Neuropedagogy as a scientific subdiscipline – possibilities and limitations

Recent years have seen a rapid development of modern neuroimaging methods. The published results were gradually becoming of interest to representatives of other fields of science, for example psychologists and, recently, pedagogists. There was an increasing number of publications that dealt with topics related to the education process and that referred to research in the field of neurobiology (Goswami, 2006; Tokuhama-Espinosa, 2010; Tokuhama-Espinosa, 2010a; Tokuhama-Espinosa, 2011; Howard-Jones, 2014; Sala, Anderson, 2012; Mareschal, Tolmie, Butterworth, 2013, Trnikova, Petlak, 2010). Interdisciplinary research started in mid-20th century. First, the research was carried out by psychologists, doctors of medicine or neurobiologists within the existing scientific disciplines. The research focussed mainly on cognitive aspects of human development. Therefore, in recent years the discussion about "brain-friendly education" has also been joined by pedagogists. At the same time, the endeavours to outline the theoretical and methodological frameworks of the novel discipline – the area of research in neurobiology, psychology and pedagogy – become more and more frequent. Due to the fact that the subject-matter was dealt with by a large number of research institutions in diverse locations, various names were used in the literature such as "neuroeducation", "neuropedagogy", "educational neurosciences", and Mind Brain Education Science (hereafter referred to as MBE).

This publication endeavours to define the theoretical assumptions of neuropedagogy. This is the first, essential stage in the research process as scientific literature is missing this scientific overview of the reality, based on which pedagogists would be able to design pedagogical and neurobiological research. The need for publishing the theoretical assumptions becomes even more urgent as there are more and more methods of work and tools used in school environments around the world that are not subjected to any research because there are no theoretical frameworks for that kind of research.

History of research on biological determinants of education – a concise review of most significant theories

The search for biological determinants of the learning process dates back to the ancient times (the detailed description can be found in: Tokuhama-Espinosa 2011). However, it was not until the second half of the 19th century that significant scientific discussions regarding the above subject-matter began to evolve in a more rapid manner. First, the discussions consisted in looking for correlations between the broadly-understood biological determinants and the effectiveness of the learning process. In 1869 Franciszek Galton started a discussion on what affects the learning process more significantly: biological determinants or upbringing. It was also the time of the appearance of the so-called Baldwin Theory implying that if learning is prerequisite for the survival of the species, then the ability to learn

is inherited biologically through genes (Broughton, 1981 after: Ferrari and McBride, 2011). Those assumptions were reflected, i.a. in the research conducted by Jean Piaget, who not only defined the four stages of the cognitive development but also attempted to find a biological explanation for those stages (Piaget, 1970; after: Ferrari and McBride, 2011).

In the 50s of the 20th century the study of process of learning was still the realm of psychologists' and biologists' research. In 1949 Donald Hebb made a supposition that there was a relation between neuroscience and learning. He presented a concept by Ivan Pavlov in relation to a network of neurons. Hebb supposed that the combination of two different stimuli created new neural connections and, as a result, a new reaction occurred. Based on those suppositions, Hebb endeavoured to explain a higher efficacy of the learning process organised in an atmosphere of positive emotions. Nowadays, this theory, among other ones, constitutes the basis for research on neuroplasticity (Tokuhama-Espinosa, 2011). In 1958 Mark R. Rosenzweig and Marian C. Diamond published the results of the experiments that showed dendritic growth in rats induced by the learning process (after: Johansson, Belichenko, 2001). Twenty years later a Russian psychologist Alexander Łuria, proved, based on that theory, that the learning process in the brain involves various memory systems and that information can be coded in various "formats" by means of various neural pathways (Tokuhama-Espinosa, 2011).

Towards the end of the 20th century the first attempts were made to create a new, separate scientific subdiscipline. In 1978 two works were published: "Brain Research and Learning" (Claycomb, 1978) and "Education and The Brain" (Chall, Mirsky,1978). Their authors attempted to integrate neurology and education as a new, independent subdiscipline. They focused only on researching the learning process, omitting the teaching process. Perhaps this is the reason why that discipline did not find many advocates and did not get as much recognition as the other area of interdisciplinary research that took shape at the same time, namely Mind, Brain and Education Science (MBE).

The subject-matter literature describes American scientists as the forerunners of MBE. In 1981 in the USA James Lee O'Dell was the first to use the notion Mind, Brain and Education (MBE) in his book „Neuroeducation: Brain Compatible Learning Strategies". He stressed that only by understanding the neural mechanisms of cognitive processes would we be able to design truly effective syllabuses. Around the same time, in 1983, American psychologists published further two important works on the subject-matter under discussion: „Frames of Mind" by Howard Gardner and „Human Brain, Human Learning" by Leslie A. Hart. Gardner developed a new concept of multiple intelligences, pointing out directly to several types of intelligence being located in specific areas of the brain. On the other hand, Hart stressed that designing educational experiments without understanding the brain was like designing gloves without understanding the human hand. It is the work by Hart that is generally considered to be the first scientific publication in the area of the new subdiscipline being developed, which was labelled *neuroeducation*.

At the same time, also in Europe scientists started their research on neurobiological determinants of the learning process. In fact, according to scientific sources, European scientists contributed to developing the bases of neuroscience over 100 years ago when a Spaniard Santiago Ramon y Cajal was engaged in a dispute with Carl Ludwig Schleich about the significance of neurons and glial cells for human behaviour. However, it was not until 1988 that Gerhard Priess (professor of didactics at the University of Freiburg in Germany, expert on early-age mathematical education) introduced the notion of neurodidactics, claiming that those who deal with school pedagogy and didactics in general must keep in mind that teaching and learning are brain-based. Conditions of learning process optimisation were meant to be the research area of neurodidactics. According to assumptions made by Preiss, neurodidactics was meant to be a new branch of the theory of education, the representatives of which were supposed to attempt to develop a teaching strategy and learning methods, utilising objective results of brain research. Since then the term "*neurodidactics* has been the subject of discussion, frequently taken as an interface of neurology, didactics, pedagogy and psychology (Sonnier, Goldsmith, 2005; Preiss, 1998). Therefore, it is frequently used interchangeably with the term *neuropedagogy* and *neuroeducation*.

