Education Mind

EDUCATION MIND
2024, VOL 3, NO 3, 452-466
DOI: 10.58583/EM.3.3.12

Research Article

Open Access

Mathematics teachers' opinions after training on educational neuroscience

Zeynep Altuntaş [1], Gökhan Özsoy [2], Süleyman Erkam Sulak [2]

[1] Institute of Social Sciences, Department of Primary Education, Ordu University, Ordu, Turkey; [2] Faculty of Education, Department of Primary Education, Ordu University, Ordu, Turkey

ARTICLE HISTORY

Received: 10.08.2024
Accepted: 19.11.2024

KEYWORDS

Mathematics teachers
Neuroscience
Educational neuroscience
Teacher training
Teacher opinion

CORRESPONDENCE

Zeynep Altuntaş,
zeynepaltuntas55@outlook.com

ABSTRACT

Educational neuroscience is a multidisciplinary field established to provide assistance to students by bringing together neuroscience, cognitive psychology and pedagogy. With the development of this field, it is likely that different approaches such as the creation of student-centered education models that appeal to different intelligence types will be applied in education. Educational neuroscience aims to understand the practices and methods in education by examining brain activity, learning processes and mental functions, and thus to create a more supportive learning environment in school environments. One way to adapt the findings obtained from neuroscience studies to education is to first inform the teacher about the basic information of the educational neuroscience approach. In this direction, the aim of the research conducted is to examine the views of mathematics teachers after the training application on educational neuroscience. In this study, a case study, which is one of the qualitative research methods, was preferred. The data of the study were obtained from mathematics teachers working in different schools, determined through easily accessible case sampling, which is one of the purposeful sampling methods. The teachers participating in the research consist of 10 people, 2 of whom have a master's degree, 1 of whom is doing a master's degree, and 7 of whom have a bachelor's degree. The findings reveal that teachers have a positive perception of the connection between neuroscience and education. In addition, the teachers particularly emphasized that educators, neuroscientists and other relevant experts should work together for the development and applicability of educational neuroscience. Teachers commented on the application of neuroscience data to educational practice in terms of mathematics lessons, such as making mathematical knowledge permanent and determining which students should use mathematical teaching materials more. It is recommended that teachers and researchers work collaboratively to advance the developing field of educational neuroscience.

Introduction

In recent years, rapid technological developments have led to changes in many areas and have also revealed the necessity of multidisciplinary studies. Educational neuroscience (neuroscience), which is still developing, is one of these fields of study. Neuroscience is a science that examines the anatomy of the brain and nervous system, investigates its structure and functioning, and concludes with different brain imaging techniques. In the field of neuroscience, imaging methods such as Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), and Electroencephalography (EEG) are frequently preferred (Koçak, 2020).

The relationship between neuroscience and learning has recently become the focus of researchers. This interest of researchers has led to the concept of educational neuroscience. (Bakır, Zorluoğlu, & Ulusoy, 2023; Keleş & Çepni, 2006). Educational neuroscience is emerging as a new field that brings together biology, cognitive science, developmental science, and education to investigate the brain and genetic basis of learning and teaching (Fisher, Goswami, & Geake, 2010). This field investigates how the brain processes information, how learning occurs, and how factors such as attention, emotion, and motivation affect learning. The field of educational neuroscience is also a basic science that examines how education changes the brain and what the mechanisms are that lead to behavioral change (or lack thereof) through education (Thomas, Ansari, & Knowland, 2019). Researchers in the field are trying to fill the gap between the scientific findings they obtain from their studies and educational practices. In the first chapter of the book Educational Neuroscience, "Why is neuroscience relevant to education?" The question was discussed and they reached the following conclusion: Neuroscience is related to education because educational neuroscience is a field that can transfer the findings obtained from neuroscience studies that support learning to classroom applications to develop and improve educational outcomes (Thomas & Ansari, 2020). Neuroscience studies show that each individual's brain structure and functioning are different (Knowland & Thomas, 2014). This means that there are variables in factors such as learning styles, memory capacity, and attention span. Understanding these differences between individuals is of great importance in making education personalized and adapting teaching methods (Dubinsky, 2010).

The development of the human brain is a very interesting subject. The fact that learning processes are related to the developmental stages and level of the brain has made the subject even more interesting in terms of education. When evaluated in this context, it is thought that the findings obtained from brain research will provide different and new approaches in education when used for education (Dündar et al., 2014; Howard-Jones, 2011). Neuroscience and education research is of particular interest to educators. Byrnes and Fox (1998) base this situation on the fact that learning is related to the brain. Although the role the brain plays in the learning process dates back to very old times, its importance has increased recently. The reason for this situation can be shown as the developments in brain imaging technologies, which provide more detailed examination opportunities for learning and behavior (Çoban Kapuoğlu, 2023; Koyuncu, 2017).

Educational neuroscience requires sustained collaboration between researchers and teachers to better conduct research on teaching and learning and to provide quality education. One of the most important factors in the development of this field is the establishment of Research Schools that bring researchers together with practitioners to shape research questions and methods (Coch et al., 2009; Hinton & Fischer, 2008). Several model Research Schools currently exist in the United States, Europe, and Israel.

