A Critical Study on the Researches about the Application of Neurotechnology in Education

Hatef Pourrashidi Alibigloo¹ and Javad Alipoor²

¹Islamic Azad University Tabriz Branch
²University of Tabriz

January 19, 2023

Abstract

The education and pedagogy have been adopted with the growth of technology in order to achieve efficient consequences by the usage of innovational and up-to-date technologies. The new methods in neuroscience and neurotechnology have influenced education and classrooms. A considerable number of researches have been projected in this field that all try to demonstrate the advantages of neurotechnology in education and classrooms. In fact, most researchers have connived its harms and disadvantages on students and learning system and the sphere of the classrooms. This paper tries to survey on the fourteen recent researches in the framework of critical theory to discuss the adverse effects of neurotechnology as well as their neglected aspects in education and the classrooms.

Introduction

In recent years, the appearance of interaction between neuroscience and education has led to the increasing of knowledge about the role of neuroscience and technology in education. Teaching, learning and education can be studied as a new field of natural sciences, ranging from early years up to old age (Bartoszeck & Bartoszeck, 2012: 301). Neuroscience is a relatively new area of biological knowledge joining, amongst others, neurophysiology, neuropharmacology, neurology, psychology, and neuro-imaging. In the last few years, many aspects of physiology, biochemistry, pharmacology and detailed structure and behavior of invertebrate and primate nervous system have been elucidated.

This new terms of research is completely related to the computer and the electrical devices can read the brain reaction in different situation. This method has utilized for lie detection in the criminal investigation. White et al. (2015) clarify that “neurotechnology is broadly defined as a set of devices used to understand neural processes and applications that can potentially facilitate the brain’s ability to repair itself”. It means that this science enable human being to manipulate nervous system. In the recent decades, “an increasingly explicit understanding of basic biological mechanisms of brain-related illnesses has produced applications that allow a direct yet noninvasive method to index and manipulate the functioning of the human nervous system” (White et al., 2015).

Neuroscience was first introduced into education in the USA during the 1990s, the so-called ‘decade of the brain’. Unfortunately, the initial movement caused the launch of many educational programs claiming to be ‘brain based’, but was not actually supported by science. These commercially motivated initiatives were accompanied by the emergence of misconceptions or neuro-myths about the brain and its function, first informed by OECD (Organization for Economic Co-operation and Development) in 2002, and later found to be widespread across every single country that was researched (Ferreira & Rodriguez, 2022: 2).

Today, neurotechnology is the main part of this process that attempts to help educational systems to have a better efficiency in the classrooms. So, experts use a wide array of terms including “neuroscience and

All these concepts illuminate the collaboration of neuroscience and the related technology to the brain activities. In other words, all of them “refer to a common goal of linking the scientific understanding of how the brain functions (including how the brain learns) to an understanding of educational best practices” (Müller, 2011: 2). The technologies used in the neuroscience as well as classrooms seek to understand how the brain works properly and which strategies are better for education.

The new researches focus on the learning improvement by the neurotechnology and try to qualify the education and learning systems. “It is common to encounter the belief that advances in technologies that allow us to measure activity in the brain will lead directly to interventions that improve learning” (Dougherty & Robey, 2018: 401). It means that the researchers try to understand how can qualify the learning and educational system throughout the neurotechnology. Moreover, this technology is utilized for the teaching systems and tries to analyze the teaching systems and suggest the new way to improvement of the teaching models. Surveying on the teachers brain activities and introducing the new methods and tools are the main duty of these researches. Deeper understanding of the mechanisms and limitations of the brain can have a powerful effect on teaching practices. “With enhanced knowledge about how the brain actually processes new information, teachers can reevaluate and adjust their methodologies to reflect how people actually learn, rather than “how people have learned in the past” (Haga, 2017: 51). Teachers are in the business of structuring learning experiences for students, therefore they are curious about the process of learning and how the developing brain grows in its ability to process information, expecting that knowledge of these processes will help them support students in achieving learning goals (Dubinsky et al, 2022: 4).