In recent years attempts have been made to define the above notions. Nowadays, according to some authors, through its in-depth insight into the processes underlying human conscience, learning and development, neuroeducation brings the knowledge about the development of the nervous system to pedagogical practice (Tokuhama-Espinosa, 2010a; Sousa, Tomlinson 2010). Whereas the understanding of the principles of how the brain works significantly affects the planning of the education process (teaching methods), it is less important in terms of the selection of the contents of the curriculum (base curriculum) (Pickering, Howard-Jones, 2007; Serpati, Loughan, 2012). Therefore, neuroeducation would be a discipline that does not propose radical changes in the areas of curriculum content, but rather it postulates emphasizing the development of cognitive abilities relevant to the upbringing and learning processes as well as postulating the educational space to be created to support optimal use of the potential of students' brains.

Over time, the notion of neuroeducation was more and more frequently identified with a more popular discipline, the above-described MBE or with educational neurosciences (Szuts, Goswani 2007; Lalancette, Campbell 2012; Battro, Fischer and 2010).

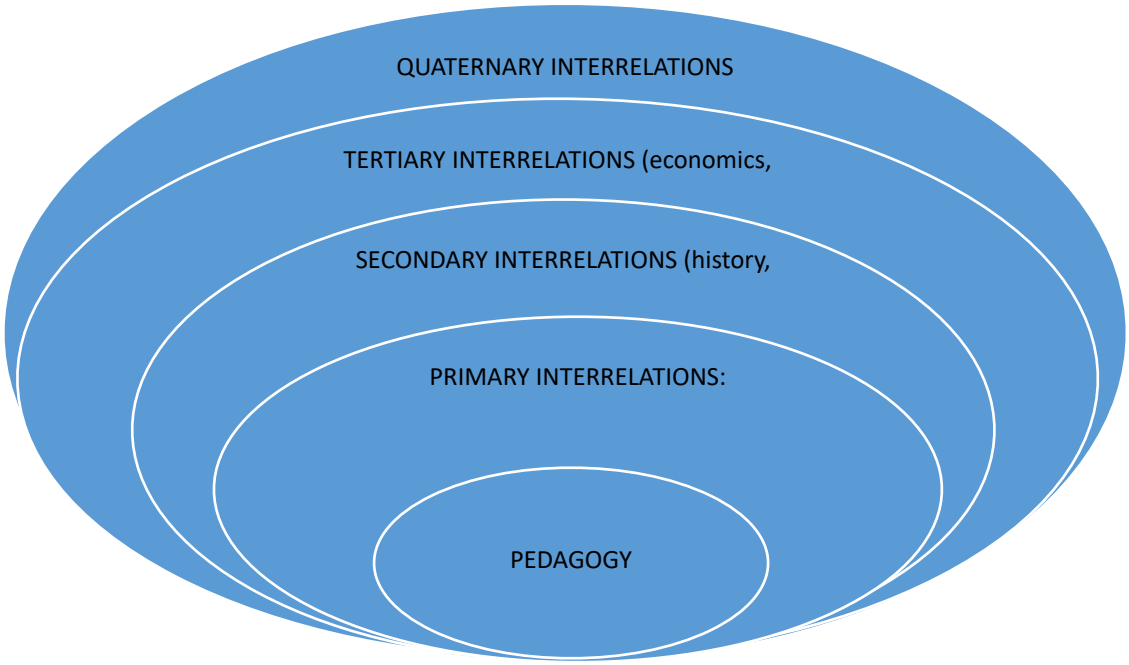
Summing up, the beginnings of the scientific theories regarding the combination of neurobiology with the learning process can be traced back to the 19th century, and both American and European (including Polish) scientists from various scientific can be named as the forerunners of those theories. At the same time, depending on the location in which the research was conducted, the novel discipline was labelled *educational neuropsychology, MBE, educational neuroscience* or, less frequently, *neuroeducation*.

Contemporary neurosciences – the analysis of the concept of combining scientific disciplines

In recent years there have been numerous publications the authors of which attempted to synthesis of the hitherto conducted research in the area of neural references to the education process (Meltzer, 2007; Santoianni, Sabatano, 2007; Olson, Torrance, 1996; Friedman, Klivington, Peterson, 1986). The inspirations in this regard can also be found in concepts by A.Ş. Neill's Summerhill School, Sudbury school , Reggio Emilia, Montessori, International Baccalaureate and Steiner-Waldorf. This means that for a long time attempts were made in numerous scientific centres to analyse neurobiological references to the processes of learning and teaching. At that time the terms *neuropedagogy, educational neuropsychology, neurobiology of education, neurodidactics*, and *MBE* were already in use. Faced with the multitude of names and the necessity to find a place for the novel discipline in the system, scientists and practitioners endeavoured to systematize those names. The efforts were two-directional.

The first method involved a traditional approach based on the interrelations between disciplines, with a specific scientific discipline (and its subdisciplines) being in the centre of those disciplines. This method draws the knowledge from other disciplines in a consistent manner, i.e. in the manner that is necessary (primary interrelations), frequent (secondary interrelations) or sporadic (tertiary interrelations). Some disciplines may constitute the subject of the activities of the central discipline (quaternary interrelations). The aim is the development of the discipline with an emphasis on its autonomy.

Figure 1. Interrelations of pedagogy with another discipline



Source: own work

The other method of describing the relations is based on the interrelation between the disciplines. The focus is not just on a single discipline. Rather, there can be several disciplines in the centre of attention as the focus is on the scope of cooperation between those disciplines. One can speak of the lack of cooperation (separateness of disciplines), multidisciplinarity, interdisciplinarity, and transdisciplinarity. Canosa and Collado-Ruano, having adopted the concept by Nicolescu (1996) for a basis, related those notions to the newly-developing disciplines dealing with neurobiology and education.

