Science System Assessment

The development of transdisciplinary learning science: promise or practice?

Femke Merkx, Reinout van Koten, Thomas Gurney, Peter van den Besselaar

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Preface

Education is an important function in society. Policy makers are interested in, and focus on, changes in the educational system that may improve its functioning: higher participation, improving the position of vulnerable social groups in the school system at all levels, better performance, avoiding student drop out, and a better mesh between societal needs and the needs of the labour market. At the same time, changes in the educational system are highly disputed and often heavily criticized with hindsight. One of the main problems with many of these changes is that they are not at all based on research and experimentation. Therefore, the need for science based educational policy has been increasingly emphasized.

Different approaches can be discerned in science based educational policies, and one of these is the application of brain science and neuroscience on teaching and educational practices. This agenda has been advanced over the last two decades, and more recently it attracted quite some attention under different labels such as 'educational neuroscience', 'new learning science', or 'mind, brain and education'. These developments represent a radically different approach compared to existing research on teaching and education, and consequently the possibilities and the usefulness of this approach is disputed.

In this report we approach the subject with a different perspective. The report addresses the question about the nature of the new paradigm, and aims to make the presence of it visible within the scholarly literature. Although the promises of the new learning sciences are highly relevant, the analysis in this report indicates that the field is in a very early stage of development at best. Brain sciences and cognitive neuroscience are hot and fast-developing fields. However, the interdisciplinary or multidisciplinary relation with educational and teaching research is programmatic at best. This is even more so the case for the transdisciplinary relation between the new learning sciences and educational and teaching practice. What seems to be lacking is - what in the medical field is called - 'translational research' that brings research results obtained in the laboratory to the class room. As the new learning sciences claim relevance for practice, we introduce in this report the term *transdisciplinary learning sciences* to describe these new developments. This study may inform decision making about shaping the conditions for fruitful development in this area.

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1 Introduction

It is claimed by many that the rapid progress made by neuro- and cognitive scientists in understanding the brain is of great relevance for improving teaching and educational practices. At an international level the OECD Centre for Educational Research and Investigation (CERI) advocates the development of 'a new learning science', that is research at the junction between the neuro- and cognitive sciences and educational research (2002, 2007). At the national level, the NWO Brain and Learning Committee advocates the same (Jolles et al., 2006). Furthermore, the Dutch National Initiative on Brain & Cognition, which aims to improve political attention and financial support for the cognitive and neurosciences selected education as one of the three domains in which neuroscientific and cognitive knowledge can be fruitfully applied (Task Force Brain & Cognition, 2006). A recent foresight study on neuro- and cognitive research by the Netherlands Study Center for Technology Trends (STT), also selected education as one of the domains of application (Van Keulen, 2008). Finally the Dutch Program Council for Educational Research (PROO) has asked an interdisciplinary committee of scientists to investigate which developments in neuro- and cognitive research could be of relevance for the educational research agenda (De Jong et al., 2009).

These expectations are not radically new. "The creation of 'neuroeducators' was proposed over 20 years ago, along with the contention that through the study of brain and behaviour the practice of teachers could be transformed and enhanced" (Ansari & Coch, 2006, p.149). In order to realise these expectations, a new type of research is needed: Transdisciplinary research, crossing the borders between different academic disciplines as well as between academia and practice (Jolles et al., 2006; OECD, 2007). Transdisciplinary research needs to be both practice-led and theory-led. If the research is too practice-led, there is the danger of epistemic drift, if research is too theory-led, there is the danger of academic fundamentalism (Tranfield & Starkey, 1998). The OECD uses the term *new learning science* to denote the field of research which would integrate the neurosciences with cognitive research, educational science and the knowledge of educational practitioners. In order to emphasize the importance of the relations between research and educational practice, we use the term *transdisciplinary learning science* (TLS) for this new and emerging field of research.

Quite some activities seem to take place around TLS. In this report we answer the question to which extent these activities over the years have resulted in a new and emerging research field. In this study we investigate the state of development of the 'new learning science'. Has it become an established research specialty already, is it an emerging specialty or is it still in an embryonic stage, visible in agenda setting efforts, but not yet in formal scholarly communication? And, if it exists as a specialty, where is it (interdisciplinarily) positioned between the broad field of neuroscience and cognitive neuroscience, and the broad field of research in education and teaching? Where are barriers and where lie opportunities to develop a new transdisciplinary learning science?

The relevance of mapping the dynamics of existing and emerging research fields is twofold. Knowledge maps inform researchers interested in the field about the position it has in the wider scholarly landscape, about the different subfields, and about the direction it takes. This may offer points of departure for new research activities and collaborations. Knowledge maps may also inform science policy makers who decide on agenda setting and funding for research programs and institutes. Mapping the structure, the content, and the stage of development of research fields is relevant for those decisions, as mature fields may require different funding instruments than emerging research fields do. And interdisciplinary fields require other instruments than disciplinary fields.

In this report we analyze the stage of development of the new learning science. *Chapter 2* discusses the promises and expectations of the last 15 years, and the institutions and organizations that emerged in the field of the new learning science. *Chapter 3* discusses the methods and data used in this study.

In *chapter 4* we will map the fields of neuroscience, cognitive neuroscience and educational research at the level of subfields, using scholarly journals as units of analysis. The analysis of citation relations between journals provides us with information about the various subfields that constitute the broad field of neuroscience, cognitive neuroscience and educational research. The chapter ends with a conclusion about the structure of the research fields: can we identify journals that represent an emerging new learning science? In *chapter 5* we will study the knowledge flows between the neurosciences, the cognitive neurosciences and educational research. In *chapter 6*, the analysis focuses on a lower level of aggregation. Using key words as point of departure, we try to identify the relevant papers, and analyze the topics emerging from the retrieved set of papers. Can we find clusters of research papers representing the emergence of the new learning science? And if so, what are the main research themes? Chapters 4 to 6 inform us about the nature and status of research at the border between the neurosciences, the cognitive neurosciences, the cognitive sciences and educational research. Is an interdisciplinary or multidisciplinary subfield emerging, and what does it focus on?

However, we are also interested in the question to which extent the field is transdisciplinary - that is practice and application oriented. Therefore, we analyze in *chapter 7* who is actually involved in Dutch educational research. Can we find transdisciplinary collaboration across the boundary of educational research and educational practice?

In *chapter 8*, we focus the analysis on a new journal specifically covering new learning sciences. What are the topics addressed in this journal and what is the knowledge base of the articles in this journal? Does this alter the conclusions of the previous chapters? *Chapter 9* concludes with the current status of new learning sciences as a research field. We briefly discuss implications for research policy.

2 Neuroscience and education - a brief overview of claims and developments

According to our knowledge, one of the first events that linked education and biology is the foundation in 1988 of the Special Interest Group (SIG) on Psychophysiology and Education as one of the SIGs of the American Educational Research Association. This SIG was renamed in 1993 to its current name: Brain and Education. Most neuroscientific research on learning and memory, in the so-called "Decade of the Brain" (the 1990's), focused on the medical applications of this knowledge. In this period the first ideas about neuroscience informing education were proposed (Geake, 2004, p. 43). However, it was mostly claimed that these ideas had no solid scientific basis whatsoever. John Bruer, director at the James S. McDonnell Foundation, commented on these developments in 1997 (Bruer, 1997), arguing that neuroscience has little, if anything, to offer education and that the focus should lie on developing links between cognitive psychology and neuroscience and between education and cognitive psychology instead.

His warnings about creating hype and about oversimplifying neuroscientific findings for application in the classroom have not resulted in the rejection of these ideas. On the contrary, promises about the implications of neuroscience for education have been around for more than two decades now. In the USA numerous concepts from neuroscience, mostly about structural brain development and its relation to functional development (e.g. left and right brain thinking, the importance of synaptic growth and pruning in certain periods and brain structures), have even found their way in school curricula.