Moreover, the assumed link between the neuroscience of brain plasticity and education seemed obvious; however, there are a number of problems with the brain-training to-education bridge. First and foremost, the available literature now strongly suggests that brain training does not reliably generalize beyond the trained tasks (Redick et al., 2013); certainly does not carry over to better education outcomes and may actually result in poorer performance on important indicator variables when students are removed from the classroom for the training intervention (e.g., Roberts et al., 2016). Second, even if brain training did generalize, establishing the link between the neuroscience underlying WM (working memory) training and education outcomes requires cognitive theory. Cognitive theory and, in particular, conceptual models of WM provide the landing spot required for establishing the plausibility of using brain training to improve education outcomes (Dougherty & Robey, 2018: 402).

It seems that the consideration of these issues is the significant part of this field in which the relation between education and neuroscience and the role of the new technologies in this relation should be defined that is the main part of the studies on neurotechnology to discover the effects of neurotechnology on education and the classroom.

This paper tries to criticize the approaches to the relation between neurtechnology and education in terms of their holistic view on the education and investigates it in the framework of critical theory. The relationship between these two categories must be differentiated according to the age of learners, the level of education, the sort of educational institutes (primary schools, high schools and universities), the field of education (Social sciences, medical science, engineering).

**Theoretical Framework**

The critical theory was introduced in 1930s in social science to challenge the predominant social theories. Indeed, the inventors analyzed contemporary forms of capitalist stabilization and social control, focusing on new modes of socialization that increased conformity and diminished individual autonomy and democratic participation. The critical theory is often associated with the so-called ‘Frankfurt School’, a term which refers to the ideas of the members of the Institut fur Sozialforschung (Institute for Social Research), where Carl Grunberg, Karl Korsch and Georg Lukacs worked on the critical theories. After Grunberg’s retirement in 1930, Max Horkheimer became the Director of the Institute and gathered talented theorists such as Leo
Lowenthal, Friedrich Pollock, Erich Fromm, Henryk Grossman, and Herbert Marcuse. After them, T. W. Adorno, Otto Kirchheimer and Franz Neumann joined the Institute and supported theorists like Korsch and Walter Benjamin (Kellner, 1991). This institute published different books in the critical studies like Materialism and Dialectics challenging the Western theories, but the institute could not continue its activities in Germany and most of the philosophers and thinkers immigrated to the US in order to promote critical studies used to study the various social problems. Moreover, the critical studies were outspreaded in other fields and turned as a main part of researches in the different sciences and scholarships.

The critical theories have influenced contemporary social theory, philosophy, communications, cultural theory and other disciplines for six decades. The dream of an interdisciplinary social theory continues to animate the sociological imaginations. The Critical theory has always produced its own particular wisdom to articulate and defend its positions in polemics with contemporary theories. During the present moment, the critical theorists have been among the most active critics of postmodern theory and the polemics between critical and postmodern theory have inspired much critical discussions and new syntheses drawing on both traditions (Kellner, 2009).

Accordingly, using this theory provides a solid foundation to question neutral performative intent and to explore the dehumanizing effects of managerial control (Harnecy, 2014). The critical views about the all human activities are the core of this theory. In fact, critical theory opens up “possibilities for analysis of power, discourse, and historical understandings. In so doing, critical theory mandates reflexivity in research, writing and attuning researchers “to the assumptions underlying their own busy empiricism” (Agger, 1991: 111). In the realm of education the critical studies define as a theory emphasizing the development of critical thinking and knowledge and the curriculum elements are designed in such a way within which critical political, cultural, economic and social knowledge have been developed for several decades (Sharifi Darvazeh et al., 2017:175).