The years 1999-2000 are defined as the "Decade of the Brain" by the United States. The United States has designated the years 2000-2010 as the "Decade of Thought" (Rose & Abi-Rached

2014). Thereupon, studies on the structure and functioning of the brain have gained momentum and serious resources have begun to be allocated in this context (Geake, 2004). The constantly increasing progress of studies on the brain has also created changes in the field of education, enabling the development of many new findings and numerous theories regarding the brain and learning (Ferrari & McBride, 2011). Kurt Fischer and his colleagues at Harvard developed a new field of study called "Mind, Brain, and Education" in 1997. This field of study began to provide a flow of information by acting with a multidisciplinary approach and created a bridge in the integration of data obtained from neuroscience into education (De Smedt, Ansari, & Grabner, 2011). With the developments in the field of "Mind, Brain and Education", significant progress has been made in education and has paved the way for studies to be conducted on the transfer of data obtained from neuroscience to education. The field of "Mind, Brain and Education" that was created has later been the subject of research by different researchers as "Educational Neuroscience", "Educational Neuroscience", "Educational Neuroscience", "Educational Neuroscience" and "Neuroeducation" (De Smedt, Ansari, & Grabner, 2011; Kara, 2021; Özer, 2023; Sousa, 2011; Watagodakumbura, 2017). Although educational neuroscience studies in the world started between 2000-2005 on average, it was seen that these studies in Turkey started after 2013. In this context, it has been seen that the field of educational neuroscience is still developing in our country and the number of studies related to the field is quite limited.

Campbell (2011) believes that educators analyzing neuroscience data pedagogically and transferring it to the educational environment will be an important step in the permanence of learning. The most important reasons for the necessity of transferring educational neuroscience data to educational environments are to better understand the learner and to support the permanence of learning with scientific evidence (Brockington et al., 2018; Carew & Magsamen, 2010; Clark, Hudnall, & Perez-Gonzalez, 2020; Howard-Jones, 2011). Another reason can be said to facilitate educators' selection of appropriate education-teaching methods for students by ensuring that the data obtained from neuroscience is used in classroom environments (Watagodakumbura, 2017). Sousa (2011) argues that transferring neuroscience data to educational environments will enable teachers to work smarter, not harder. All these reasons, and the presentation of data indicating that learning can be learned at any age by undergoing structural or physiological changes in the brain by explaining learning with neuroplasticity, also known as brain plasticity or neural plasticity (McGann, 2015), and the explanation of the functioning of the brain in language learning and mathematics achievement based on scientific findings (Ferrari, 2011), provide important findings to teachers about why we should use educational neuroscience in learning environments. Zambo (2013) expressed the value of neuroscience in education as follows:

"My teacher was Dr. Jill Stamm, and in her class, I learned about brain structure and function. This helped me understand how different and unique my young students' brains are and how this difference translates to their brains. In Dr. Stamm's class, I learned about the amygdala and how it works with other structures to activate the fight-or-flight response. When I learned this, I understood why David, a young boy in my class who was neglected and abused as a baby, would hide under his desk whenever he heard a loud noise. When Dr. Stamm showed our class pictures of brains with and without fetal alcohol syndrome, I could see the differences in size and structure in these brains. Seeing these images helped me understand why Matthew, a child in my class with fetal alcohol syndrome, struggled to learn. Neuroscience helped me understand the biology of my students' learning and behavior, and I'm sure it has done the same for countless teachers, parents, and caregivers like you."

Sylwester (1995) emphasized the importance of the concept of educational neuroscience in terms of learning by saying, "Can teachers whose profession is to develop the human brain and who are paid for this continue to remain ignorant about the brain?" In order to meet the needs of learners, teachers need to have basic knowledge about the human brain and its functioning (Koyuncu, 2017). This study aims to examine the views of mathematics teachers after the implementation of educational neuroscience training. De Smedt and Grabner (2016) state that understanding the findings of neuroscience will also facilitate the understanding of the biological processes that play a role in learning mathematical skills. For this reason, it was deemed appropriate to conduct the study with mathematics teachers. Koyuncu (2017) stated that as a way to adapt the findings obtained from neuroscience to education, teachers should be informed about the basic information of the educational neuroscience approach. It has been clearly stated in studies that teachers need to have sufficient knowledge about the characteristics and functioning of educational neuroscience in order to understand and apply learning and teaching, and to make sense of how the brain acquires new information (Schrag, 2013; Sigman et al., 2014). Wilcox et al., (2021) similarly stated in their studies that teacher support is required for educational neuroscience to be effectively implemented in schools and that teacher participation in the conduct and evaluation stage of the research will increase the quality of the research. In this respect, teachers need to have sufficient knowledge about the concept of neuroscience.

In the literature, studies on teachers' knowledge levels and perceptions on educational neuroscience in Turkey are quite limited (Gülsün & Köseoğlu, 2020; Koyuncu, 2017; Özer, 2023; Özkara, 2020; Palavan & Demir, 2017). It is thought that studies in this field will provide an understanding of the current situation and the shaping of educational policies. This research on educational neuroscience conducted with teachers may pave the way for the adoption of science-based methods instead of traditional approaches in education. It can also provide guidance on the integration of neuroscience-based strategies into classroom practices. There is not yet sufficient evidence on the extent to which neuroscientific knowledge changes or affects teaching practices. This gap can be filled by studies conducted with teachers. In this context, it is thought that the study conducted will contribute to the literature and raise awareness among educators. It is also expected that this study will contribute to offering innovative approaches in terms of teacher education, pedagogical methods and educational policies.