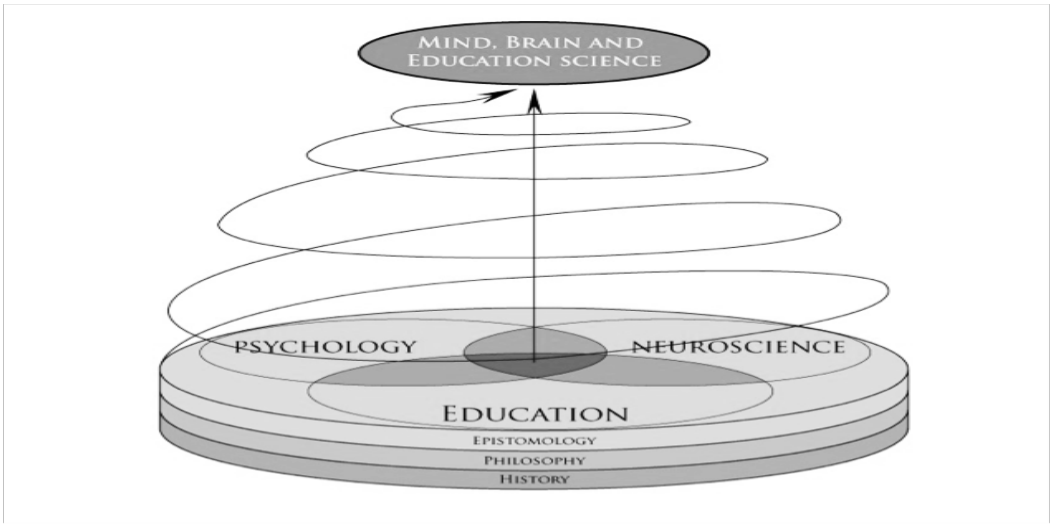
In this context, multidisciplinarity can be spoken of when the same problem is dealt with by specialists from various disciplines. However, their activities are limited only to their own discipline. Scientists do not cooperate in an interactive but only in a cumulative manner. The so-called education sciences can serve as an example here. In educational sciences various aspects of education can be studied by psychologists, sociologists, philosophers etc. If scientists start an interactive cooperation (going beyond the frameworks of their own disciplines) and involve the people with hands-on experience in the discussions (acknowledging their knowledge and experience as being an equivalent and valuable for the purposes of decision-making), then such a situation becomes a basis for creating a new research field and, with time, also for a new discipline. All the participants address the same issue and they focus their expert knowledge on it. In such a case we speak of transdisciplinarity (Smuels 2009). The previously described MBE can serve as an example. Interdisciplinarity is the final type of interrelation. Transdisciplinarity means that research is conducted at the interface of various disciplines. In case of interdisciplinary studies interactions between academics (without the involvement of those with hands-on experience, albeit their activities are the sources of research problems and can be used to verify hypotheses) can result in the developments of a new academic discipline (e.g. psychology of education or neuropsychology).

Discussing the issue of relations between the disciplines, especially in the context of transdisciplinarity, it is worth paying attention to the determinants of interdisciplinarity. Collective, issue-based work is not a good approach in all situations. There are numerous situations when a specialized, unidisciplinary knowledge is required, the knowledge that is not available to those with the so-called hands-on experience. Then, they should not be involved in the discussion. A study showed that within the area of neurobiology only the experts were critical and reliable enough regarding the provided information such as neuromyths (Weisberg et all. 2008). Both “ordinary” participants as well as students with limited knowledge on the subject claimed that the explanation of phenomena by evidence unsupported by research but related to neurobiology is more reliable and satisfactory than if they were not related to neurobiology. The occurrence of situations like the one mentioned above is proven by numerous popular science publications the authors of which quote (often unreliably, not objectively and without presenting research-based evidence) excerpts from neurobiology to support their theories. Scientific research has also proven that magnetic resonance imaging has the so-called authenticating and scientifying effect (McCabe and Castel, 2008). The above-mentioned research implies that, as regards teachers, courses in the basics of neurobiology or neuroscience research will not significantly affect the objectivity of

assessing other reports grounded in neuroresearch. Samuels goes as far as claiming that teachers are not able to acquire specialist neurobiological knowledge (Samuels 2009).

Summing up, the systematization of the naming convention is based on interrelations of various kinds, determined by i.a. the subject-matter of research. The most popular among the attempts to systematize the developing neurosciences is the one that combines two concepts: physics and neurobiology by Hideaki Koizumi, and pedagogy and psychology by Boby Samuels. Both scientists focused on MBE.

Figure 2. Diagram of theoretical assumptions of MBE



Source: Tokuhama-Episona 2010

They assumed the new field of research to be of transdisciplinary nature and involves both people with hands-on experience and theoreticians in the area of psychology, neurosciences, and education. Those assumptions were proven and complemented in 2005 during an interdisciplinary conference in Delphi. Over 30 experts in neurobiology, psychology, and pedagogy met there to look into the available literature and organize the body of knowledge within the newly-developing discipline. The conference participants adopted the name Mind Brain and Education Science as the one that best describes the novel discipline that constitutes the field for an interdisciplinary discussion, first and foremost between pedagogists, psychologists, and the representatives of neurosciences (biology, chemistry, physics, or medicine). In the course of numerous discussions, the participants demonstrated that MBE specialists should accept various historical roots of three disciplines (cf. Fig. 2) This means, for example, that teachers must realize that although psychology and neurobiology have different goals, methods and procedures than those of education, both are equally useful for planning the learning and the teaching processes. In a similar vein, psychologists practising the new discipline must acknowledge that the information from the area of neurology and education are equally valuable despite the differences in

methodology. On the other hand, neurologists should, for example, learn to appreciate the significance of qualitative research. In addition, Bruno della Chiesa, Vanessa Christoph and Christina Hinton (2009) demonstrated that scientists practising MBE must verify research hypotheses based on the methods available for each of the disciplines and to recognise the obtained results as equally valid. Such an approach is also highlighted by the very name of the discipline that implies a three-way information flow. This means that if some results are to be adapted in a novel discipline, pedagogists, psychologists and neurologists must prove their hypotheses not only in their own disciplines but also in the other two (Fischer et all., 2007).