In this regard, neurotechnology in the classrooms can be evaluated in the framework of the critical theories due to its relation to the humanity and social science. Neurotechnology facilitates the better understanding of the brain and contributes the treatment of the neurological and psychiatric diseases of the nerves system in order to offer more effective or efficient solutions (Calderon & Barrera, 2015). This paper analyzes the researches in the field of Neurotechnology in the classrooms in the framework of the critical theory. This analysis is not only about the process and the methods of Neurotechnology, but also is about the technologies using in the classrooms.

A Survey on the Researches about Neurotechnology and Education

In the last 5 decades, the various types of technologies have been used in the classrooms and education to achieve the better result in in the process of teaching and learning. Analyzing the learning and teaching methods and studying the appropriate ways of effects on the students and children’s brain are the main part of the researches in this field. In other words, neurotechnology tries to find the good ways in the application of the educational technologies. This is a new approach that is “beginning to be used in the educational field, trying to understand how the brain learns and therefore seeks to make clear how students acquire new knowledge with the help of the Information and Communication Technologies (ICT) (Zambrano et al, 2021, 947). This approach seeks to improve the quality of education and enhance the learning methods. There are some related concepts in neurotechnology that all of them related to the brain, learning, education and their relation. The best definition of the neurotechnology is belongs to the Calderón and Barrera (2015). Based on this definition, neurotechnology accelerates the better understanding of the brain and helps to understand how technology can be used to access the better results in the classrooms and education. According to Mullr and Rotter (2017) “neurotechnology is defined as the assembly of methods and instruments that enable a direct connection of technical components with the nervous system. These technical components are electrodes, computers, or intelligent prostheses”. Therefore, all of the technologies which are related to improvements of the learning and education can count as a neurotechnology tool.

On the other hand, this concept is utilized in other field of studies like medical trophy and clinical studies and
the new perspectives are defined, like Jonna Brenninkmeijer’s paper, ‘Neurotechnologies of the Self: Mind, Brain and Subjectivity’ (2016). This research is “an ethnographic and historical study of contemporary neurotechnologies, replaces visions of a reductive cerebralization with an account of how contemporary technologies that provide ‘direct access’ to the brain expand and complicate, rather than curtail, the possibilities of selfcontrol in the 21st century” (Freeborn, 2019: 146).

For this paper, the authors selected fourteen papers examining the role and application of neuroscience and neorotechnology in different realm of education and the classrooms. Table 1 shows the researches and their subjects and findings.