Research problem

The problem and sub-problems are stated below in line with the main purpose of the research.

The problem statement of the research is: “What is the effect of educational neuroscience-related training practice on the views of mathematics teachers?”

Sub-problems:

1. How did Educational Neuroscience make a difference in teachers’ perspectives on learning?
2. What do teachers think about the application of neuroscience data to educational practice in terms of mathematics lessons?
3. How can teachers contribute to the development of educational neuroscience, which is a young research field?
4. What are the general views of teachers on educational neuroscience and their suggestions, if any?

Method

Research model

In this study, a case study, which is one of the qualitative research methods, was preferred. A case study is a method in which an in-depth examination of any situation or event is made and data is collected systematically (Subaşı & Okumuş, 2017). In this study, a case study was preferred in order to conduct a detailed examination of the subject of educational neuroscience.

Participants

The data in the study were obtained from mathematics teachers working in different schools, who were determined through easily accessible case sampling, which is one of the purposeful sampling methods. Easily accessible case sampling is a type of sampling based on volunteering and used when the researcher does not have the opportunity to reach the entire universe (Baltacı, 2018). The reason for choosing this method in the study was that the researcher could easily reach the schools. The teachers who participated in the study consisted of 10 people, 2 of whom had a master's degree, 1 of whom was doing a master's degree, and 7 of whom had an undergraduate degree. Four of this group of 10 teachers were male and six were female. Three of the teachers had 0-5 years of experience, while the remaining seven teachers had 10-15 years of experience in their profession. The participant teachers were contacted face to face and informed about the purpose of the study and the teachers were invited to the teacher training application related to educational neuroscience. Since the participants' availability and willingness to participate in the study can provide useful information to answer the questions and hypotheses (Creswell, 2017), a study group was formed with teachers who volunteered to participate in the study.

Data collection tool

A semi-structured interview form was used in the interviews conducted with the participant group of the study. The semi-structured interview technique is a flexible structure technique that allows the researcher to elaborate on the questions planned in advance and the flow of the interview with sub-questions (Altunay et al., 2014). This situation constituted the reason for preferring the semi-structured interview technique in the study. While creating the questions of the interview form, the relevant literature was scanned in depth and a question pool was created. The questions were shown to the field expert and their opinions were obtained on which ones would be suitable for the research. Semi-structured interview questions were created with the support of the field expert. The interview questions were sent to 2 experts from the field of education programs and teaching and 1 expert from the field of measurement and evaluation. In line with the feedback from the experts, the form was reviewed and evaluated again and took its final form.

The interview form of this study included easily understandable questions related to the research problem and each question also constituted the sub-problems of the study. This technique was preferred in the study to obtain comprehensive information from mathematics teachers and to ensure that teachers could express the information easily. Four open-ended questions were determined to be asked to teachers in the semi-structured interview form and the following order was made.

1. How has educational neuroscience changed your perspective on learning?
2. What do you think about the application of neuroscience data to educational practice in terms of mathematics?

3. What kind of contributions can you make to the development of Educational Neuroscience, a young field of research?
4. What are your general views on educational neuroscience and, if any, your suggestions?

In this context, firstly, a presentation was made to the teachers about the developing field of educational neuroscience and the international studies that were done on this subject were mentioned. After the teachers were sufficiently informed about this subject, the opinions of the teachers were obtained by asking the questions in the semi-structured interview form.

The interviews with the participant group were completed in a total of 5 days. The data collection period lasted between 30-40 minutes for each teacher. The notes taken during the interviews with the participants were transcribed word by word. In order to verify the accuracy of the process, each participant read and approved their own text. The analysis process was started after all the data were collected.

Analysis of data

The data of the study was analyzed using the content analysis method. The data obtained in the content analysis is subjected to a detailed process and organized in a certain framework that the readers can understand and is interpreted objectively (Koçak & Arun, 2006; Selçuk et al., 2014). In the analysis of the study, themes and sub-themes were determined and categories were created accordingly. In the content analysis, the opinions of the teachers were quoted directly and codes such as T1, T2, T3 were determined to represent each teacher according to the number of teachers and the names of the teachers were kept confidential.

In order to increase the quality of the data in the research, the principles of validity and reliability were taken into account. In qualitative research, the concept of validity refers to the fact that the researcher observes the phenomenon he/she is researching as it is and as impartially as possible (Yıldırım & Şimşek, 2021). In this research, in order to ensure the validity of the qualitative data, interviews were conducted in an environment where teachers could feel safe and comfortable while collecting data. In addition to observing the teachers' gestures and facial expressions while recording the data, each word was recorded word by word and the semantic accuracy of the notes taken and what they meant were confirmed by the participants. In order to minimize bias while interpreting the data, the opinions of a field expert other than the researcher were used. In order to ensure the internal validity of the research, it was taken into account that the concepts that emerged formed a meaningful whole and that the findings were compatible with the conceptual framework, thus contributing to internal validity. External validity is related to the generalizability of the research results (Büyüköztürk et al., 2020). In this study, in order to ensure external validity, the teachers' statements were directly included, and the data was transferred as is. Reliability generally refers to the stability of the data sets in the answers of more than one coder (Creswell, 2020). The data of this study were analyzed by obtaining the opinions of a measurement and evaluation expert other than the researcher.