The potential impact of neuroscience on education has led over the past decade to a number of initiatives aimed at developing the field. This field, operating under different names such as 'mind, brain and education', 'new learning science' or 'educational neuroscience' tries to link the fields of education and cognitive neuroscience rather than trying to build a direct bridge between neuroscience and education. In this report we will use these names as synonyms. Noticeably, over the last couple of years, claims have been made that this field of educational neuroscience indeed has 'arrived' (Petitto & Dunbar, 2004). However, the debate still continues as to what extent neuroscience and cognitive neuroscience can inform educational practice. Critics, Bruer for example, still warn of too much enthusiasm and note that policymakers, educationalists and researchers themselves often propose applications without much scientific proof (Bruer, 2002). It is probably safe to say that there is no simple answer to the question of what neuroscience means for education. As Geake argues, in specific circumstances neuroscience can inform educational practice and in others it can't (Geake, 2004).

It is clear from a quick sum-up of events that the interest in establishing linkages between educational research and neuroscience is indeed growing. In both the USA and Europe numerous symposia have been organised on the topic of educational neuroscience. Next to the already mentioned SIG Brain and Education, the National Science Foundation (NSF) founded a number of Science of Learning centres in the Science of Learning centres program (2004). Four of these centres, consisting of multidisciplinary teams (one led by the sceptic Bruer), are specifically aimed at bridging the gap between neuroscience and education. The centre with the strongest neuroscience component, the Center for Cognitive and Educational Neuroscience (CCEN) at Dartmouth College, closed only a year after it started following the departure from the program of two of its leading investigators.

In the United Kingdom the Crucible Group for Educational Neuroscience Research was established at the UWE in Bristol (2000). Other centres also emerged, such as the University of Oxford Cognitive Neuroscience - Education Forum (2001) and the Centre for Education and Neuroscience at the University of Cambridge (2003). All were founded by strong advocates of research in the field of Educational Neuroscience (Geake, Blakemore, Goswami). Similar developments in other countries can also be observed, such as in Denmark (LearningLab) and the Netherlands (Brain and Learning Centres at the University of Maastricht and the VU University Amsterdam), and the OECD has conducted two studies about educational neuroscience (OECD, 2002, 2007).

Scholarly literature has been, to a large extent, programmatic and focused on the precautions of bringing neuroscience to the classrooms (Bruer, 2002) and on how to 'build the bridge' (Ansari and Coch 2006; Gura 2005). More recently however, publications have appeared that discuss (with some precaution) the implications of cognitive neuroscience *research* for education (Goswami, 2004; Petitto & Dunbar, 2004). Other publications describe the impact of neuroscience research as a confirmation and explanation of existing psychological theories of learning and education. (e.g.(OECD, 2007). In addition, a new journal appeared in 2007 focusing on cognitive neuroscience and education: *Mind, Brain and Education*.

Together, these activities suggest that the research field is in development. In the remainder of this report, we will try to identify where this development is located cognitively, in terms of scholarly journals and papers. Can we identify - in the academic literature - an emerging research field of cognitive neuroscience and education, and what is the nature of the new field?

3 Methods and Data

We aim to identify the dynamics of the new learning sciences at the interface of the brain sciences and neurosciences, cognitive sciences and educational research. To do this, we use bibliometric methods, combined with expert consultation at several stages of the project in which we essentially study the dynamics of research fields in terms of the emerging, stabilizing and changing formal communication networks. This can be done at two levels: the level of scientific journals and the level of research papers. The first approach focuses on research fields and specialties, the latter on research topics and research fronts. In this report we start at the journal level, and following that we focus the analysis at the level of papers. In this section, we explain briefly the methods used.

3.1 Research fields as journal networks

Researchers use journals as a means for communication. Through citations, the papers in a journal relate to the relevant stock of knowledge. We expect journals belonging to the same subfield to (a) cite each other at a reasonable level, and (b) refer to the relevant literature in the same way. The method we use here for identifying the set of journals that constitute a subfield is explained in detail elsewhere (Van den Besselaar & Leydesdorff, 1996) and therefore we only describe it here briefly.

The analysis starts with the core journals in a field, as indicated by specialists. These core journals form the entrance journals for the analysis. We determine the citation environment of these entrance journals, by including all journals in the analysis that cite or are cited by the entrance journals. We used a low (0.5%) threshold in the citing and in the cited dimension to determine the citation environment of the entrance journals. A rather low threshold was chosen, in order to include a broad set of citing and cited journals. After all we are interested in the linkages between the subfields of neuroscience, cognitive science and educational research and these linkages may only be weakly developed. After having determined the set of journals, we create a journal-journal citation matrix, using ISI's Journal Citation Reports. Table 1 shows as an example a part of this matrix for the *Journal of Cognitive Neuroscience*, one of the main journals in the field under study.

Table 1 Journal-journal citation matrix of J Cogn Neurosci (partially)

	ann ny acad sci	annu rev neurosci	biol psychol	brain	brain cognition	brain lang	brain res	brain res bull	cereb cortex	clin neuro physiol	…
ann ny acad sci	641	9	35	64	13	15	365	60	25	0.01	…
annu rev neurosci	23	59	10	46	13	8	190	24	121	0.06	…
biol psychol	4	0	122	9	17	10	101	7	11	0.28	…
brain	58	18	39	1042	119	187	373	146	254	0.39	…
brain cognition	15	0	26	49	134	48	104	8	27	0.09	…
brain lang	11	0	5	59	37	645	116	3	23	0.01	…
brain res	196	40	34	139	8	14	3091	481	206	0.13	…
brain res bull	32	9	12	20	3	2	320	193	24	0.22	…
cereb cortex	31	16	30	128	35	67	348	33	571	0.16	…
….	…	…	…	…	…	…	…	…	…	…	…

Then, a factor analysis of the journal-journal citation matrix is made. Journals that have similar citation patterns cluster within the same factor. Thus, a factor-analysis of the matrix results in a set of factors, with each representing a specific research subfield. As an example, table 2 shows the factor analysis for the *Journal of Cognitive Neuroscience*. The columns of the table represent the factors and the rows of the table represent the factor loadings of the individual journals. The factor that includes the entrance journal represents the field under study, whereas the other factors (of which the entrance journal does not load on) represent the localised research field environment, either as providers of knowledge for the focal field, or as users of the focal research field, or both.

In this case, we see the entrance journal (*Journal of Cognitive Neuroscience*) loading on the human brain mapping factor, and has an almost equally high loading on the cognitive neuropsychology factor. The local environment of the *Journal of Cognitive Neuroscience* consists primarily of a large neuroscience factor (factor 1). Other factors are cognitive neuropsychology (factor 2), cognitive psychology (factor 3), general science (factor 4), brain research (factor 5), human brain mapping (factor 6), psychophysiology (factor 7) and finally perception research (factor 8). The naming of the factors is derived from the titles of the journals belonging to a factor. The *Journal of Cognitive Neuroscience* loads on neuroscience (factor 1), cognitive neuropsychology (factor 2) and human brain mapping (factor 6) and therefore may be called multidisciplinary. This method will be used to study the relations between the different fields of brain and neuroscience, cognitive science and educational research. The relations between the various subfields can have three forms (Van den Besselaar, 2009; Van den Besselaar & Heimeriks 2001):

1. Parts of the mentioned fields have merged into a new **interdisciplinary** learning science. If that is the case, the factor analysis will show a cluster of journals representing the new field of TLS, but also factors representing the different research fields it emerges from.

