application of neuroscientific principles and ideas.

6.1 Limitations and future directions

There are at least three limitations of the current study. First, adequate interpretation and representation of data must be addressed. The researcher subjectivity might have influenced the research process and the possibility of interpretation and representation of data. This was taken into consideration, so both data analysis and theme construction were undertaken through peer learning. Additionally, ethical considerations were taken into account to ensure ethical compliance and voluntary participation. These constraints influenced the decision to inform PSTs that answering the open-ended questions was not mandatory. This approach led to the absence of the voices of the entire class, which limits the conclusions that can be made. While this was necessary, we acknowledge that it may have limited the breadth of our data. Future research could benefit from incorporating strategies to encourage broader participation while still adhering to ethical guidelines. Second, the qualitative paradigm has its limitations as to the analysis and sample population of the study. Eleven PSTs were included in the interview group as a multiple case study giving insights into the research population following the NMTTP. As such, the limitations of the analysis are based on the findings from the interviews of specified PSTs who had participated in the NMTTP and were chosen in a purposive sampling, which might cause a bias. Nevertheless, the research population can be considered to adequately represent PSTs in their second year of studies in the special education track, while they are engaged in preparing and providing reading lessons for students with learning disabilities. Third, additional research on the subject is recommended to gain further understanding of the attitudes of PSTs involved in NE courses in other colleges. In this qualitative study, all the participants were PSTs who had participated in the same NE training program. Future studies could shed light on additional aspects related to NE, in the context of special education and in general education as well. One such idea might be a longitudinal study, which will follow the teachers 5 years after participating in the NMTTP, and investigate their possible use of the NE concepts acquired in the program.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Levinsky-Wingate Academic Center. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

EL: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. MS: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. AR: Formal analysis, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The publication of this research was supported by the research authority of Levinsky-Wingate Academic Center and the research authority of Beit Berl College.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Achva Model of Neuropedagogy. (2016). Available at: (Hebrew)http://www.achva.ac.il/sites/default/files/PedagogyAchvamodule.pdf

Ansari, D., De Smedt, B., and Grabner, R. H. (2012). Neuroeducation—a critical overview of an emerging field. *Neuroethics* 5, 105–117. doi: 10.1007/s12152-011-9119-3

Baker, L., Zeliger-Kandasamy, A., and DeWyngaert, L. U. (2014). Neuroimaging evidence of comprehension monitoring. *Psihol. Teme* 23, 167–187.

Baxter, P., and Jack, S. (2008). Qualitative case study methodology: study design and implementation for novice researchers. *Qual. Rep.* 13, 544–559. doi: 10.46743/2160-3715/2008.1573

Blake, P. R., and Gardner, H. (2007). A first course in mind, brain, and education. *Mind Brain Educ.*, 1, 61–65. doi: 10.1111/j.1751-228X.2007.00007.x

Boomgard, M. (2013). "Changes in perceived teacher self-efficacy and burnout as a result of facilitated discussion and self-reflection in an online course designed to prepare teachers to work with students with autism" in Doctoral dissertations (University of San Francisco). Available at: http://repository.usfca.edu/cgi/viewcontent.cgi?article=1085&context=diss

Carew, T. J., and Magsamen, S. H. (2010). Neuroscience and education: an ideal partnership for producing evidence-based solutions to Guide 21(st) Century Learning. *Neuron* 67, 685–688. doi: 10.1016/j.neuron.2010.08.028

Chang, Z., Schwartz, M. S., Hinesley, V., and Dubinsky, J. M. (2021). Neuroscience concepts changed teachers' views of pedagogy and students. *Front. Psychol.* 12:685856. doi: 10.3389/fpsyg.2021.685856

Ching, F., So, W., Lo, S. K., and Rong, S. (2020). Preservice teachers' neuroscience literacy and perceptions of neuroscience in education: implications for teacher education. *Trends Neurosci. Educ.* 21:100144. doi: 10.1016/j.tine.2020.100144

Coch, D. (2018). Reflections on neuroscience in teacher education. *Peabody Journal of Education*, 93, 309–319. doi: 10.1080/0161956X.2018.1449925

Creswell, J. W. (2009). Research design: qualitative, quantitative, and mixed methods approaches. California, USA: Sage Publications.