Results

In this section of the research, the findings related to the question “What is the effect of educational neuroscience training on the views of mathematics teachers?” are included. The answers given by mathematics teachers in the light of the questions in the semi-structured interview form are presented under 4 headings. These are; general overview of educational neuroscience, educational neuroscience and mathematics, educators' contribution to the field and suggestions regarding educational neuroscience application. While examining the findings obtained from the research, direct quotes regarding the participants' views were included. In this process, the real names of the participants were kept confidential by using the codes determined for each participant and the teachers' views were included accordingly.

Table 1 Themes, subthemes and categories created based on the views of mathematics teachers on educational neuroscience training application

Theme	Sub Theme	Category
Teacher Comments	Educational neuroscience overview	Individual differences in learning and understanding - getting to know the learner better
		Efficient use of mental capacities
		The relevance of learning to different areas outside education
		Depth of learning
	Educational neuroscience and mathematics	Making mathematical knowledge permanent
		Understanding fully why students have difficulty in mathematics
		Being able to make sense of the activity of the mathematical area of the brain through brain imaging
		For which students should mathematical teaching materials be used (teaching by concretization)
	Educators' contribution to the field	Use of different perspectives
		Examining the effect of neuroscience on education with coding and software
		Following current research and developing different learning strategies accordingly
		Applying data correctly in the classroom environment by communicating with neuroscientists
	Recommendations for educational neuroscience applications	Working in collaboration with stakeholders
		Conducting more academic studies and informing teachers of the results
		Providing regular training to teachers on this subject
		Informing teachers about current information on neuroscience and education follow up on research
		Opening centers that conduct educational and neuroscience research and accepting visitors to these centers
		Supported by more practical methods

As seen in Table 1, when the educational neuroscience training application is examined in terms of the views of mathematics teachers, it is seen that they are grouped under 4 sub-themes as "general overview of educational neuroscience, educational neuroscience and mathematics, educators' contribution to the field and suggestions regarding educational neuroscience application". The sub-themes created were obtained after the similar views obtained as a result of the teacher responses were collected in the same category. The responses given by mathematics teachers in the light of the questions in the semi-structured interview form are presented below under 4 headings.

Table 2 General view of educational neuroscience

Teacher Opinions	Individual differences in learning and understanding - getting to know the learner better
	Efficient use of mental capacities
	The relevance of learning to different areas outside of education
	Depth of learning

In Table 2, the factors related to the topics "How did your perspective on educational neuroscience and diversity change?" are seen to focus on individual differences in learning and understanding (T5, T6, T8, T9), getting to know the learner better (T1, T5, T7), efficient use of mental capacity (T2, T10), the relationships between learning and other fields (T3) and understanding the depths of learning (T4, T7). In this context, some of the answers are as follows:

"I understood better that each student has different thoughts and understanding systems, and when I looked at it from this perspective, my approach changed." (T6)

"Thanks to this area, students can use their mental capacities in the most efficient way. We see that most students perform below their capacity due to reasons such as not yet understanding their learning style, etc. I think that thanks to this area, students can discover themselves and thus use their capacity to the highest level." (T2)

"I think that more importance should be given to individual differences among students, and that it will also make it easier to realize that everyone's learning styles and behaviors are different." (T8)

Table 3 Educational neuroscience and mathematics

Teacher Opinions	Making mathematical knowledge permanent
	Completely understanding why students have difficulty in mathematics
	Being able to understand the activity of the mathematical area of the brain through brain imaging
	For which students mathematical teaching materials should be used (teaching by concretization)

As seen in Table 3, in response to the question "What do you think about the application of neuroscience data to educational practice in terms of mathematics lessons?", teachers focused on making mathematical knowledge permanent (T1, T5, T6), fully understanding why students have difficulty in mathematics (T2), efficient use of mental capacities (T7), being able to understand the activity of the mathematical area of the brain through brain imaging (T8, T10) and which students should use mathematical teaching materials (T3, T4). In this context, the answers given by some teachers are as follows:

"I think that this will result in more permanent learning. Because when we design course content according to students' understanding styles, a more efficient learning environment will be created." (T5)

"When educators understand individual differences through brain imaging techniques, they can design materials and activities that appeal to students' different learning styles and improve learning outcomes." (T4)

"Thanks to educational neuroscience, we can understand why students have such difficulty in mathematics, and this can allow us to follow a different path than usual. It helped me understand better that each student has different levels of learning styles." (T2)

"I think that thanks to brain imaging, we can see the areas of interest and intelligence and provide guidance in that direction. In this way, it may be possible to maximize students' cognitive capacities." (T7)

Table 4 Contribution of educators to the field

Teacher Opinions	Use of different perspectives
	Examining the effect of neuroscience on education with coding and software
	Following up-to-date research and developing different learning strategies in this direction
	Applying data correctly in the classroom environment by communicating with neuroscientists

As seen in Table 4, in response to the question "What kind of contributions can you make to the development of Educational Neuroscience, which is a young field of research?", teachers focused on using different perspectives (T4, T7, T8, T10), examining the effects of neuroscience on education through coding and software (T2), following current research and developing different learning strategies accordingly (T3, T6), and communicating with neuroscientists and applying data correctly in the classroom (T1, T9). In this regard, some teachers' answers are as follows:

"We can guide the methods applied with the studies conducted. It is also a very different field of study for us. A roadmap can be created by benefiting from experiences. Method changes can be applied without forgetting that every child is special, has his/her own life and differences within the scope of neuroscience and needs to be developed accordingly." (T6)