2. A single journal or a few **multidisciplinary** journals function as 'integrators' between different subfields. In table 2, we see several journals loading moderately to high on more than one factor, such as the *Journal of Cognitive Neuroscience*. This journal loads on three factors: human brain mapping, cognitive neuropsychology and neuroscience - and can be considered as a multidisciplinary link between these factors. This should be distinguished from the journals loading on the brain research factor. Almost all of these journals also load on the neuroscience factor, suggesting that brain research is a subfield of neuroscience.

3. No new subfield is emerging, but the various relevant research subfields become **increasingly related**. This means that citation relations between the subfields emerge and become more intensive. If that is the case, we may find journals on education increasingly citing neuroscience journals and vice versa. The two subfields then remain distinctive, but use each other's results and approaches.

To distinguish whether a new learning science is emerging and in what form, we will apply the described method on a series of relevant journals, as mentioned by specialists in the field. The results of the factor analysis will also be presented in the form of a map. The position of a cluster of journals (a factor or subfield) on this map indicates the similarity between different subfields. The closer two subfields are together, the higher the similarity between the subfields.

Table 2 Journal of Cognitive Neuroscience 2006 - Rotated Component Matrix, 8 factor solution

	Neuro-science	Cogn neuro psychol	Cognitive psychology	Science/ Nature	Brain research	Human brain mapping	Psycho-physiol	Perception
j neurosci	.977							
curr opin neurobiol	.959							
trends neurosci	.959							
annu rev neurosci	.946							
nat neurosci	.939							
eur j neurosci	.916							
neuron	.906							
nat rev neurosci	.900			.366				
cereb cortex	.860					.357		
neuroscience	.820				.455			
j physiol-paris	.791			.349				
j neurophysiol	.761							
brain res	.712				.540			
neuroreport	.698				.332	.437		
neurosci biobehav r	.682				.483			
neurosci lett	.671				.578			
trends cogn sci	.627			.336		.361		
neuropsychology		.906						
j int neuropsych soc		.902						
cortex		.856						
brain cognition		.825				.352		
neuropsychologia		.824				.375		
cogn neuropsychol		.675						
brain lang		.598						
brain		.593			.436			
neurology		.445			.419			
j exp psychol gen			.923					
j exp psychol learn			.922					
mem cognition			.897					
j mem lang			.874					
psychol rev			.786					
psychol sci			.681					.334
cognition			.558	.329				
lect notes comput sc	.313			.896				
Science				.862				
p natl acad sci usa	.379			.862				
nature	.300			.835				
ann ny acad sci	.359			.806				
prog brain res	.506				.692			
brain res bull	.598				.690			
exp brain res	.336				.500			.478
clin neurophysiol					.466		.428	
hum brain mapp						.897		
neuroimage						.880		
j cognitive neurosci	.332	.513				.672		
cogn affect behav ne	.511	.380				.569		
psychophysiology							.956	
boil psychol							.949	
int j psychophysiol							.917	
percept psychophys			.372					.766
vision res								.687
j exp psychol human			.603					.664

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a Rotation converged in 8 iterations.

The question to answer is whether we find signs of an emerging - brain and neuroscience based - new paradigm in the learning sciences and whether it has a multi-, inter-, or transdisciplinary nature. Emerging interdisciplinary fields are represented by heterogeneous journals, which load together on a new - generally not too large - factor. The second form, where a single multi-disciplinary journal functions as an integrator between fields, can also be identified by inspecting the factor analysis results: do we find journals loading on the different relevant factors, e.g., on a cognitive neuroscience factor *and* on an educational research factor? Finally, the third form of interaction between existing fields can be answered by studying the citation *relations* between the research fields: do the fields under study communicate with each other? Do the factors representing the fields show substantial mutual citation relations? How important is the information stream between the research fields, compared to the internal information streams?

3.2 Research topics as paper networks

After having analyzed the relevant journal set, we proceed with analyzing in more detail the dynamics of research topics. For this we focus the analysis on the level of journal articles to see whether we can find clusters of related journal articles that address topics in new learning science. To do so we calculate similarities between journal articles, based on the sharing of word-reference combinations (Van den Besselaar & Heimeriks, 2006). Two articles share a word-reference combination, when both articles share a title word as well as a reference. When two articles are highly similar it indicates that they are close to each other both in terms of the knowledge they use (indicated by the sharing of references) as well as in terms of subject matter (indicated by the sharing of title words). The set of articles that forms input into the analysis is created by an extensive topic word search in the ISI database. More details of the method are explained in chapter 6.

3.3 Transdisciplinary research networks

In order to find out whether transdisciplinary research is emerging, we analyze the institutional affiliation of authors, as well as the co-author relations within educational sciences. We are especially interested in the question whether researchers can be found that are based in organizations in the educational practice, and whether co-authorships between academic researchers and these '*practice researchers*' can be found. Details of the method are explained in chapter 7.

3.4 Core journals in brain, neuro and cognitive sciences

We identified the main researchers in brain and neuroscience, and in cognitive science, through university websites and through the NOD database which contains details of all of the Netherlands' full and associate professors. We started with a letter to 45 full professors, asking them to list the main journals in the broad field of neurosciences, brain research and cognitive sciences. From the 18 respondents a list of 74 journals was created of which 44 were only mentioned once.[1] 30 journals were mentioned at least twice. These are presented in table 3.
We notice a few characteristics of this long list of journals:

1. The dominance of neuroscience journals at the top of the list.
2. Cognitive science, and (cognitive) psychology journals are lower on the list.
3. Several general journals are - of course - mentioned often, such as *Nature*, *Science*, *PNAS*.

We used all journals mentioned at least twice as entrance journal for the analysis, excluding the general review journals *Science, Nature, PNAS, Nat Review Neuroscience, Current Biology* and *PLOS Biology*. We also excluded the journals *Cognitive Brain Research* and *Cognitive, Affective*

1 See annex 1 for the list of respondents and annex 3 for the list of journals.

and Behavioral Neuroscience as these journals are not covered by the Web of Science. Finally, because of limitations in data processing capacity we had to exclude one other journal from the analysis, *Brain and Development* (this journal has the lowest number of total citations, the lowest number of citations per issue and the lowest impact factor.)

Table 3 Core journals in cogn/neuro/brain science, mentioned by specialists

Journal name	Times mentioned	Total cites	Number of issues	Cites per issue	Impact factor
Nature Neuroscience	13	22657	206	110	14.8
Journal of Neuroscience	11	103022	1415	73	7.4
NeuroImage	10	20723	761	27	5.6
Nature	9	-	-	-	-
Science	9	-	-	-	-
Cerebral Cortex	8	9614	209	46	6.4
Journal of Cognitive neuroscience	8	7778	168	46	5.2
Neuron	8	48224	294	164	13.9
Brain Research	7	54874	1397	39	2.3
Nature reviews neuroscience	7	-	-	-	-
Proc National Academy Sciences	7	-	-	-	-
Brain	6	26132	276	95	7.6
Trends in Cognitive science	6	5965	71	84	9.4
Trends in Neuroscience	6	15117	84	180	13.5
Human Brain Mapping	5	4943	89	56	4.9
Psychophysiology	4	6645	73	91	3.2
Current opinion in neurobiology	3	8648	94	92	9.3
European journal of neuroscience	3	20835	707	29	3.7
Psychological Review	3	14712	31	475	8.8
Behavioral and brain sciences	2	4425	10	443	15.0
Brain and Cognition	2	3388	86	39	2.9
Brain and Development	2	2033	127	16	1.6
Cognition	2	5717	75	76	4.2
Cognitive Brain Research[2]	2	3319	-	-	2.6
Cogn, Affective & Behav Neurosci[3]	2	-	-	-	-
Current Biology	2	28406	340	84	11.0
Hippocampus	2	4259	99	43	4.2
Learning and Memory	2	2931	105	28	5.1
Neuropsychologia	2	11856	283	42	3.9
Public Libary of Sci - Biology PLOS	2	6100	192	32	14.1

Highlighted journals are used as entrance journal in the analysis.