Curtis, L., and Fallin, J. (2014). Neuroeducation and music: collaboration for student success. *Music Educ. J.* 101, 52–56. doi: 10.1177/0027432114553637

De Vos, J. (2015). Deneurologizing education? From psychologisation to neurologisation and back. *Stud. Philos. Educ.* 34, 279–295. doi: 10.1007/s11217-014-9440-5

Dekker, S., Lee, N. C., Howard-Jones, P., and Jolles, J. (2012). Neuromyths in education: prevalence and predictors of misconceptions among teachers. *Front. Psychol.* 3:429. doi: 10.3389/fpsyg.2012.00429

Dresler, T., Bugden, S., Gouet, C., Lallier, M., Oliveira, D. G., Pinheiro-Chagas, P., et al. (2018). A translational framework of educational neuroscience in learning disorders. *Front. Integr. Neurosci.* 12:25. doi: 10.3389/fnint.2018.00025

Dubinsky, J. M., Guzey, S. S., Schwartz, M. S., Roehrig, G., MacNabb, C., Schmied, A., et al. (2019). Contributions of neuroscience knowledge to teachers and their practice. *Neuroscientist* 25, 394–407. doi: 10.1177/1073858419835447

Dubinsky, J. M., Roehrig, G., and Varma, S. (2013). Infusing neuroscience into teacher professional development. *Educ. Res.* 42, 317–329. doi: 10.3102/0013189X13499403

Erlingsson, C., and Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *Af JEM.*, 7, 93–99. doi: 10.1016/j.afjem.2017.08.001

Etikan, I., Musa, S. A., and Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *Am. J. Theor. Appl. Stat.* 5, 1–4. doi: 10.11648/j.ajtas.20160501.11

Friedman, I. A., Grobgeld, E., and Teichman-Weinberg, A. (2019). Imbuing education with brain research can improve teaching and enhance productive learning. *Psychology* 10:122. doi: 10.4236/psych.2019.102010

Fullan, M. (2001). The new meaning of educational change. *3rd* Edn. New York: Teachers College Press.

Fullan, M. (2007). The new meaning of educational change. *4th* Edn. New York: Teachers College Press.

Gabrieli, J. D. (2016). The promise of educational neuroscience: comment on bowers (2016). *Psychol. Rev.* 123, 613–619. doi: 10.1037/rev0000034

Gola, G., Angioletti, L., Cassioli, F., and Balconi, M. (2022). The teaching brain: beyond the science of teaching and educational neuroscience. *Front. Psychol.* 13:823832. doi: 10.3389/fpsyg.2022.823832

Goodman, B. E., and Huckfeldt, V. E. (2014). The rise and fall of a required interdisciplinary course: lessons learned. *Innov. High. Educ.* 39, 75–88. doi: 10.1007/s10755-013-9261-4

Goswami, U. (2006). Neuroscience and education: from research to practice? *Nat. Rev. Neurosci.* 7, 406–413. doi: 10.1038/nrn1907

Guba, E. G., Lincoln, Y. S., Denzin, N., and Lincoln, Y. (1998). "Competing paradigms in qualitative research," in The Landscape of qualitative research: heories and issues Eds. N. K. Denzin and Y. S. lincoln. (Thousand Oaks, California: Sage). 105–117.

Hardiman, M. (2012a). Informing pedagogy through the brain-targeted teaching model. *J. Microbiol. Biol. Educ.* 13, 11–16. doi: 10.1128/jmbe.v13i1.354

Hardiman, M. (2012b). The brain-targeted teaching model for 21st-century schools. Thousand Oaks, California: Sage.

Hassinger-Das, B., Hirsch-Pasek, K., and Golinkoff, R. M. (2017). The case of brain science and guided play: a developing story. *Young Child.* 72, 45–50.