"We can contribute to the field by being involved in neuroscience research and sharing our experiences after the applications. I think that sharing our views and suggestions with other educators and neuroscientists after the programs we will organize in the light of educational neuroscience will gradually fill the gap in the new field." (T9)

"Educational neuroscience allows us to learn about the cognitive differences of learners and how they learn best. We can help improve learning by following current research and organizing teaching plans accordingly." (T3)

Table 5 Opinions and suggestions regarding educational neuroscience application

Teacher Opinions	Working in collaboration with stakeholders
	Conducting more academic studies and informing teachers about the results
	Providing regular training to teachers on this subject
	Informing teachers about current information on neuroscience and education follow research
	Opening centers that conduct educational and neuroscience research and accepting visitors to these centers
	Supported by more practical methods

As seen in Table 5, in response to the question "What are your general views and suggestions, if any, regarding educational neuroscience?", teachers made the following suggestions: working in collaboration with stakeholders (T6, T8), conducting more academic studies on this subject and informing teachers about the results (T3, T4), raising awareness by providing regular training to teachers on the subject (T5, T9), teachers following current research on neuroscience and education (T1, T10), opening centers conducting education and neuroscience research and accepting visitors to these centers (T2), and support with more practical methods (T7). In this regard, the answers given by some teachers are as follows:

"Since it is a new field of science, more research should be done on this subject, and thesis or article results should be shared with teachers by scientists. In this way, teachers can have at least a general view on this subject." (T4)

"I would be glad if the studies progress further, so that lessons can be taught in the classroom with a different educational approach. However, examining the brain structure of each student can be difficult, laborious and time-consuming. I think it should be supported with more practical and different methods. However, I think that educational neuroscience will be quite useful in the areas where we have difficulties in education or have difficulty finding solutions." (T7)

"As teachers, following current research on neuroscience and education, putting what we have learned into practice and sharing our experiences with each other as a result of the practices can play an important role in advancing educational neuroscience." (T10)

Discussion and conclusion

The results of this study, which examined the views of mathematics teachers after the training application of educational neuroscience, were discussed in accordance with the order of the sub-problems.

When the results of the first sub-problem of the study are examined, the differences created by educational neuroscience in teachers' perspectives on learning under the general view of educational neuroscience sub-theme are categorized as; individual differences in learning and understanding and better recognition of the learner, efficient use of mental capacities, awareness of the relevance of learning to different areas outside of education and the depth of learning. Özer (2023) states that neuroscience studies, which support these results, will help to better understand individual differences and abilities. The depth of the learning process is generally related to how information is processed and stored. Educational neuroscience can also investigate the neurological basis of deep learning by examining the processes of long-term memory formation (Varma & Schwartz, 2008). In terms of mental capacity, studies argue that in order to develop a program that will help increase children's mental capacity, their cognitive capacity must first be understood in detail (De Jong et al., 2009; Smedt & Verschaffel, 2010).

When the results of the second sub-problem of the study are examined, under the sub-theme of educational neuroscience and mathematics, teachers' questions about the application of neuroscience data to educational practice in terms of mathematics lessons are categorized as; making mathematical knowledge permanent, fully understanding why students have difficulty in mathematics, being able to make sense of the activity of the mathematical area of the brain through brain imaging, determining which students should use mathematical teaching materials more, that is, teaching by concretization. Educational neuroscience studies have shown how different brain regions interact in how students process and understand mathematical concepts. Educational neuroscience provides valuable insights into the cognitive and neural mechanisms underlying mathematical abilities (Yu, 2023). While some students understand certain mathematical concepts better visually, others learn better through concrete experiences. By understanding such differing cognitive processes, educators can provide more effective mathematics teaching by taking individual differences into account (Mutlu & Akgün, 2016). Based on this research and other supported research findings, by examining the cognitive processes in the brain through educational neuroscience, it is possible to better understand why students have difficulty in mathematics and to develop more effective educational strategies in this direction. Studies have shown that activities in different parts of the brain may differ when performing numerical operations or solving problems. Based on this information, educators can design course content and assignments in accordance with different brain activations (Grabner et al., 2017; Nes, 2011; Sušac & Braeutigam, 2014). Learning is the changes that occur in the brain. Campbell (2011) states that understanding and explaining these changes and the processes that occur in the brain together with their causes will create new ways for learning to become more permanent.

When the results of the third sub-problem of the research are examined, under the sub-theme of educators' contribution to the field, teachers stated that they could contribute to the development of educational neuroscience by using different perspectives, examining the effect of neuroscience on education with coding and software, following current research and developing different learning strategies accordingly, and communicating with neuroscientists to apply the data correctly in the classroom environment. Özer (2023) stated that after the interviews he conducted with teachers in his study, teachers made a positive contribution to their pedagogical knowledge and skills in the transfer of neuroscience data to the field of education. They also stated that this situation was reflected in the lesson plans they made after the training. Teachers stated that the data obtained from neuroscience should not be considered alone when transferring it to educational practices, and that additional information should be obtained from other disciplines instead of transferring the raw data obtained from this field to teaching. In order to respond to the needs of learners, educators need to have at least basic knowledge about the brain and its functioning. Only in this direction can they contribute to the field (Chang et al., 2021).