2 This journal is not processed by ISI.
3 This journal is not processed by ISI.

4 Mapping the relevant research fields

4.1 The structure of the neuro- and cognitive sciences

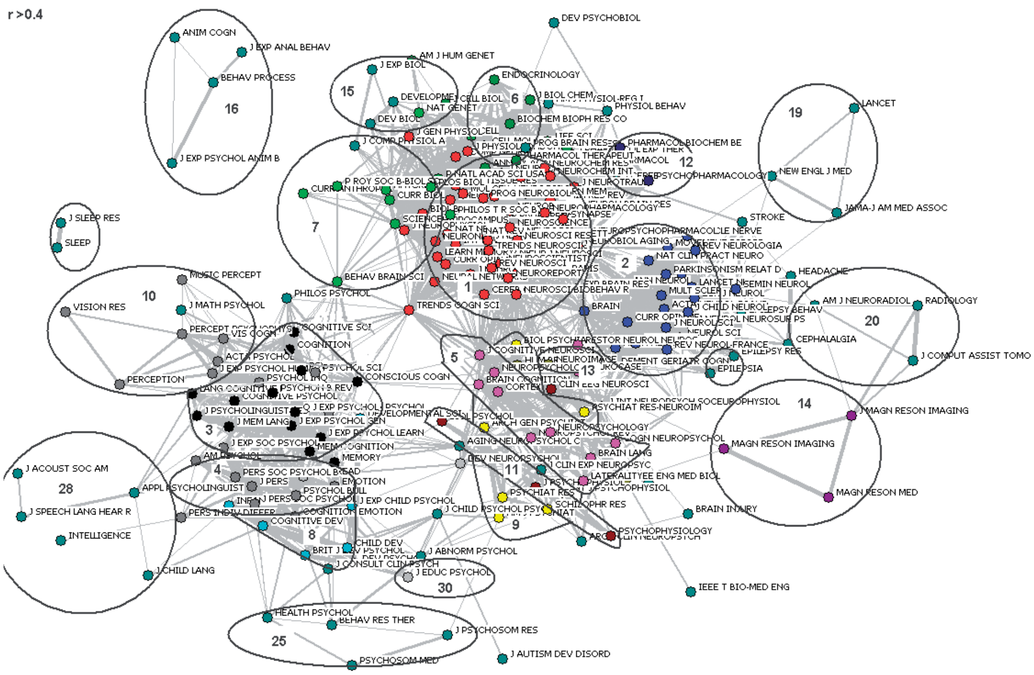
Using our tool for journal-journal citation analysis enables us to include several entrance journals at once. We selected the journals highlighted in table 3. These 21 journals have overlapping citation environments, and together their environment consists of 228 journals. A factor analysis of the journal-journal citation matrix results in 39 factors with an eigenvalue larger than 1.
An overview of all factors is presented in table 4. As we can see there is a limited number of large factors in which many journals cluster together and a long tail of small factors in which only a few journals cluster together. Figure 1 shows the clustering of the journals resulting from the factor analysis.

Table 4 Factors in the citation environment of brain, neuro, and cognitive science journals

Factor	Factor name	Nr jrnls		Factor	Factor name	Nr jrnls
1	Neuroscience	50		20	Radiology	3
2	Neurology	23		21	Experimental brain research	2
3	Cognitive psychology	14		22	Clinical psychology	3
4	Social and personal psychology	12		23	Clinical neuropsychology	4
5	Cognitive neuropsychology	12		24	Headache	2
6	Life sciences / pharmacology	11		25	Health psychology	3
7	Science / nature, etc.	12		26	Sleep research	2
8	Developmental psychology	7		27	Stroke	2
9	Psychiatry	6		28	Speech	2
10	Perception	8		29	Exp comp boil	2
11	Psychophysiology	6		30	Educational psychology	3
12	Psychopharmacology	3		31	Mathematical psychology	2
13	Human brain mapping	3		32	Child language	2
14	Magnetic Resonance Imaging	3		33	Aphasiology	1
15	Developmental biology	2		34	Autism	2
16	Animal behavior	4		35	Medical imaging	2
17	Epylepsia	3		36	Neurosurgery	1
18	Psychobiology / physiol & behavior	3		37	Intelligence	1
19	Medicine general	3		38	Sport/ exercise	1
				39	Pain	1

The main factors are indicated in the figure. Proximity of journals in the map indicates their similarity in terms of citation behaviour. The closer two journals are, the more similar their citation behaviour. The entrance journals of the analysis are not equally distributed over all factors. Table 5 presents the main factor loadings of the entrance journals. It appears that the broad field of research that we are mapping here is dominated by a large **Neuroscience factor** (F1). Eleven of the entrance journals belong to this factor: *European Journal of Neuroscience*, *Journal of Neuroscience*, *Trends in Neuroscience*, *Hippocampus*, *Nature Neuroscience*, *Current Opinion in Neurobiology*, *Learning and Memory*, *Neuron*, *Brain Research*, *Cerebral Cortex* and *Trends in Cognitive Science*. Other subfields that are represented by the entrance journals are smaller and include: **Neurology** (F2) with the entrance journal *Brain*; **Cognitive Psychology** (F3), with the entrance journals *Psychology Review* and *Cognition*; **Cognitive Neuropsychology** (F5),

Figure 1 The factor structure of brain research, neuroscience and cognitive science



with the entrance journals *Neuropsychologia; Brain and Cognition* and the *Journal of Cognitive Neuroscience*; a factor with broad **multidisciplinary** science journals (F7) like *Nature*, *Science* and *PNAS*, including the entrance journal *Behavioral and Brain Sciences*; **Psychophysiology** (F11), with the entrance journal *Psychophysiology*; and **Human Brain Mapping** (F13), with the entrance journals *Neuroimage* and *Human Brain Mapping* (all marked yellow in table 5). Other larger factors, representing related subfields in this map are **Social and personal psychology** (F4), **Life Sciences/ Pharmacology** (F6), **Developmental Psychology** (F8), **Psychiatry** (F9) and **Perception** (F10). For an overview of the smaller factors we refer to table 4.

The loadings on the neuroscience factor are high and most of the neuroscience journals do not load on any of the other factors, indicating that the neuroscience factor represents a disciplinary field of research. The journal *Trends in Cognitive Sciences* forms a noticeable exception, as it has a relatively low loading on the neuroscience factor and also loads on two other factors: cognitive neuropsychology and human brain mapping and as such, this journal has a multidisciplinary nature. Other entrance journals that show a multidisciplinary citation pattern are

- *Psychology Review*, in between cognitive psychology, personal and social psychology and a factor with mathematical psychology;
- *Cognition*, in between cognitive psychology, developmental psychology, perception, and child language;
- *Journal of Cognitive Neuroscience*, in between cognitive neuropsychology, neuroscience, psychophysiology and human brain mapping and;
- *Behavioral and Brain Science*, in between social and personal psychology, broad multidisciplinary science and mathematical psychology.