Hook, C. J., and Farah, M. J. (2013). Neuroscience for educators: what are they seeking, and what are they finding? *Neuroethics* 6, 331–341. doi: 10.1007/s12152-012-9159-3

Howard-Jones, P. (2014). Neuroscience and education: myths and messages. *Nat. Rev. Neurosci.* 15, 817–824. doi: 10.1038/nrn3817

Im, S. H., Cho, J. Y., Dubinsky, J. M., and Varma, S. (2018). Taking an educational psychology course improves neuroscience literacy but does not reduce belief in neuromyths. *PLoS One* 13:e0192163. doi: 10.1371/journal.pone.0192163

Israel Central Bureau of Statistics (2019). Annual report. Jerusalem . (Hebrew) http://www.cbs.gov.il.

Jolles, J., and Jolles, D. D. (2021). On neuroeducation: why and how to improve neuroscientific literacy in educational professionals. *Front. Psychol.* 12:752151. doi: 10.3389/fpsyg.2021.752151

Kerchner, M., Hardwick, J. C., and Thornton, J. E. (2012). Identifying and using 'core competencies' to help design and assess undergraduate neuroscience curricula. *J. Undergrad. Neurosci. Educ.* 11:A27.

Kosaraju, S., Gorman, M. A., and Berry, K. (2014). Conceptualizing the NET: the neuroeducation translational (NET) research model-a framework for neuroscience research to special education practice. *J. Interdiscip. Stud.* 2, 38–49.

Koziol, L. F., Budding, D. E., and Hale, J. B. (2013). "Understanding neuropsychopathology in the 21st century: current status, clinical application, and future directions" in Neuropsychological assessment and intervention for youth: an evidence-based approach to emotional and behavioral disorders. eds. L. A. Reddy, A. S. Weissman and J. B. Hale (American Psychological Association), 327–345.

Lincoln, S., and Guba, E. G. (1985). "Establishing trustworthiness" in Naturalistic Inquiry (Thousand Oaks: SAGE), 289–327.

Luzzatto, E., and Rusu, A. S. (2019). Pre-service teachers' self-efficacy and attitudes regarding using motifs from neuroeducation in education and teaching. *Educatia* 21, 41–48. doi: 10.24193/ed21.2019.17.04

Luzzatto, E., and Rusu, A. (2020). Development of a neuroscience motifs-based teacher training program for pre-service teachers in special education in Israel. *Education* 21, 180–191. doi: 10.24193/ed21.2020.19.23

Mariage, T. V., and Garmon, M. A. (2003). A case of educational change: improving student achievement through a school—university partnership. *Remedial Spec. Educ.* 24, 215–234. doi: 10.1177/07419325030240040501

Martín-Lobo, P., Santiago-Ramajo, S., and Vergara-Moragues, E. (2018). Neuropsychological differences among students with learning difficulties, without learning difficulties, and with high capacity. *Mind, Brain, and Education*, 12, 140–154. doi: 10.1111/mbe.12184

Peregrina Nievas, P., and Gallardo-Montes, C. D. P. (2023). The neuroeducation training of students in the degrees of early childhood and primary education: a content analysis of public universities in Andalusia. *Educ. Sci.* 13:1006. doi: 10.3390/educsci13101006

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

Privitera, A. J. (2021). A scoping review of research on neuroscience training for teachers. *Trends Neurosci. Educ.* 24:100157. doi: 10.1016/j.tine.2021.100157

Rhoten, D., Mansilla, V. B., Chun, M., and Klein, J. T. (2006). "Interdisciplinary education at liberal arts institutions" in Teagle Foundation White Paper: 6. Available at: http://info.ncsu.edu/strategic-planning/files/2010/10/2006ssrcwhitepaper.pdf

Rogers, E. M. (2003). Diffusion of innovations. *5th* Edn. New York: The Free Press.

Rooks, D., and Winkler, C. (2012). Learning interdisciplinarity: service learning and the promise of interdisciplinary teaching. *Teach. Sociol.* 40, 2–20. doi: 10.1177/0092055X11418840

Ruhaak, A. E., and Cook, B. G. (2018). The prevalence of educational neuromyths among pre-service special education teachers. *Mind Brain Educ.* 12, 155–161. doi: 10.1111/mbe.12181

Sandholtz, J. H. (2011). Pre-service teachers' conceptions of effective and ineffective teaching practices. *Teacher Educ. Quart.* 38, 27–47.