When the results of the fourth sub-problem of the study are examined, under the sub-theme of suggestions regarding educational neuroscience application, the opinions and suggestions of teachers regarding educational neuroscience are as follows; working in collaboration with stakeholders, conducting more academic studies and informing teachers about the results, raising awareness by providing regular training to teachers on this subject, teachers following current research on neuroscience and education, opening centers conducting education and neuroscience research and accepting visitors to these centers, and supporting them with more practical methods in terms of applicability. Similarly, Ansari and Coch (2006), Hook and Farah (2013) and Özer (2023) emphasized in their studies that the participation of teachers stated that the collaboration of educators, researchers and scientists could be beneficial for the development and applicability of the field. Brick et al. (2021) stated that after their educational neuroscience-based study, it was difficult for teachers to apply some of the data coming from neuroscience, especially in crowded classroom environments and the physical conditions of schools. While Sayan (2020) emphasizes that collaboration with other disciplines is necessary for educational neuroscience to develop; Dreyer (2023) states that in order for educational neuroscience to be implemented more effectively, it would be beneficial for participants, especially in conferences on learning and the brain, to collaborate with practitioners, especially instructional leaders, to help them understand how to better implement educational neuroscience in the classroom. Pincham et al. (2014) offer a four-step practical approach regarding the concrete applicability of data obtained from neuroscience in classrooms: determining the need for education, developing a research proposal, testing in the classroom, communicating, and evaluating. In this practical approach, the need for communication and collaboration between teachers and field researchers is also one of the similar results.

Recommendations

Based on the results obtained in this section of the research, the following suggestions are presented to those who want to study and practice in the field of educational neuroscience.

- This research was conducted with the participation of mathematics teachers. Research can be conducted with teachers from different branches.
- Only teachers were trained in the research and their opinions were obtained. Students can also participate in other studies.
- Teachers and researchers can work together to advance the developing field of educational neuroscience.
- Research centers based on interdisciplinary collaboration can be established in the field.
- Teachers can be given regular training on Neuroscience and Education. Information can be provided on current research on this subject and the results of this research.

Acknowledgements

Extended summary of this article was presented as an oral presentation at the International Congress of Integrated Social Research and Interdisciplinary Studies (ISRIS), held from May 30 to June 1, 2024, in Batumi, Georgia.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Altunay, E., Oral, G., & Yalçınkaya, M. (2014). A qualitative research on mobbing practices in educational institutions. *Sakarya University Journal of Education, 4*(1), 62-80.

Ansari, D., & Coch, D. (2006). Bridges over troubled waters: Education and cognitive neuroscience. *Trends in Cognitive Sciences, 10*(4), 146-151. https://doi.org/10.1016/j.tics.2006.02.007

Bakır, S., Zorluoglu, S. L., & Ulusoy, T. (2023). Bibliometric analysis of studies in science education and neuroscience. *Mehmet Akif Ersoy University Journal of Education Faculty*, (67), 52-70. https://doi.org/10.21764/maeuefd.1263640

Baltacı, A. (2018). A conceptual review on the sampling methods and sample size problem in qualitative research. *Bitlis Eren University Journal of Social Sciences Institute, 7*(1), 231-274.

Brick, K., Cooper, J. L., Mason, L., Faeflen, S., Monmia, J., & Dubinsky, J. M. (2021). Tiered neuroscience and mental health professional development in liberia improves teacher self-efficacy, self-responsibility, and motivation. *Frontiers in Human Neuroscience*, 207. https://doi.org/10.3389/fnhum.2021.664730

Brockington, G., Balardin, J. B., Ziemo Morais, G. A., Malheiros, A., Lent, R., Moura, L. M., & Sato, J. R. (2018). From the laboratory to the classroom: The potential of functional near-ınfrared spectroscopy in educational neuroscience. *Frontiers in Psychology, 9*(1840), 1-7. https://doi.org/10.3389/fpsyg.2018.01840

Büyüköztürk, Ş., Çakmak, E. K., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2020). *Eğitimde Bilimsel Araştırma Yöntemleri* [Scientific Research Methods in Education], (29 b.). Ankara: Pegem.

Byrnes, J. P., & Fox, N. A. (1998). The educational relevance of research in cognitive neuroscience. *Educational Psychology Review*, *10*, 297-342. https://doi.org/10.1023/A:1022145812276

Campbell, S. R. (2011). Educational Neuroscience: Motivations, methodology, and implications. *Educational Philosophy and Theory, 43*(1), 7-16. https://doi.org/10.1111/j.1469-5812.2010.00701.x

Carew, T. J., & Magsamen, S. H. (2010). Neuroscience and education: An ideal partnership for producing evidence-based solutions to guide 21st century learning. *Neuron, 67*(5), 685-688. https://doi.org/10.1016/j.neuron.2010.08.028

Clark, C. A., Hudnall, R. H., & Pérez-González, S. (2020). Children's neural responses to a novel mathematics concept. *Trends in Neuroscience and Education,* 20, 100128. https://doi.org/10.1016/j.tine.2020.100128

Coch, D., Michlovitz, S. A., Ansari, D., & Baird, A. (2009). Building mind, brain, and education connections: The view from the upper valley. *Mind, Brain, and Education, 3*(1), 27-33. https://doi.org/10.1111/j.1751-228X.2008.01050.x

Creswell, J.W., (2017). Educational Research: Planning, *Conducting and Evaluating Quantitative and Qualitative Research* (1.b.). (H. Ekşi, Trans.) Istanbul: Educational Consultancy and Research Center.