In 2016, during the following meeting in Delphi, over 50 scientists from eleven countries held another interdisciplinary discussion. Among the guidelines for work for the following ten years was the popularization of the postulate that MBE and educational neurosciences or neuroeducation were not the same thing (Tokuhama-Espinosa 2017). This way, for the first time a group of specialists representing various disciplines adopted an official position regarding the scopes of meaning of new terms. The differences between them are presented below.

Figure 3. Comparison of neurosciences

		learning sciences	Cognitive neurosciences	Educational neurosciences	Neuroeducation	Mind, Brain and Education
REFERENCE GROUP	people	✓	✓	✓	✓	✓
	animals	✓				
	plants	✓				
	humanity	✓				✓
	society	✓				✓
	class/group	✓		✓	✓	✓
	entity	✓	✓	✓	✓	✓
	"molecular" level	✓	✓	✓	✓	✓
SUBJECT-MATTER	learning	✓	✓	✓	✓	✓
	teaching			✓	✓	✓
AUTONOMY	separate discipline	✓	✓	✓	✓	✓
	two-way communication	✓		✓	✓	✓
	transdisciplinarity					✓
	no subdiscipline			subdiscipline of neurosciences	subdiscipline of education	✓

Source: own work based on Tokuhama-Espinosa, T. 2019

The above table presents the most common sciences related to education and neurobiology with regard to their subject-matter of research, reference group and autonomy among academic disciplines. *Learning sciences* seems to be the broadest term (learning understood as the acquisition of skills, capabilities, and knowledge), i.e. all academic disciplines which in some way deal with the issue in relation to plants, animals or people (from a molecular to social level). In this case relations between the disciplines are based on an interdisciplinary discussion involving only academics. On the other hand, *cognitive neurosciences,* in which we can include medicine and neuropsychology, seem to have the narrowest meaning. The assumptions describing the educational neurosciences and neuroeducation seem interesting. They are identical, except that the former is the subdiscipline of neurosciences (understood as a group of all disciplines that deal with neuronal aspects of the education process), while the latter is the subdiscipline of education. This distinction seems to result from the orientation of the research i.e. whether it is only basic research that focuses on the human nervous system or, rather, applied research focussing on practical applications within the education system.

Neuropedagogy within the system of sciences

To be able to relate to neuropedagogy, one must first raise the issue of the naming convention applied to the disciplines. In the deliberations hitherto replacing the term *pedagogy* with *education* has become prominent. In the USA, in the Scandinavian countries and in the Anglosphere any research dealing with the school and studying is labelled as *education*, which is not classified as an academic discipline. The term *pedagogy* is practically absent from the literature (cf. Feiler, Stabio 2018). In Western Europe, in turn, the term *educational sciences* is commonly used. In Germany, Switzerland and Austria it constitutes a separate academic discipline (although it shares the methodology, terminology, and the subject-matter of research with pedagogy). On the other hand, in the Czech Republic and in Slovakia the term *educational sciences* is also used, but not in relation to the discipline. In other Central European Counteies, Brazil and, for example, in Australia most academics (cf. Tanaś 2015, Genovesi 1999, Saviani 2007, Zogla 2018) regard pedagogy as a separate academic discipline (has its own methodology, terminology, and the subject-matter of research), the subject-matter of which is education (understood mainly as upbringing, teaching, and learning at the same time), with didactics being one of its subdisciplines.

From its beginnings, pedagogy, which derives from the Greek word *pediagogos,* has been associated with upbringing, understood as supporting the child in physical and, later, also in moral development (Smith 2006). An academic status of pedagogy began to develop in the Enlightenment (Komeński, Radke, Roussau, Peztalozzi). At the end of the 18th century courses in pedagogy were made available at some German universities. The world's first chair of pedagogy was established by E.C Trapp at an university in Halle, Germany. In 1870 Trapp published a treatise for students titled "Versuch einer Pädagogik" in which he acknowledged

pedagogy not only as an independent academic discipline but also stressed that pedagogy is based on anthropology and medicine. However it is J.F. Herbert who is regarded as the founding father of academic pedagogy. He separated pedagogy from philosophy and based it on philosophical ethics (which defines the goals of upbringing) and on psychology (which indicates the means to those goals). He was the first to point out to the duality of pedagogy which, on one hand, is grounded in the humanities, but one the other hand – in social science (Smith 2006). This is because pedagogy deals with both describing the reality and establishing the directives for actions to be taken to change this reality. Therefore, it comes as no surprise that some pedagogists are strongly in favour of treating their discipline as a science that explains the realities studied. On the other hand, others see the sense in practising pedagogy as a science that interprets the existing educational reality and in reflecting over that reality. Others still use either the methods of social sciences or of humanities depending on what is the subject-matter of their research and which methods are better suited to solve the basic problem of their research. Therefore, pedagogy studies the reality which it creates. This is why philosopher Radim Palouš claims that the essence of pedagogy is exemplified not by the prefix *ped* but by the suffix *agogy* as pedagogy, after all, deals also with adults and the elderly. *Agogé* derives from a Greek notion for "leading", "upbringing", "discipline", "way of life", "crossing", "departure", where *agón* means "competition", "effort", "striving"*; agein* means "to lead", "haul"; and *age* means "further", "up". In that sense agogy can deal with the theory of education in two ways:

1) fundamental – where it searches for the sources, sense and ontological premises of upbringing,
2) practical (applied) – when it sets current and specific goals and means of upbringing (Palous 1991).