Table 5 Parts of the factor solution underlying map 1. (Entrance journals (yellow) and educational journals (green) only)

	1 neuroscience	2 neurology	3 cognitive psychology	4 social & personal psy	5 cognitive neuropsychology	7 science / nature	8 developmental psychology	10 perception	11 psychophysiology	13 human brain mapping	30 educational psychology	31 mathematical psychology	32 child language
Eur J Neurosci	0.98												
J Neurosci	0.96												
Trends Neurosci	0.94												
Hippocampus	0.91												
Nat Neurosci	0.88												
Curr Opin Neurobiol	0.88												
Learn Memory	0.86												
Neuron	0.86												
Brain Res	0.86												
Cereb Cortex	0.84									0.31			
Trends Cogn Sci	0.56				0.32					0.30			
Brain	0.38	0.77			0.32								
Psychol Rev			0.55	0.50								0.42	
Cognition			0.46				0.39	0.33					0.34
Neuropsychologia					0.84								
Brain Cognition					0.82								
J Cognitive Neurosci	0.40				0.56				0.33	0.50			
Behav Brain Sci				0.32		0.52						0.33	
Psychophysiology									0.91				
Hum Brain Mapp					0.33					0.84			
Neuroimage	0.32				0.32					0.79			
J Educ Psychol							0.39				0.75		
J Res Read			0.40				0.37				0.70		
Dev Neuropsychology					0.53						0.56		

Note that we only found two journals on education: the *Journal of Educational Psychology* and the *Journal of Research in Reading*, which form a small factor (F30) together with *Developmental Neuropsychology*. Analyzing the citation environment of the latter journal, it shows itself as a multidisciplinary journal which links developmental psychology, neuropsychology and child neurology. In its environment we also find a minor factor of educational psychology, learning disabilities and reading/writing. However, the journal itself does not focus on educational practice, apart from learning disabilities.[4] In other words, looking from the perspective of the neurosciences and cognitive sciences, the citation relations with educational research are very small.

4.2 The structure of educational research

In a similar manner as before, we asked specialists in the field about the important journals in educational research, and received 17 responses (see annex 2). This resulted in a list of 75 journals of which 13 journals were mentioned three times or more and 40 journals were mentioned only once (see annex 4). As for the neurosciences, this indicates that the field of educational research is very broad with many probable sub-disciplines. Table 6 shows the journals that were mentioned by at least three of our informants, plus *Teaching and Teacher Education* of which we expect that it gives some additional perspective. The table is completed with ISI data on citations, issues and impact factors. The citation environment of these journals exists of 240 journals, of which 170 are processed in the ISI citation index. The factor analysis of this set of journals results in 46 factors (See table 7).

Table 6 Entrance journals used for mapping the field of educational research

Journal name	Times mentioned	no of issues	no of citations	citations per issue	impact factor
Learning And Instruction	8	40	696	17.4	1.717
Journal Of Educational Psychology	8	63	5152	81.8	2.025
Reviews Of Educational Research	6		1529		1.897
Instructional Science	4	17	350	20.6	1.810
Journal Of The Learning Sciences	4	15	456	30.4	3.040
Child Development	3	114	13831	121.3	3.893
Developmental Psychology	3	107	8591	80.3	3.556
Journal Of Experimental Child Psychol	3	55	2379	43.3	2.062
Cognition And Instruction	3	13	582	44.8	1.000
Contemporary Educational Psychology	3	19	694	36.5	1.089
Educational Psychologist	3	18	1367	75.9	2.795
Science Education	3	48	1084	22.6	1.362
Journal Of Research In Science Teaching	3	43	1377	32.0	1.022
Teaching And Teacher Education	2	85	606	7.1	0.496

Figure 2 shows the clustering of the journals resulting from the factor analysis in which the main factors/subfields are indicated. This includes the subfields to which the entrance journals belong. Five out of the 14 entrance journals are found within the field of educational psychology (F3): *Contemporary Educational Psychology, Educational Psychologist, Learning and Instruction, Journal of Educational Psychology* and *Instructional Science*. The journals *Cognition and Instruction* and *Journal of the Learning Sciences* form small factors (F27 and F37 respectively), but are close to the field of educational psychology on which they also load (see table 8). Three journals belong to the first factor, which is the subfield of developmental psychology: *Child Development, Developmental Psychology* and the *Journal of Experimental Child Psychology*.

4 It is stated on the journal's website: "Devoted to exploring relationships between brain and behavior across the life span, *Developmental Neuropsychology* publishes scholarly papers on the appearance and development of behavioral functions, such as language, perception, and social, motivational and cognitive processes as they relate to brain functions and structures. Appropriate subjects include studies of changes in cognitive function—brain structure relationships across a time period, early cognitive behaviors in normal and brain-damaged children, plasticity and recovery of function after early brain damage, the development of complex cognitive and motor skills, and specific and nonspecific disturbances, such as learning disabilities, mental retardation, schizophrenia, stuttering, and developmental aphasia. In the gerontologic areas, relevant subjects include neuropsychological analyses of normal age-related changes in brain and behavioral functions, such as sensory, motor, cognitive, and adaptive abilities; studies of age-related diseases of the nervous system; and recovery of function in later life." (http://www.tandf.co.uk/journals/titles/8756-5641.asp , accessed 04-12-2008).

And another three journals *Science Education*, *Journal of Research in Science Teaching* and *Reviews of Educational Research* belong to the science education factor (F6). Finally, the last entrance journal - *Teaching and Teacher Education* - loads on a factor with other teacher education journals (F10).

Table 7 Factors in the citation environment of educational journals

Factor	Factor name	Nr jrnls		Factor	Factor name	Nr jrnls
1	Developmental psychology	33		24	Developmental disorders	3
2	Psychology	20		25	Various	3
3	Educational psychology	19		26	Intelligence	3
4	Cognitive psychology	16		27	J res math educ/ cogn & instruction	2
5	Nature/science etc	12		28	Human-computer interaction	2
6	Science education	7		29	Motor skills	3
7	Dyslexia	8		30	Adolescence	1
8	Special educ / learning dissabilities	6		31	Education mixed	3
9	Clinical psychology	5		32	Modern languages	2
10	Teacher education	8		33	Decision support	2
11	Sports education	5		34	Pediatrics	3
12	Perception / psychophysics	4		35	Human factors	2
13	Literature/reading	4		36	Engineering education	2
14	Educational technology	4		37	Learning science	2
15	Medical teaching/education	3		38	Computers and human behavior	2
16	Computers / artificial intelligence	5		39	Pedagogy	2
17	British educational research	4		40	Higher education	2
18	Cognitive neuropsychology	4		41	Gifted children	2
19	Higher education	3		42	Teaching psychology	1
20	Speech-language -hearing	3		43	Chemistry education	2
21	Family	3		44	Career assessment	1
22	Various / methods	4		45	Teaching physiology	2
23	Cognition - child language	3		46	Deaf	1