<table>
<thead>
<tr>
<th>Title of Research</th>
<th>Subject/ Purpose</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>How In-Service Teachers Perceive Neuroscience as Connected to Education: an Exploratory Study</td>
<td>pre-school, primary school, and secondary school teachers' knowledge about brain, mind and their educational implications</td>
<td>It precluded any meaningful analysis of the role of gender in the perception of the relevance of neuroscience to education.</td>
</tr>
<tr>
<td>The Promise of Neurotechnology in Clinical Translational Science</td>
<td>Potential benefits and hurdles, both technical and methodological, of neurotechnology in the context of clinical dysfunction</td>
<td>Neurotechnologies provide a window into brain activity and better understand the neural processes that underlie socioemotional difficulties</td>
</tr>
<tr>
<td>Neuroscience and Education: A Bridge Astray?</td>
<td>Neuroscience findings have failed to generalize to classroom contexts by highlighting the recent popularity and failed results from brain-training research</td>
<td>A need to improve funding for basic and translational research in the areas of cognitive and social psychology to synergize evidence-based interventions in education science. Caveat venditor and pertains to the tendency that scientists sometimes have toward hyperbole when discussing the implications of their results.</td>
</tr>
<tr>
<td>Neuroscience and Special Education</td>
<td>How links are being developed between the rapidly expanding field of neuroscience and the practice of special education</td>
<td>While neuroscience holds much promise for the field of special education, the process of translating brain research into classroom practice must be handled methodically.</td>
</tr>
<tr>
<td>Title of Research</td>
<td>Subject/ Purpose</td>
<td>Findings</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5 Effect of a Science of Learning Course on Beliefs in Neuromyths and Neuroscience Literacy</td>
<td>The effect of a one-year Science of Learning (SOL) course on neuroscience literacy and beliefs in neuromyths in a sample of Chilean pre-service teachers</td>
<td>The SOL course significantly improved overall neuroscience literacy and reduced neuromyth belief among pre-service teachers, but the effect of the intervention was small.</td>
</tr>
<tr>
<td>6 Neuroscience in the Classroom: Understanding How New Information is Processed</td>
<td>Briefly outline the science of how the brain processes new information, and specifically how learning gets transferred into long term memory</td>
<td>The role of the teacher is changed from one who simply introduces new information to one that promotes human learning.</td>
</tr>
<tr>
<td>7 Educational Neurotechnology in Attention to the Specific Needs of Higher Basic General Education Students</td>
<td>Analyzing the contribution of neurotechnology as a contribution to the specific needs of students</td>
<td>Neurotechnology positively affects the improvement of the specific needs of students, since the use of ICT is given the correct neural interpretation and understanding how students learn.</td>
</tr>
<tr>
<td>8 A Place for Neuroscience in Teacher Knowledge and Education</td>
<td>Promoting the idea that neuroscience content appropriate for education should be incorporated into both teacher preparation and professional development but leaves such implementation details for further discussion.</td>
<td>Teachers can utilize neuroscience knowledge to make pedagogical choices. Knowledge of students (KOS) should be positioned as a central focus of teachers’ education, with neuroscience as an integral part of its core.</td>
</tr>
<tr>
<td>Title of Research</td>
<td>Subject/ Purpose</td>
<td>Findings</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Assessment of Mapping the Brain, a Novel Research and Neurotechnology Based</td>
<td>Whether the course improved student research article analysis and neurotechnology</td>
<td>Reveal new insights and pedagogical approaches for engaging students in research and improving their critical analysis of research articles and neurotechnologies. The researchers multifaceted approach increased student confidence and promoted a data focused mentality when tackling research literature. Through the integration of authentic research and a neurotechnology focus, mapping the brain provides a unique model as a modern neuroscience laboratory course.</td>
</tr>
<tr>
<td>Approach for the Modern Neuroscience Classroom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational Neurotechnology: Where Do We Go from Here?</td>
<td>Outlining the potential of educational neurotechnology including what we know, what we do not yet know, and additional considerations for the ethical, successful adoption of these tools in classrooms around the world</td>
<td>Special consideration is given to the training needs of pre- and in-service educators whose support will be essential to the successful adoption of educational neurotechnology.</td>
</tr>
<tr>
<td>The Emerging Role of Educational Neuroscience in Education Reform</td>
<td>Exploring suggestions for the appropriate training of the educational neuroscientist and the emerging ways of the educational neuroscientist can inform professional development of educators</td>
<td>Using the new methods of education by teachers School reform needs to begin of a new vision for working together of scientists, educators, and the hybrid educational neuroscientist</td>
</tr>
<tr>
<td>Future of Smart Classroom in the Era of Wearable Neurotechnology</td>
<td>Requirement and infrastructure of envisioned smart classrooms and personalized education in the future of smart classroom, throughout advances in neuroscience and machine learning</td>
<td>These challenges have to surmount: Decision making in the face of system variability Restructuring the pedagogical materials Internet-of-Things design and robustness to errors</td>
</tr>
<tr>
<td>Title of Research</td>
<td>Subject/ Purpose</td>
<td>Findings</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>13 Neuroscience Research in the Classroom: Portable Brain Technologies in Educational Research</td>
<td>Evaluation of the opportunities and limitations afforded by portable and wearable brain technologies in educational research</td>
<td>Proposed three research areas where portable brain technologies can add value: engagement in group work, cognitive load, and self-regulation</td>
</tr>
<tr>
<td>14 Educational Neuroscience: Neuroethical considerations</td>
<td>Integrating ethical positions to research design and methods in educational neuroscience</td>
<td>Education is a truly transformative process, educational theorists, researchers, and practitioners alike have a leading role to play in the development of a mindful, radically embodied educational neuroethics</td>
</tr>
</tbody>
</table>