Sawyer, R. K. (2006). "The new science of learning: the Cambridge handbook of the learning sciences" in ed. R. K. Sawyer (New York: Routledge), 1–18.

Seidman, I. (2006). Interviewing as qualitative research: a guide for researchers in education and the social sciences. New York: Teachers College Press.

Serpati, L., and Loughan, A. R. (2012). Teacher perceptions of neuroeducation: a mixed methods survey of teachers in the United States. *Mind Brain Educ.* 6, 174–176. doi: 10.1111/j.1751-228X.2012.01153.x

Sherry, L. (2000). The Nature and Purpose of Online Discourse: A Brief Synthesis of Current Research as Related to The WEB Project. International Journal of Educational Telecommunications (Charlottesville, VA: Association for the Advancement of Computing in Education (AACE)), 19–51. Available at: https://www.learntechlib.org/primary/p/8018/ (Accessed September 6, 2024).

Shkedi, A. (2011). The meaning behind the words: methodologies of qualitative research: theory and practice. Ramot Press: Tel Aviv University.

Sigman, M., Peña, M., Goldin, A. P., and Ribeiro, S. (2014). Neuroscience and education: prime time to build the bridge. *Nat. Neurosci.* 17, 497–502. doi: 10.1038/nn.3672

Stern, E., Grabner, R. H., and Schumacher, R. (2016). Educational neuroscience: a field between false hopes and realistic expectations. *Z. Psychol.* 224, 237–239. doi: 10.1027/2151-2604/a000258

Tan, Y. S. M., and Amiel, J. J. (2022). Teachers learning to apply neuroscience to classroom instruction: case of professional development in British Columbia. *Prof. Dev. Educ.* 48, 70–87. doi: 10.1080/19415257.2019.1689522

Tan, Y. S. M., Amiel, J. J., and Yaro, K. (2019). Developing theoretical coherence in teaching and learning: case of neuroscience-framed learning study. *Int. J. Lesson Learn. Stud.* 8, 229–243. doi: 10.1108/IJLLS-10-2018-0072

Tashakkori, A., and Teddlie, C. (2003). Handbook on mixed methods in the behavioral and social sciences. California: SAGE.

Tillery, D. A., Varjas, K., Meyers, J., and Collins, A. S. (2010). General education teachers' perceptions of behavior management and intervention strategies. *J. Posit. Behav. Interv.* 12, 86–102. doi: 10.1177/1098300708330879

Tokuhama-Espinosa, T. (2011). Mind, brain, and education science: a comprehensive guide to the new brain-based teaching. *1st* Edn. USA: WW Norton & Company.

Tokuhama-Espinosa, T. (2017). International Delphi panel on mind brain, and education science. Quito, Ecuador: Harvard University Extension School; Latin American Faculty for Social Science.

Tracy, S. J. (2010). Qualitative quality: eight "big-tent" criteria for excellent qualitative research. *Qual. Inq.* 16, 837–851. doi: 10.1177/1077800410383121

van der Linden, W., Bakx, A., Ros, A., Beijaard, D., and van den Bergh, L. (2015). The development of student teachers' research knowledge, beliefs and attitude. *J. Educ. Teach.* 41, 4–18. doi: 10.1080/02607476.2014.992631

Walker, Z., Chan, A. S. H., Poon, K., and Hale, J. B. (2017). Brain literacy empowers educators to meet diverse learner needs. (NIE Working Paper Series No. 10). Singapore: National Institute of Education.

Walker, Z., Hale, J. B., Annabel Chen, S. H., and Poon, K. (2019). Brain literacy empowers educators to meet diverse learner needs. *Learn. Res. Pract.* 5, 174–188. doi: 10.1080/23735082.2019.1674910

Warner, S., and Templeton, L. (2010). Embedded librarianship and teacher education: a neuroeducational paradigm using guided inquiry. *Public Serv. Q.* 6, 250–258. doi: 10.1080/15228959.2010.497747

Wu, L., Ye, X., and Looi, C. K. (2015). Teachers' reflection in early stages of diffusion of an innovation. *J. Comput. Educ.* 2, 1–24. doi: 10.1007/s40692-014-0022-x