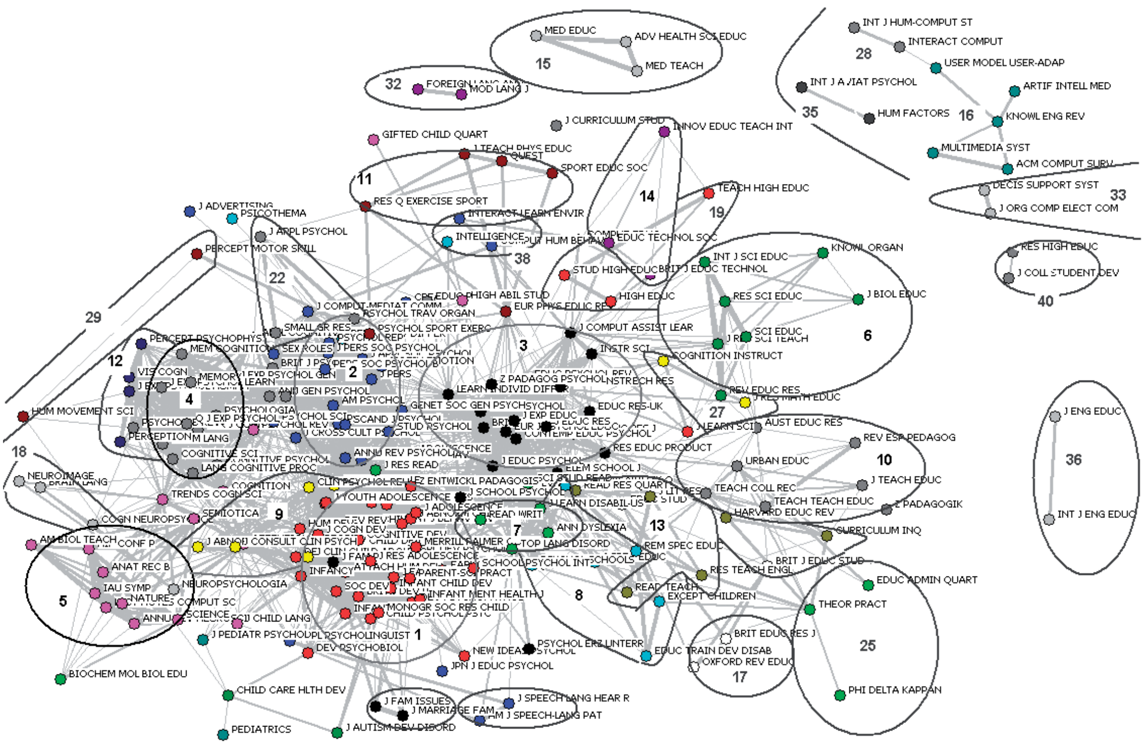
Some larger subfields in the educational research map are Psychology (F2), Cognitive Psychology (F4), Dyslexia (F7), Special Education/Learning Disabilities (F8), Clinical Psychology (F9) and Perception/Psychophysics (F12).

Apart from a variety of education and teaching related research fields, we also find some journals from the neurosciences and from cognitive neuropsychology. Factor 5 contains the journals *Annual Review of Neuroscience* and *Trends in Cognitive Science* as well as a number of science review journals like *Nature* and *Science*. Factor 18 represents the field of cognitive neuropsychologia and human brain mapping and includes the journals *Neuropsychologia*, *Neuroimage* and *Cognitive Neuropsychology*. Finally we find the journal *Cognition* in factor 23.

Finally we find a large number of small factors that deal with small specialties within the heterogeneous field of educational research. For example sports education (F11) or engineering education (F36).

The factor loadings of the entrance journals and of the neuroscience and cognitive neuroscience journals are shown in table 8 (in yellow and green respectively). We did not find any journals that load both on an educational factor as well as on a factor in neuroscience, cognitive neuropsychology or cognitive psychology. Only the entrance journal *Journal Experimental Child Psychology* loads both on developmental psychology as well as on cognitive psychology.

Figure 2 The factor structure of educational research



As no journals in educational sociology and educational economics were included in the top 13 list of the educational research field, we checked whether the citation environment of three sociological and economics journals (i.e. *Sociology of Education*; *British Journal of the Sociology of Education*; *Economics of Education Review*) would add to the analysis. However, the citation environment of these three journals consists of some 140 journals, of which no cognition and neuroscience journals. Only a few psychological journals are included, such as *Developmental Psychology*, the *Journal of Educational Psychology*, and the *Journal of School Psychology*. The environment of *Sociology of Education* is dominated by sociological journals. There are some linkages to other educational subfields, among which educational psychology. The environment of the *British Journal of the Sociology of Education* is dominated by British educational journals, which indicates a national orientation within the field of educational research. Finally, the *Economics of Education Review* represents a strand of applied economics. Other educational subfields are only marginally visible in the environment of *Economics of Education Review*. And fields like educational psychology and developmental psychology are absent.

In other words, although an additional map based on these three entrance journals would add to a complete overview of the educational research field, this would not inform our question here: the relation between the educational research field and the field of neuroscience and cognitive neurosciences. Therefore we do not include this additional map here.

Table 8 Parts of the factor solution underlying map 2
(Entrance journals (yellow) and (cognitive)neuroscience journals (green) only)

	1 Developmental psych	3 Educational psych	4 Cognitive psychology	5 Nature/science/neurosci	6 Science education	7 Dyslexia/reading/writing	10 Teacher education	13 Literature/reading	14 Educational technol	18 Cognitive neuropsychol	23 Cognition, attention, child language	27 J res math educ/ cogni&instr	37 J learning sciences
Child Dev	0.98												
Dev Psychol	0.97												
J Exp Child Psychol	0.59		0.36			0.41							
Contemp Educ Psych		0.90											
Educ Psychol		0.86											
Learn Instr		0.83											
J Educ Psychol	0.31	0.78				0.39							
Instr Sci		0.59			0.38				0.33				
Annu Rev Neurosci				0.95									
Trends Cogn Sci			0.38	0.52						0.47	0.31		
Sci Educ					0.96								
J Res Sci Teach					0.92								
Rev Educ Res					0.73			0.34					
Teach Teach Educ							0.86						
Neuropsychologia										0.83			
Neuroimage										0.69			
Cogn Neuropsychol			0.30							0.61			
Cognition	0.30		0.52								0.57		
Cognition Instruct		0.34										0.77	0.29
J Learn Sci		0.32										0.32	0.60

4.3 The structure of cognitive psychology and developmental psychology

In this section we will present a third map, which focuses on the structure of two subfields - cognitive psychology and developmental psychology. The reason for this focus is that both these subfields were visible in the map of the neuro and cognitive science field as well as in the map of the educational research field. These subfields are thus interesting, because they may form a bridge between the two larger fields represented in the first and second map. After having done this, we have the complete map of the domain under analysis.

As entrance journal for this map we used eight journals. Three were mentioned by the informants from the field of neuro and cognitive science: *Psychological review*, *Behavioral and Brain Sciences* and *Cognition*; two were mentioned by the informants from the field of educational research: *Child Development* and *Developmental Psychology*; and three journals were selected because they are high impact journals from the field of Cognitive Psychology: *Journal of Experimental Psychology: Learning, Cognition and Memory*; *Cognitive Psychology* and *Cognitive Science*. The total number of journals in the citation environment is 160 and the factor analysis results in 29 factors (See table 9). Figure 3 shows the map based on these entrance journals of cognitive psychology / developmental psychology. The main factors/ subfields are indicated in the figure.

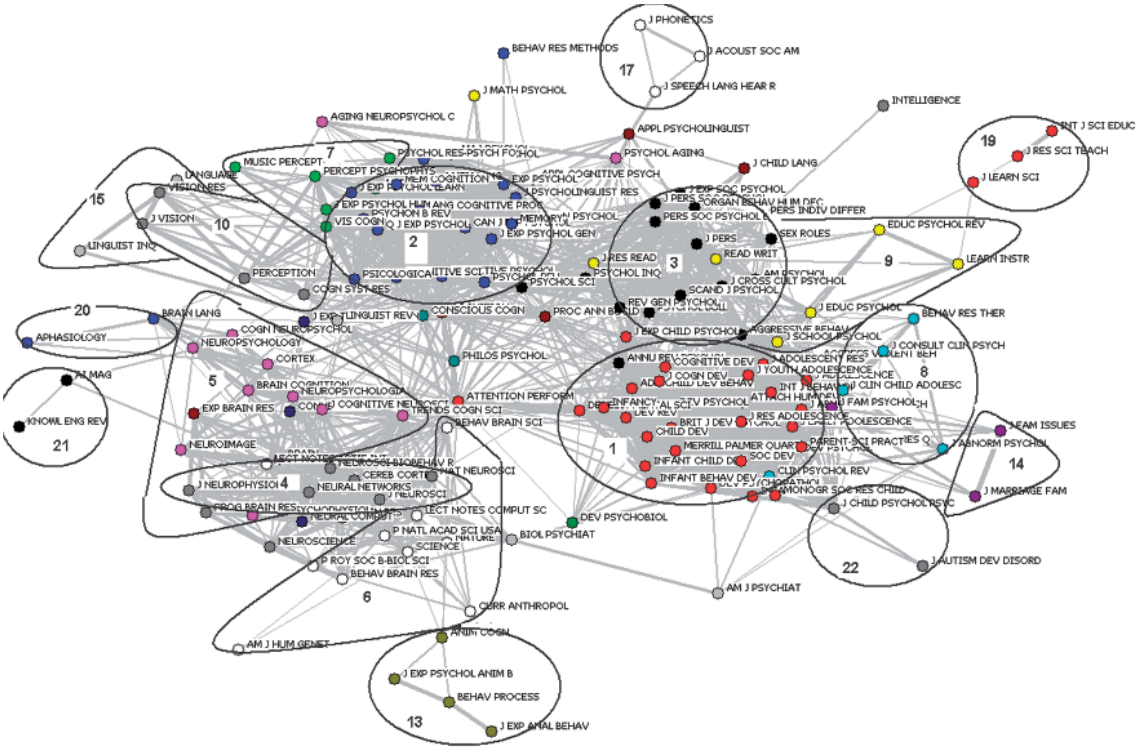
Table 9 Factor structure of Cognitive Psychology and Developmental Psychology