Therefore, abandoning the term *pedagogy* in the above sense in favour of the schooling-related term *education* also means confining the research to education understood as "contextual" activity that is guided neither by the awareness of goals nor by the conviction of understanding the nature of upbringing. **Therefore, it seems legitimate to point out that the branch of science should be called *pedagogy*, whereas education is the subject-matter of its research.**

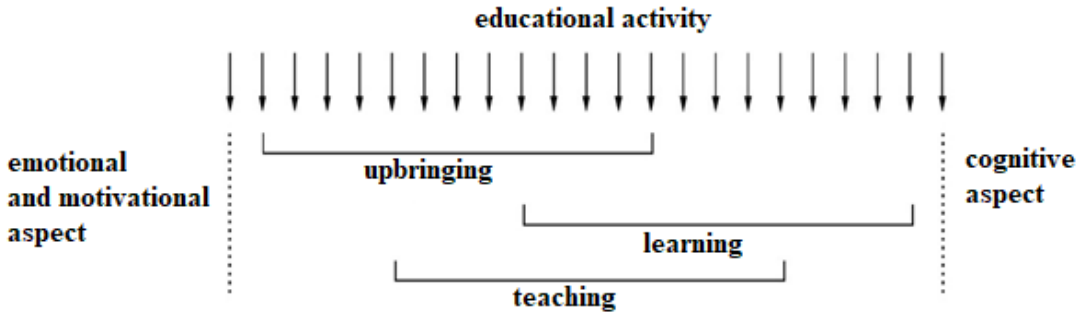
The term *education* is generally understood as a process of teaching, training and learning, especially in schools, colleges or universities, to improve knowledge and develop skills (Oxford Learner's Dictionaries). In that context education is the subject-matter of research in psychology, sociology but also in neurobiology.

However, if we assume that educational activities affect the emotional and educational as well as cognitive processes , the meaning of the term becomes broader. The former processes concern feelings, motives, attitudes and values, while the latter concern knowledge, skills, and effectiveness of actions. Depending on the role of those aspects in designing, performing and evaluating the results of educational activities we can distinguish: **upbringing (emotional education), learning (cognitive education), teaching (sustainable education)**

(Niemierko 2009). Within this concept the term *education* has the broadest meaning, encompassing all the above-mentioned activities – cf. Figure 4.

Summing up, the term *education* can be understood in a narrower sense (as teaching and learning) or in a broader sense – as activities encompassing upbringing, educating and teaching. It is this broader context that defines the subject-matter of research in pedagogy.

Figure 4. A diagram of educational activities

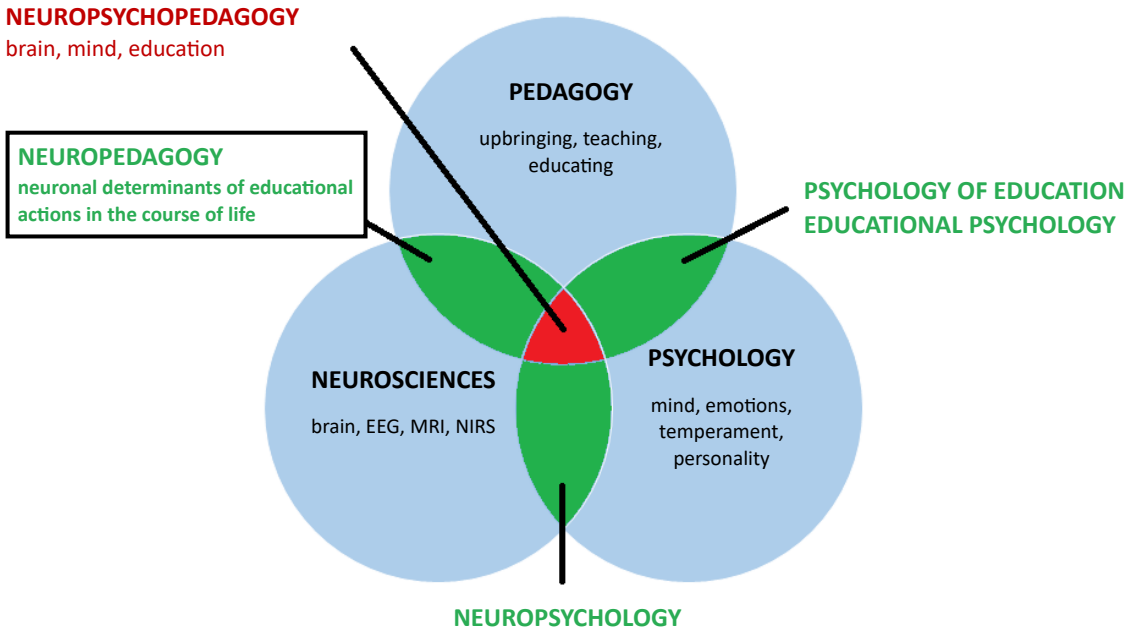


Source: B. Niemerko (2009). Diagnostyka edukacyjna. Warsaw PWN, p.35.

Based on the above, one can attempt to place neuropedagogy in the system of sciences.

Assuming that the term *pedagogy* describes an academic discipline the subject-matter of which is education, then the pattern of relations between the disciplines could look as presented in Figure 5.