De Jong, T., Van Gog, T., Jenks, K., Manlove, S., Van Hell, J., Jolles, J., & Boschloo, A. (2009). *Explorations in learning and the brain: On the potential of cognitive neuroscience for educational science*. Springer Science & Business Media. https://doi.org/10.1007/978-0-387-89512-3

De Smedt, B., Ansari, D., Grabner, R. H., Hannula-Sormunen, M., Schneider, M., & Verschaffel, L. (2011). Cognitive neuroscience meets mathematics education: It takes two to tango. *Educational research review, 6*(3), 232-237. https://doi.org/10.1016/j.edurev.2011.10.003

De Smedt, B., & Grabner, R. H. (2016). Potential applications of cognitive neuroscience to mathematics education. *ZDM, 48*, 249-253.https://doi.org/10.1007/s11858-016-0784-x

Dreyer, T. M. (2023). *Educational leaders' experiences with and perceptions of educational neuroscience* (Order No. 30567308). Available from ProQuest Dissertations & Theses Global. (2844595121). Retrieved from https://www.proquest.com/dissertations-theses/educational-leaders-experiences-with-perceptions/docview/2844595121/se-2

Dubinsky, J. M. (2010). Neuroscience education for prekindergarten–12 teachers. *Journal of Neuroscience*, *30*(24), 8057-8060. https://doi.org/10.1523/JNEUROSCI.2322-10.2010

Dündar, S., Canan, S., Bulut, M., Özlü, Ö., & Kaçar, S. (2014). The investigation of brain waves in problem solving process. *Journal of Education Faculty, 16*(2), 1- 23. doi: https://dx.doi.org/10.17556/jef.72111.

Ferrari, M. (2011). What can neuroscience bring to education? *Educational Philosophy and theory, 43*(1), 31-36. https://doi.org/10.1111/j.1469-5812.2010.00704.x

Ferrari, M., & McBride, H. (2011). Mind, brain and education: The emergence of a new science. *Learning landscapes, 5*(1), 85-100.

Fisher, K.W., Goswami, U., & Geake, J. (2010). The future of educational neuroscience. *Mind, Brain and Education, 4*, 68-80. https://doi.org/10.1111/j.1751-228X.2010.01086.x

Geake, J. (2004). How children's brains think: Not left or right but both together. *Education 3-13, 32*(3), 65-72. https://doi.org/10.1080/03004270485200351

Goswami, U. (2006). Neuroscience and education: from research to practice?. *Nature reviews neuroscience, 7*(5), 406-413. https://doi.org/10.1038/nrn1907

Grabner, R. H., Obersteiner, A., De Smedt, B., Vogel, S., von Aster, M., Leikin, R., & Nuerk, H. C. (2017). Mathematics Education and Neuroscience. *In Proceedings of the 13th International Congress on Mathematical Education: ICME-13* (pp. 657-658). Springer International Publishing.

Gülsün, Y., & Köseoğlu, P. (2020). Determination of biology teachers' neuromyths and accurate knowledge about brain functions. *Education and Science, 45*(204).

Hinton, C., & Fischer, K. W. (2008). Research schools: Grounding research in educational practice. *Mind, Brain, and Education, 2*(4), 157-160. https://doi.org/10.1111/j.1751-228X.2008.00048.x

Hook, C. J., & Farah, M. J. (2013). Neuroscience for educators: What are they seeking, and what are they finding? *Neuroethics,* 6, 331-341. Access address: https://0310d2472-y-https-link-springercom.msgsu.proxy.deepknowledge.io/article/10.1007/s12152-012-9159-3

Howard-Jones, P. A. (2011). A multiperspective approach to neuroeducational research. *Educational Philosophy and Theory, 43*(1), 24-30. https://doi.org/10.1111/j.1469-5812.2010.00703.x

Kapuoglu, E. Ç. (2023). Physiological basis of education and learning: Neuroplasticity. *Journal of Philosophy and Social Sciences,* (36), 447-464. https://doi.org/10.53844/flsf.1359914

Kara, H., (2021). *Educational Neuroscience and Its Reflection in Education*. (pp.3-32), Ankara: İksad Publishing House.

Keleş, E., & Kol, E. (2015). An Overview of the brain imaging techniques from the education perspective. *Elementary Education Online, 14*(1), 349-363.

Knowland, V. C., & Thomas, M. S. (2014). Educating the adult brain: How the neuroscience of learning can inform educational policy. *International Review of Education, 60*, 99-122. https://doi.org/10.1007/s11159-014-9412-6

Kocak, G. (2020). Reflections of brain research on education: Imaging studies related to mathematics. *Yeditepe University Faculty of Education Journal, 9*(11), 1-16.

Kocak, A., & Arun, Ö. (2006). Sampling problem in content analysis studies. *Selçuk University Faculty of Communication Academic Journal, 4*(3), 21-28.

Koyuncu, B. (2017). Educational neuroscience neuroeducation: Why should educators use neuroscience data?. *Turkish Academic Publications Journal, 1*(1), 22-34. https://doi.org/10.29329/tayjournal.2017.482.02

McGann, J.P. (2015). Associative learning and sensory neuroplasticity: How does it happen and what is it good for? *Learning and Memory, 22*(11), 567-76. https://doi.org/10.1101/lm.039636.115

Mutlu, Y., & Akgun, L. (2016). Mathematics learning disability and educational neuroscience. *In Innovations and Qualification Search in Educational Sciences,* 1133-1145. https://doi.org/10.14527/9786053183563b2.068

Nes, F. (2011). Mathematics Education and Neurosciences: Towards interdisciplinary insights into the development of young children's mathematical abilities. *Educational Philosophy and Theory, 43*, 75 - 80. https://doi.org/10.1111/j.1469-5812.2010.00710.x.