Factor	Factor name	Nr jrnls		Factor	Factor name	Nr jrnls
1	Developmental psychology	29		16	Philosophy of psychology	2
2	Cognitive psychology	20		17	Acoustics	3
3	Personal and social psychology	15		18	Psychiatry	2
4	Neuroscience	10		19	Science teaching	3
5	Cognitive neuropsychology	10		20	Aphasiology	2
6	Nature/science	7		21	Knowledge engineering / ai	2
7	Perception psychophysics	6		22	Autism	2
8	Clinical psychology	6		23	Psychology ogf aging	2
9	Education	6		24	Developmental psychobiology	1
10	Vision/perceptiom	4		25	Computers educ & human behav	3
11	Child language	4		26	Pediatrics	2
12	Artificial intelligence	5		27	Mathematical psychology	1
13	Behavior	4		28	Intelligence	2
14	Family	3		29	Exp. Brain research	1
15	Lingusitic research	3				

We find the following factors - in order of importance. The largest factor is on **Developmental psychology**. The entrance journals *Developmental Psychology* and *Child Development* belong to this factor. The second is the **Cognitive Psychology** factor with the entrance journals: *Journal of Experimental Psychology: Learning, Cognition and Memory*, *Cognitive Psychology, Cognitive Science* and *Psychological Review*. The third factor is on **Personal and social psychology** and as a fourth and fifth factor we find the fields of **Neuroscience** and of **Cognitive Neuro-psychology** respectively. The sixth factor is the **General science** factor with journals like Science and *Nature* and the entrance journal *Behavioral and Brain Sciences*. As we can see in table 10 this journal also loads on a smaller factor on the **Philosophy of psychology** (factor 16).[5]

5 This position reflects the journal's special character. As can be read on the journal's homepage: "BBS is the internationally renowned journal with the innovative format known as Open Peer Commentary. Particularly significant and controversial pieces of work are published from researchers in any area of psychology, neuroscience, behavioural biology or cognitive science, together with 10-25 commentaries on each article from specialists within and across these disciplines, plus the author's response to them. The result is a fascinating and unique forum for the communication, criticism, stimulation, and particularly the unification of research in behavioural and brain sciences from molecular neurobiology to artificial intelligence and the philosophy of the mind."

Figure 3 The map of cognitive psychology and developmental psychology



Then we find some medium-sized factors on **Perception and psychophysics** (F7), **Clinical Psychology** (F8) and a factor on **Education** (F9), which includes the journals *Educational Psychology Review*, *Journal of Educational Psychology, Learning and Instruction, Journal of School psychology, Reading & Writing* and the *Journal of Research on Reading*. The latter two journals also load on the cognitive psychology factor and on the child language factor. The entrance journal *Cognition* belongs to a smaller factor on **Child language** (F11), but also loads (0.4) on the Cognitive Psychology factor (F2).

Finally there is a second factor related to education, factor 19 on **Science Teaching**, to which belong *International Journal on Science Education*, *Journal of the Learning Sciences* and *Journal of Research in Science Teaching*. For an overview of the other smaller factors see table 9.

The factor structure overlaps with the structure of neuroscience, and several factors included in the map of figure 3 are also in figure 1. However, whereas figure 1 includes two psychology factors (cognitive and developmental psychology), map 3 has five psychology factors that are also somewhat larger than in map 1. And, importantly, we now find more education related journals in the map.

Table 10 Factorloadings of entrance journals (yellow) and educational journals (green) in the field of cognitive psychology and developmental psychology

	1 Developmental psychology	2 Cognitive psychology	6 Nature/science	7 Perception psychophysics	9 Education	11 Child language	15 Lingusitic research	16 Philosophy of psychology	19 Science Teaching	27 Mathematical psychology
Child Dev	0.98									
Dev Psychol	0.97									
J Exp Psychol Learn		0.97								
Cognitive Psychol		0.70		0.46						
Cognitive Sci		0.62					0.32	0.30		
Psychol Rev		0.54								0.41
Behav Brain Sci			0.52					0.51		
Educ Psychol Rev					0.89					
J Educ Psychol	0.36				0.87					
Learn Instr					0.80					
Read Writ		0.31			0.68	0.38				
J School Psychol	0.64				0.66					
J Res Read		0.34			0.54	0.38				
Cognition		0.40		0.33		0.43				
J Res Sci Teach									0.94	
Int J Sci Educ									0.93	
J Learn Sci									0.54	

4.4 Conclusions

We mapped the broad field of the cognitive sciences - ranging from neurosciences to cognitive neuropsychology and cognitive psychology (fig. 1) as well as the broad field of educational research (fig. 2) to see whether we could find the development of a learning science. The two maps show a large number of research fields that are positioned in the environment of the fields under study. But in none of the two do we find an emerging cluster that consists of journals from the various constituent research fields, thus we do not find an emerging interdisciplinary factor of a learning science.

There is some overlap in the citation environments between both maps. In the first map (neuroscience and cognitive research) we find one educational research journal and one journal in reading research. In the second map (educational research), we find a few general neuroscience journals and a few journals in cognitive neuropsychology. Also in the environment of both maps we find a factor on cognitive psychology and a factor on developmental psychology.

We therefore made a third map in which we zoom in on this overlapping citation environment of cognitive psychology and developmental psychology. This third map overlaps partly with the first one, but adds a wider set of psychological subfields to the map. Two factors from the educational research field are visible, a factor dominated by educational psychology and a smaller factor on science education. Again, we do not find an emerging interdisciplinary factor of a learning science.

In all three maps we find some multidisciplinary journals that load on a heterogenous set of factors. Only a few of these journals bridge the first and the second map. In the first map we find *Journal of Research in Reading* loading both on the educational research factor as well as on the cognitive psychology factor. In the second map we find *Journal of Experimental Child Psychology* loading both on the developmental psychology factor and on the cognitive psychology factor. In the third map we find the journals *Reading & Writing* and *Journal of Research on Reading* loading on an educational factor as well as on cognitive psychology. However no single journal was found that loads on the various factors representing neuroscience, cognitive neuropsychology, cognitive psychology and educational research. In other words, we did not identify strongly multidisciplinary journals bridging more factors.

Thus, the third option remains: is there a stream of knowledge between cognitive sciences, neurosciences and educational research emerging? Do these fields inform each other in a substantial way? The next section focuses on the citation relations between the various subfields: so not on similarity and emerging integration, but on knowledge streams and mutual dependency between the various subfields.