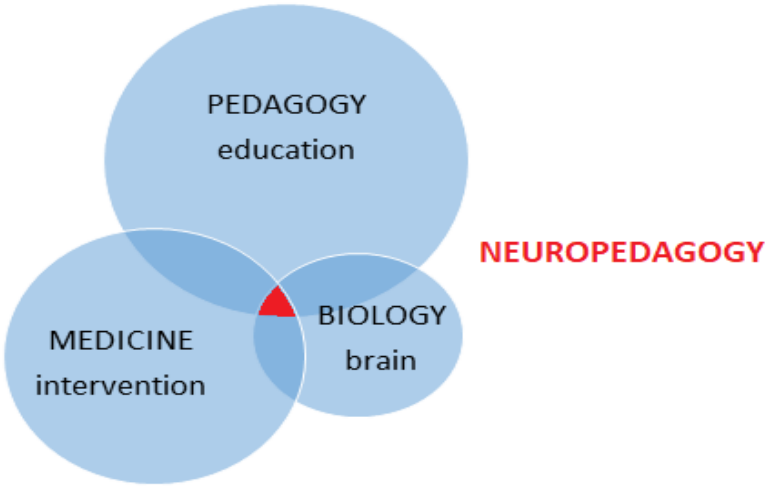
Figure 5. Diagram of relations between specific neurosciences



Source: own work

Therefore, neuropedagogy should be regarded as an interdisciplinary field of research in pedagogy and neurosciences (i.a. biological and medical neurosciences), **where a given thesis should be proven using research methods of both neuropedagogy and neurosciences. Therefore, the process of education i.e. upbringing, educating and teaching would constitute the subject-matter of neuropedagogy, analysed within the context of neurosciences, while a person describing him- or herself as neuropedagogist should have thorough knowledge in the area of three disciplines, with pedagogy being the core area.**

Figure 6. Neuropedagogy as the field of research of three disciplines (the diagram also shows the scope of knowledge it draws from the three discipline)



Source: own work

The presented concept is not only based on a clear distinction of the terms *pedagogy* and *education* but also postulates the conscious usage of those terms in academic publications. If theoretical considerations are made at the level of academic disciplines, then the term *pedagogy* should be used in texts, diagrams and charts. On the other hand, the word *education* could be retained in the naming convention of interdisciplinary fields of research/areas of research, when the representatives of various disciplines focus exclusively on the social aspect of education, without delving into its history or axiology. However, the above term must not be used to label an academic discipline or subdiscipline, and so far, despite its growing popularity, it has not gained the status of an academic discipline or subdiscipline in any publication. Moreover, the scope if its meaning in that context would be narrower, i.e. it would cover only the learning and teaching processes in the course of life.

Based on the above, Figure 3 should be modified.

Figure 7. Actual place of neuropedagogy among neurosciences

		Learning sciences	Cognitive neurosciences	Educational neuroscience	Neuropedagogy	MBE
Object of research	**People a) humanity**	+				+
	b) society	+			+	+
	c) class/group	+		+	+	+
	d) entity	+	+	+	+	+
	e) body cell	+	+	+		+
	Animals	+				
	Plants	+				
Subject-matter	**Learning**	+	+	+	+	+
	Teaching			+	+	+
Research autonomy	**Interrelations of disciplines**	Field of research of separate disciplines	Field of research of separate disciplines with neuronal determinants of cognitive processes being their research	Field of research of separate disciplines with neuronal determinants of education being their research	Subdiscipline of pedagogy	Separate discipline, no subdisciplines
	Relations with other disciplines	Interdisciplinary	Interdisciplinary	Interdisciplinary	Interdisciplinary	Transdisciplinary
Examples of discipline (acc. to classification applicable in Poland)		i.a. psychology, sociology, biology, medicine and subdisciplines thereof	i.a. psychology, medicine, biology and subdisciplines thereof	i.a. pedagogy, psychology, medicine, biology and subdisciplines thereof	pedagogy, medicine, and subdisciplines thereof	pedagogy, psychology, medicine, biology and other disciplines involving the study of

Source: own work

Based on the above, it must be stressed that neuropedagogy is identical neither to MBE nor to educational neurosciences. As opposed to MBE and educational neurosciences, neuropedagogy:

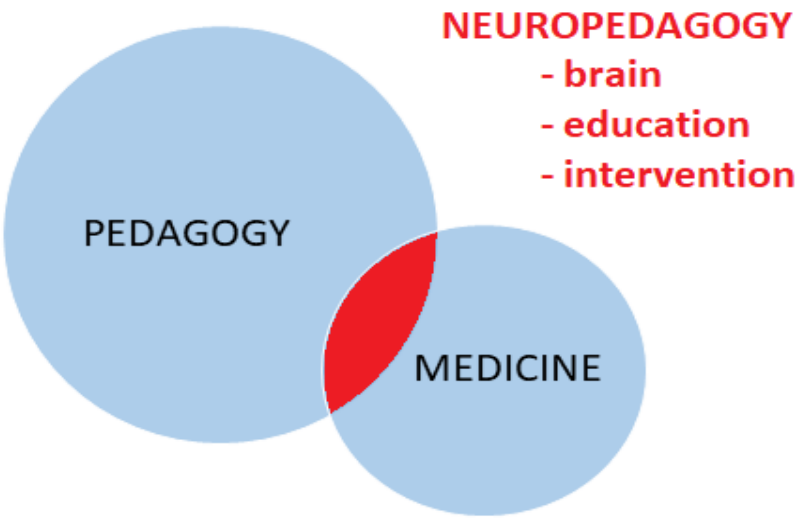
- studies the society to analyse historical references and to set axiological goals i.a. of the education process,
- its studies do not have to cover the nervous system at a molecular level as neuropedagogists will not search for neuromarkers required for diagnosing disorders, but rather, they will verify

the available teaching or therapeutic methods (i.e. the so-called interventions). Hence the suggestion to utilize achievements of medicine rather than biology;
- it can be classified as a subdiscipline of pedagogy (just as neuropsychology is the subdiscipline of psychology).