Table 1: Researches on neurotechnology in education and the classrooms

Discussion

These articles try to illuminate the connection and relation between neurotechnology and the classroom and to persuade the audiences that the classrooms in particular and education in general depend on neurotechnology. This idea is somewhat true due to the role of brain and its function in education and understanding. But, it is so crucial to know what kind of technologies try to affect human brain. In fact, the technologies which are affecting the brain in a bad and undesirable way have to eliminate from experiments. These researches just report the good sides and advantages, while there are no information about the disadvantages and undesirable effects of neurotechnology.

No one can deny the optimal effects of technology in education, but the harmful effects must not be ignored in the application of any kind of technology. The main point is the ethical problems, which may not to be considered in the studies. There are different reports that show the ethical factors ignored by governments or researchers, especially in the case of disabilities (Hetzel, 2022: 1). Moreover, neurotechnology affects the brain and its functions. There is no difference where this kind of technology is used, but the significant point is about its long term effects. This issue is not supported by researches in spite of using various types of the technologies in human lives in particular education.

The other unconsidered point in these researches is about the satisfaction of the experimental groups and data usage. In this regards, some questions are concentrated including is there any right for using the experimental groups’ data? Are experimental groups satisfied by these experiments? In the last three years, the Covid 19 have forced the authorities to develop the technologies in education and classrooms, but there is less researches and surveys on the bad effects, like satisfaction of the students and teachers, of this kind of education and distance Learning. Neurotechnology is in the same way; the secret and hidden data and information are considerable on the one hand and ethical issues on the other hand. This issue is more important all around the worlds and the governments make strategies in this field. In October 2021, Chile anticipated these problems and tried to find solutions by passing a law protecting citizens' "brain rights", which covers the protection of neurorights, including the rights to personal identity, free will and mental privacy (Hetzel, 2022: 4). In this regards, a study by Dikker et al. (2017) proves that using a portable electroencephalogram (EEG) device for recording brain activity from a class of 12 high school students over a semester during regular activities, analyzing the group-based neural coherence is possible where the brain activity is synchronized across students in both student class engagement and social dynamics. Another
study by Babini et al. (2020) comparatively measured the learning of the students in a virtual reality (VR) environment for using a wearable electroencephalogram (EEG), but the consideration of the students’ rights is not clear in this study. Also, it did not illustrate the harmful effects of these experiments and avoiding the misuse of data.

Furthermore, teachers have exclusive methods for teaching, which derived from their culture, educational system and their morality. This is the main factor in the differences between teachers and their ability for persuading the students. All of these differences and advantages may be lost in the use of neurotechnology. Also, “neurobiological changes occur in the brain and “fixation” of knowledge occurs in the cognitive structure of the individual’s mind, few know how the brain and peripheral nervous system as a whole works as a relevant factor in the educational world” (Bartoszec & Bartoszec, 2012: 302). In fact the teacher’s exclusive methods of teaching and education may influence by the neurotechnology. On the other hand, neurotechnology cannot support all types of the students and cannot develop all of the teaching strategies. Most researches basically concentrate on the advantages of neurotechnology and its power to change teaching strategies has not seen.

The other critical part of neurotechnology’s research in the classroom is about the teachers’ cognitive and knowing system in the classrooms and about the students. The teachers have their own methods for recognizing and reconnaissance the students’ ability and advantages. Using the neurotechnology changes this procedure and the teachers cannot make a difference between the students. The educational system during the Corona pandemic is the explicit example of this problem. Due to this matter, the teachers cannot recognize the students’ talent and their problems in understanding of concepts because of using the technologies during the teaching and education and all of the process seems great in front of the monitors, so today after the pandemic, the schools face with an academic failure.