Özer, Ö. (2023). *The effect of teacher training on educational neuroscience on self-efficacy and course designs* [Unpublished Master's Thesis]. Mimar Sinan Güzel Sanatlar University.

Özkara, M. N. (2019). *Investigating the change in the cognitive structures of primary school mathematics teacher candidates towards mathematics and mathematics education* [Unpublished Master's Thesis]. Uşak University. Retrieved from *https://platform.almanhal.com/Details/Thesis/2000180331?ID=4-2000180331*.

Palavan, Ö., & Demir, H. (2017). Classroom teachers' views on brain-based learning. *Siirt University Journal of Social Sciences Institute, 5*(8), 99-132.

Pincham, H. L., Matejko, A. A., Obersteiner, A., Killikelly, C., Abrahao, K. P., Benavides-Varela, S., ... & Vuillier, L. (2014). Paving a new path for educational neuroscience: An international young researcher perspective on combining neuroscience and educational applications. *Trends in Neuroscience and Education, 3* (1), 28-31. https://doi.org/10.1016/j.tine.2014.02.002

Rose, N., & Abi-Rached, J. (2014). Governing through the brain: Neuropolitics, neuroscience and subjectivity. *The Cambridge Journal of Anthropology*, *32*(1), 3-23. https://doi.org/10.3167/ca.2014.320102

Schrag, F. (2013). Can this marriage be saved? The future of 'neuro-education'. *Journal of Philosophy of Education, 47*(1), 20-30. https://doi.org/10.1111/1467-9752.12015

Selcuk, Z., Palanci, M., Kandemir, M., & Dundar, H. (2014). Trends in research published in education and science journal: Content analysis. *Education and Science, 39*(173), 430-453. https://doi.org/10.15390/eb.v39i173.3278

Sigman, M., Peña, M., Goldin, A. P., & Ribeiro, S. (2014). Neuroscience and education: prime time to build the bridge. *Nature neuroscience, 17*(4), 497-502. https://doi.org/10.1038/nn.3672

Smedt, B., & Verschaffel, L. (2010). Traveling down the road: from cognitive neuroscience to mathematics education ... and back. *ZDM, 42*, 649-654. https://doi.org/10.1007/S11858-010-0282-5.

Sousa, D. A. (2011). Commentary: Mind, brain, and education: The impact of educational neuroscience on the science of teaching. *Learning landscapes*, *5*(1), 37-43. https://doi.org/10.36510/learnland.v5i1.529

Subası, M., & Okumus, K. (2017). Case study as a research method. *Atatürk University Social Sciences Institute Journal, 21*(2), 419-426.

Sušac, A., & Braeutigam, S. (2014). A case for neuroscience in mathematics education. *Frontiers in Human Neuroscience, 8* (314). https://doi.org/10.3389/fnhum.2014.00314.

Sylwester, R. (1995). *A celebration of neurons: An educator's guide to the human brain*. Association for Supervision and Curriculum Development, 1250 N. Pitt St., Alexandria, VA 22314 (ASCD Stock No. 1-95085).

Thomas, M. S., Ansari, D., & Knowland, V. C. (2019). Annual research review: Educational neuroscience: Progress and prospects. *Journal of Child Psychology and Psychiatry*, *60*(4), 477-492. https://doi.org/10.1111/jcpp.12973

Thomas, M. S., & Ansari, D. (2020). Educational neuroscience: Why is neuroscience relevant to education?. *In Educational Neuroscience* (pp. 3-22). Routledge. https://doi.org/10.4324/9781003016830-2

Varma, S., & Schwartz, D. (2008). How should educational neuroscience conceptualise the relation between cognition and brain function? Mathematical reasoning as a network process. *Educational Research, 50*, 149 - 161. https://doi.org/10.1080/00131880802082633.

Watagodakumbura, C. (2017). Principles of Curriculum Design and Construction Based on the Concepts of Educational Neuroscience. *Journal of Education and Learning*, *6*(3), 54-69. https://doi.org/10.5539/jel.v6n3p54

Wilcox, G., Morett, L. M., Hawes, Z., & Dommett, E. J. (2021). Why educational neuroscience needs educational and school psychology to effectively translate neuroscience to educational practice. *Frontiers in Psychology*, *11*, 618449. https://doi.org/10.3389/fpsyg.2020.618449

Yıldırım, A., & Şimşek, H. (2021). *Qualitative Research Methods in Social Sciences* (12th ed.). Ankara: Seçkin Publishing.

Yu, H. (2023). The neuroscience basis and educational interventions of mathematical cognitive impairment and anxiety: a systematic literature review. *Frontiers in Psychology, 14*. https://doi.org/10.3389/fpsyg.2023.1282957.

Zambo, D. (2013*). The practical and ethical concerns of using neuroscience to teach young children and help them self-regulate*. In L. H. Wassreerman & D. Zambo (Eds). *Early childhood and neuroscience- links to development and learning*. (pp. 7-22). New York: Springer. https://doi.org/10.1007/978-94-007-6671-6_2