The analyses of relations between the disciplines and research areas presented in the table allow for even more precise definition of the meaning of **"neuropedagogy", which should study neuronal determinants (causes, course, consequences) of the education process, i.e. any broadly understood interventions regarding the upbringing, educating and teaching aimed at persons in varying age and health condition. Any hypotheses should be subjected to the research process utilising the methods available in pedagogy and medicine. Therefore, a neuropedagogist should be thoroughly educated in pedagogy (as a core discipline) as well as having the knowledge of medicine (in particular, neurobiology and neuroimaging techniques) at least at an intermediate level.**

Summing up, neuropedagogy and the subject-matter(s) of its interest can be finally graphically represented as below:

Figure 8. Actual scope of the meaning of the term *neuropedagogy*



Source: own work

Instead of a summary

The adoption of the method of defining neuropedagogy described herein is justified considering the methodology of future research in the newly-developing subdiscipline. Supposing the research to be interdisciplinary, one must acknowledge that suppositions or

hypotheses adopted by neuropedagogists should be verified using the methods and tools used in medicine and pedagogy.

It is, however, difficult because there are currently significant differences between the research methodologies of the above-mentioned disciplines. Medical analyses are governed by stringent, structured and consistent procedures but are only quantitative in nature. On the other hand, in pedagogy standard tools are hardly available and the rapidly evolving stream of qualitative research seems to not to be applicable to medical sciences at all. However, what medicine and pedagogy have in common is the rapidly developing concept of "evidence-based practice". The said concept assumes that when making a decision a doctor of medicine/ teacher should take into consideration the evidence (results of reliable tests, metanalyses, expert recommendations), patient's/student's current needs and limitations and his/her own experience. It is assumed that in such a situation the quantitative methods (evidence, doctor's/ teachers knowledge) should be combined with qualitative methods (patient's/student's subjective opinion, doctor's/teacher's intuition). The development of the methodology of neuropedagogy will also facilitate the development of neuroimaging methods and improve the availability of near-infrared spectroscopy (NIRS). This method does not require immobilization (a person can perform various educational activities), the equipment is mobile (tests can be conducted in natural developmental environments) and makes it possible to test several people simultaneously. Therefore, pedagogists can combine the pedagogical methods with brain imaging in their research, obtaining data from a certified medical tool.

This type of research procedure makes it possible to obtain reliable and objective data which can make the so-called "evidence-based education and "neuroevidence-based education" more widespread.

Naming convention in neuropedagogy remains another important issue. **Terminology, in a similar vein to methodology, should take into account the interdisciplinarity of this field, i.e. the terms typical of pedagogy (upbringing, education, teacher, care, or social rehabilitation) should be included in/combined with/complemented with medical terminology (brain, nervous system, neuroplasticity, magnetic resonance imaging). It is also important that the neuropedagogical terminology include only the terms that are scientifically proven and well-established in previous publications.**

The deliberations undertaken herein constitute only the first stage in the development of a new subdiscipline. Neuropedagogy is the answer to the increasing interest in brain research among teachers and to the increasing number of pseudo-scientific theories, methods, and therapies making their way into the education process, claiming to be "neuroresearch-based". The scientists must base their activities on theoretical assumptions to be prepared for the newly-developing field of research which is likely to become a new subdiscipline. Not only will the standardization of the naming convention facilitate the interdisciplinary international research cooperation but it will also allow for an objective and reliable dialogue

between scientists on the one side, and teachers, parents and other institutions involved in the education process on the other side.

Abstract

In recent years teachers have intensified their efforts to find the ways to improve the quality of their work. Methods, therapies and teaching aids labelled as "neuroresearch-based" have made their way into the available scientific publications and commercial offers. Terms such as *neuroeducation*, *neurodidactics, educational neurosciences, educational neurosciences* or *„Mind, Brain & Education"* have gained popularity.

The present article endeavours to systematize the theory regarding the issues of the application of neuroresearch in education, setting them, first and foremost, in neuropedagogy – a novel subdiscipline of pedagogy. The proposed concept can constitute the basis for designing research methodologies and procedures which will make it possible to verify the neuroscience-based solutions proposed, among others, to teachers. Notwithstanding the above, the current situation (crisis of education, increase in professional burn-out cases among teachers, low prestige of the teaching profession, increasing interest in brain research among those involved in education, and readily available and aggressively promoted pseudo-scientific theories and solutions) obliges scientists to take active actions based on reliable evidence.

Bibliography:

1. Battro, A.M., Fischer, K.W & Lena, P.J (2010) The educated brain: Essays in neuroeducation. Cambridge: Cambridge University Press.
2. Broughton, JM (1981). The genetic psychology of James Mark Baldwin. American Psychologist, 36, 396–407.
3. Buckingham, D. (2003). Media Education: Literacy, Learning and Contemporary Culture. Cambridge: Polity Press.
4. della Chiesa, B., Christoph, V., Hinton, C. (2009). How many brains does it take to build a new light: knowledge management challenges of a transdisciplinary project. Mind Brain and Education, 3(1), 17 – 26.
5. Ruano J.C., Canosa A.F. (2019). Transdisciplinary epistemological foundations of education and neuroscience. Sophia, Colección de la Educación, 26(1), 83-112.
6. Chall, J. S., Mirsky, A. F. (Eds) (1978). Education and the brain. Chicago: University of Chicago Press.
7. Claycomb, M. (1978). Brain research and learning: a position paper. Washington, D.C: National Education Association.