Last but not least, the non-verbal communication has enormous role in education and the interaction between teachers and students. The teachers use their non-verbal abilities in communication as the supplement to the verbal communication in education. Most of the messages and concepts transfer via the non-verbal communication and the process of communication in education will not be complicated without using of this factor. In this regard, eye contact, mimics and gestures play a significant role in class management as well as powerful communication. Teachers can evaluate the students and classroom’s situation with the aim of these items. According to Zekia (2009) the use of eyes and facial expressions is considered in managing the classrooms as well as show a student who is talking that the teacher is taking notice; to check that everyone is concentrating; to indicate to a student that you want to talk to him or you want him to do something; to encourage contributions when one is trying to elicit ideas; a teacher only knows students have something to say by looking at them; and to hold the attention of students not being addressed and encouraging them to listen to those doing the talking and to maintain attention. The reports show that a teacher who never looks students’ eyes seems to lack confidence and gives the students a sense of insecurity (Zekia, 2009). These researches prove the role of non-verbal communication’s significance in education and the classrooms. However, the appearance of the new technologies changes the situation even in education and the learning systems like neuroscience. Most of the non-verbal factors in communication eliminate through using of neurotechnological tools and the communication between the teachers and the students will be defective. This factor is the other critical neglected part of the researches in this field.

Conclusion

Most of the researchers in the field of the neurotechnology in education and the classrooms try to clarify and describe the positive aspects of utilizing neurotechnology and its positive and efficient effect in education and on students. There is no doubt that using of technology in all fields, especially in neuroscience and exclusively neurotechnology, make the education most attractive and better for the students and the teachers. Despite of these advantages, technology has harmful effects on the students and education which was described in the previous section. The lack of attention to these critical points changes the function of technology. This paper tries to discover and highlight the neglected aspects and harmful or parlous effects of neurotechnologies in education and the classrooms in the framework of the critical theory. The important findings of this article including the ignorance of bad and undesirable effects of neurotechnology on human being in the classrooms;
the inconsideration of ethical issues based on human rights, brain rights, mental privacy, free will and personal identity; the negligence of teachers’ various teaching and accessing methods and their different abilities; and the reduction of non-verbal communications in the interactions between the students and the teachers. In terms of ethical perspectives, just the two articles to some extend payed attentions to these matters. So, future studies on the neurotechnology and education and the classrooms should notice these shortages in this field in order to present a comprehensive approach and demonstrate the importance of these critical points regarding the role of neurotechnology in education.

References

7. Dikker, Suzanne; Wan, Lu; Davidesco, Ido; Kaggen, Lisa; Oostrik, Matthias; McClintock, James; Rowland, Jess; Michalareas, Georgios; Van Bavel, Jay J.; Ding, Mingzhou; Poeppel, David (2017). Current Biology Report, Published by Elsevier Ltd., No 27, 1375–1380
27. Taherisadr, Mojtaba; Utku Demirel, Berken; Al Faruque, Mohammad Abdullah; Elmalaki, Salma (2021). Future of Smart Classroom in the Era of Wearable Neurotechnology
30. White, Susan W.; Richey, , J. Anthony; Gracanin, Denis; Bell, Martha Ann; LaConte, Stephen; Coffman, Marika; Trubanova, Andrea; Kim, Inyoung (2015). The Promise of Neurotechnology in Clinical Translational Science, Clinical Psychological Science, Vol. 3(5), 797– 815
31. Zambrano, Kleyner Cristóbal Demera; Vera, , Liseth Stefania López; Zambrano-Romero, Merly Genoveva; Solórzano, David Alejandro Navarrete; Troya, Nubia Stefania Quijije; Gámez, María Rodríguez (2021). Educational Neurotechnology in Attention to the Specific Needs of Higher Basic General Education Students, Palarch’s Journal of Archaeology of Egypt/Egyptology 18(10), 943-957