8. Feiler, J.B., Stabio M.E., (2018), Three pillars of educational neuroscience from three decades of literature. Trends in Neuroscience and Education, 13, 17-25.
9. Ferrari, M., & McBride, H. (2011). Mind, Brain, and Education: The birth of a new science. Learning Landscapes, 5(1), 85-100.
10. Fischer, K.W., Daniel, D.B., Immordino-Yang, M.H., Stern E., Battro, A. Koizumi H. (2007), Why mind, brain, and education? Why now? Journal Compillation, 1(1), 1-2.
11. Friedman, S.L., Klivington, K.A., Peterson, R.W. (1986). The brain, cognition, and education. New York: Academic Press.
12. Genovesi, G. (1999). Pedagogía, dall'empiria verso la scienza. Bologna: Pitagora.
13. Goswami, U. (2006). Neuroscience and education: from research to practice? Nature reviews neuroscience, 7(5), 406-413.
14. Gundem, B. B. (1998). Understanding European didactics – an overview: Didactics (Didaktik, Didaktik(k), Didactique). Oslo: University of Oslo. Institute for Educational Research.
15. Hebb, D.O. (1949). The organization of behavior. New York: Wiley.
16. Howard-Jones, P.A. (2014), Neuroscience and education: myths and messages, Natural Review Neuroscience, 15 (12).
17. Feiler, J.B., Stabio, M.E. (2018). Three pillars of educational neuroscience from three decades of literature, Trends in Neuroscience and Education, Elsevier.
18. Lalancette H., Campbell, S.R., (2012), Educational Neuroscience: neuroethical considerations, Mind Brain Education, 7(1) , 37-52.
19. Mareschal, D., Butterworth, B., Tolmie, A., (2013), Educational Neuroscience. Wiley-Blackwell.
20. McCabe, D.P., Castel A.D., (2008). Seeing is believing: The effect of brain images on judgments of scientific reasoning, Cognition, 107, 343-352.
21. Meltzer, L. (Ed.). (2007). Executive function in education: From theory to practice. Guilford Press.
22. Moricca, C., Pellegrini, M. (2016). Evidence-Based Education. Ten points of dispute. Form@re - Open Journal Per La Formazione in Rete, 16(2), 365-373.
23. Nicolescu, B. (1996) La transdisciplina. Manifiesto. Mónaco: Du Rocher.
24. Niemierko B. (2009) Kształcenie szkolne. Podręcznik skutecznej dydaktyki. Warszawa.
25. Olson D.R., Torrance, N. (1996). Models of thought. Explorations in Culture and Cognition. Cambridge, MA: Cambridge University Press.
26. Palouš R. (1991). Čas výchovy. Praha : Státní pedagogické nakladatelství.
27. Piaget, J. (1970). Piaget's theory. In P. H. Mussen (Ed.), Carmichael's manual of child psychology (3rd ed., Vol. 1, pp. 703–723). New York: Wiley.
28. Pickering S.J., Howard-Jones P., (2007), Educators' views on the role of neuroscience I education: findings from a study of UK and international perspectives, Mind Brain Education, 1(3), 109–113;

29. Preiss, G. (1998). Neurodidaktik. Theoretische und praktische Beitrage. Herbolzheim: Centaurus.
30. Sala, D., Anderson, M. (2012), neuroscience in Education: The good, the bad, and the ugly. Oxford Univesity Press.
31. Samuels, B.M. (2009), Can the Differences Between Education and Neuroscience be Overcome by Mind, Brain, and Education?. Mind, Brain, and Education, 3: 45-55. doi:10.1111/j.1751-228X.2008.01052.x
32. Santoianni, F., Sabatano, C., (2007), Brain development in learning environments. Embodied and perceptual advancements. Cambridge: Cambridge Scholars Publishing.
33. Saviani D. (2007). Pedagogy: the space for education at the University, Cad. Pesqui. vol.37 no.130 São Paulo Jan./Apr. 2007
34. Serpati, L., & Loughan, A.R. (2012). Teacher Perceptions of NeuroEducation: A Mixed Methods Survey of Teachers in the United States. [Article]. Mind Brain and Education, 6(3), 174-176.
35. Smith, M. J. (2006). 'The Role of the Pedagogue in Galatians', *Faculty Publications and Presentations*. Liberty University. https://core.ac.uk/download/pdf/58823409.pdf
36. Samuels, B. M. (2009). Can the differences between education and neuroscience be overcome by mind, brain, and education?. Mind, Brain, and Education, 3(1), 45-55.
37. Sonnier I.L., Goldsmith J., 1985, The Role of brain lateralization in learning and behavior modification. „Methods and Techniques of Holistic Education", 11–16.
38. Sousa, D.A., Tomlinson C.A. (2010). Differentiation and the Brain: How Neuroscience Supports the Learner-Friendly Classroom.
39. Szűcs D, Goswami U (2007), Educational neuroscience: Defining a new discipline for the study of mental representations. Mind, Brain and Education 114-127.
40. Tanaś M. (2015). Distance Education as an Object of Study and Reflection of Pedagogy in Poland, International Journal of Electronics and Telecommunications, 61(3).
41. Tokuhama-Espinosa T., 2010, Mind, brain, and education science. A comprehensive guide to the new brain-based teaching. W. W. Norton & Company, Nowy Jork.
42. Tokuhama-Espinosa, T. (2011). A brief history of the science of learning: Part 1 (3500 B.C.E.-1970 C.E.) & Part 2 (1970–the present). New Horizons for Learning, 9(1). Published on line (http://education.jhu.edu/newhorizons/Journals/Winter2011/).
43. Tokuhama-Espinosa, T. (2017). Mind Brain, and Education science: An International Delphi Survey 2016-2017. Quito, Ecuador: Author.
44. Tokuhama-Espinosa, T. (2019). An Overview of the Historical Development of the Field of Mind, Brain, and Education Science [on line] https://www.researchgate.net/publication/331960601_An_Overview_of_the_Historical_Development_of_the_Field_of_Mind_Brain_and_Education_Science

45. Trníková J., Petlák E., 2012, Neuroscience as a basis for innovations in education. „Acta Technologica Dubnicae", vol. 2, s. 43–51.
46. Weisberg, D. S., Keil, C., Goodstein, J., Rawson, E., & Gray, J. R. (2008). The seductive allure of neuroscience explanations. Journal of Cognitive Neuroscience, 20(3), 470–477.
47. Zogla I. (2018).Science of Pedagogy: Theory of Educational Discipline and Practice, Journal of Teacher Education for Sustainability 20(2), 31-43