5 Knowledge transfer between neuroscience, cognitive research and educational research

Now that we have mapped both the fields of educational research as well as the fields of neuroscience and cognitive neuroscience research, we can address the question to what extent there is knowledge exchange between these fields, what is the direction of knowledge exchange and between which subfields is knowledge exchange the strongest?

5.1 The strength of knowledge flows between subfields

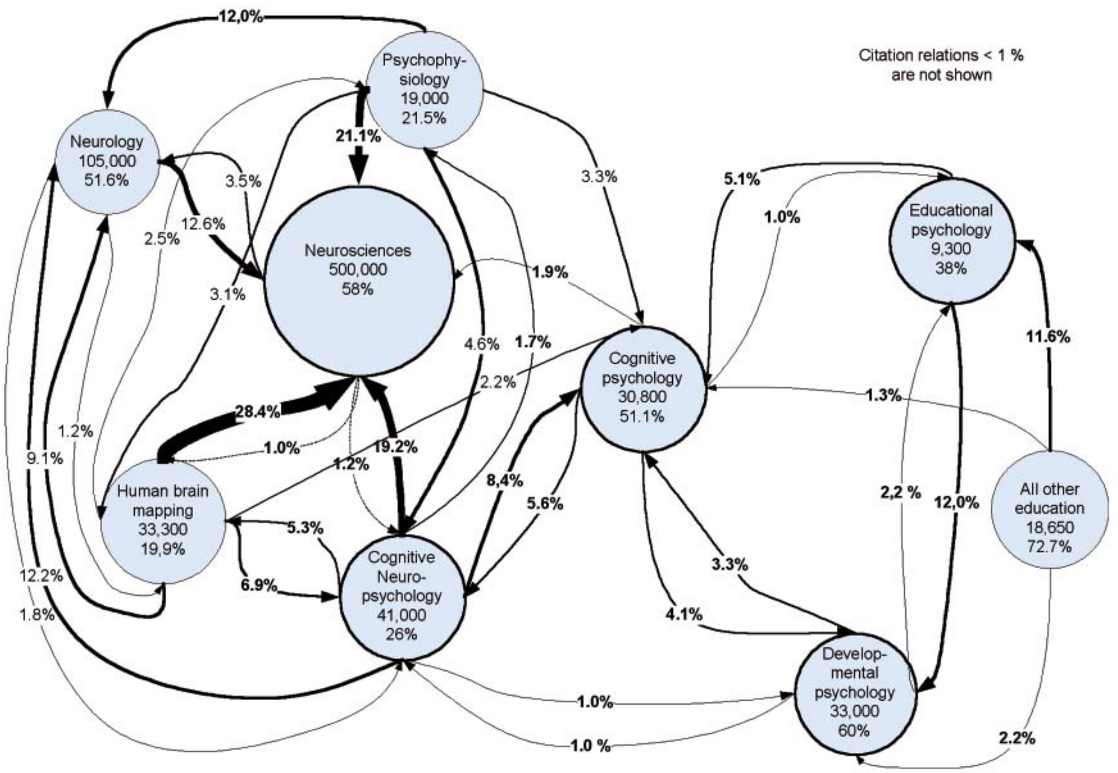
Instead of determining the *positions* of the various fields in the journal networks, we now focus on the *relations* between the research fields: the intensity of knowledge flows between them, as indicated by citations. The more substantial the flow, the more one could expect that a research field uses the knowledge produced by the other. Figure 4 summarizes the results for 2006. The blue circles represent the various subfields. The size of the different subfields varies widely. A rough indicator for field size is given by the total number of citations, which is depicted within the circles. For each subfield we determined the share of citations to the other subfields. This is depicted by the arrows. The direction of the arrows follows the direction of citations. In the case of human brain mapping for example 28.4% of citations found in this field are to publications in the field of neurosciences. Note that in terms of knowledge flow, the arrows should be read backwards. That is to say that 28.4% of the knowledge - used in human brain mapping - is published in neurosciences journals. We also determined the percentage of citations within the subfield. These percentages are printed in the blue circles. Citation relations smaller than 1% are omitted in figure 4. To preserve readability of the figure, we only depicted the major subfields that are relevant for this study. Therefore, we left out the lifesciences or pharmacology, which are important knowledge sources for the neurosciences, but not relevant for transdisciplinary learning science.

In chapter 4 we found a few educational journals within the citation environment of neuroscience, brain research and cognitive neuroscience. Conversely, we found some neuroscience journals and cognitive neuropsychology journals in the citation environment of educational research. However, figure 4 shows that the citation relations between these two large fields of research are actually very low. Between educational psychology and neurosciences and between educational psychology and cognitive neuropsychology citation relations are less than 1%. The same holds for the other educational research subfields, which are taken together as one in figure 4, under the name “All other education.”

Chapter 4 suggested that the subfield of cognitive psychology is one possible bridge between educational research and neuroscience, brain research and cognitive neuropsychology . The analysis of citation relations confirms this expectation. Slightly more than 5% of the citations from educational psychology are to cognitive psychology. Following this, 5.6% of citations in cognitive psychology journals are to the subfield of cognitive neuropsychology and 1.9% of its citations are to the field of neuroscience. Thus, via the field of cognitive psychology, knowledge from neuroscience and cognitive neuropsychology may channel into the field of educational psychology. The knowledge stream in the opposite direction is less developed. Although cognitive neuropsychology has 8.4% of its citations to the field of cognitive psychology, cognitive psychology does not cite much research in educational psychology (only 1.0%).

In chapter 4 we also identified the field of developmental psychology as a possible bridge

Figure 4 Citation relations between the various subfields of neuroscience, brain research, cognitive sciences and educational research



between the two fields of neuroscience/cognition and educational research. It is seen as part of the educational research field by the experts that we consulted and it appeared as one of the subfields in the first map of neuroscience and cognition research. From the analysis of citation relations we learn that developmental psychology is an important knowledge source for the field of educational psychology. 12.0% of citations in educational psychology are to developmental psychology. However the field of developmental psychology hardly functions as a channel for knowledge from the field of neuroscience/cognition. Developmental psychology does not cite the neurosciences and only 1% of citations in developmental psychology are to cognitive neuropsychology.

5.2 Discussion

Many authors have discussed the question where to position the nexus between neuroscience and educational science. Bruer (1997) claimed that a nexus between neuroscience and education is a bridge too far and that the mediation of cognitive psychology is required. Geake (2004) on the other hand says that this is an unnecessary distinction as he claims that "for nearly a decade these two disciplines have been married as one - cognitive neuroscience." (p.93). Pettito & Dunbar (2004) position educational neuroscience within cognitive neuroscience, which they positioned as separate and different from neuroscience. And according to Campbell (2006, p.260) "educational research in cognitive psychology informed by, and informing cognitive neuroscience should constitute the core of educational neuroscience".

The analysis in this chapter and in chapter 4 sheds some interesting light on this discussion. As we showed in chapter 4, Geake's claim that one need not make a distinction between neuroscience and cognitive psychology is wrong in our opinion. Although it is true that cognitive neuroscience - or as we called it cognitive neuropsychology - forms an interdisciplinary field in between neuroscience, human brain mapping/imaging, neurology and cognitive psychology, the fields of neuroscience and cognitive psychology clearly continue to be separated fields. Further, the field of cognitive neuropsychology does not have a particularly strong impact on the field of neuroscience, as only 1.2% of citations in neuroscience are to cognitive neuropsychology.

The next question is whether educational neuroscience or new learning science may emerge from cognitive neuropsychology or from cognitive psychology. The former is claimed by Geake (2004) and Pettito & Dunbar (2004), the latter is claimed by Bruer (1997) and Campbell (2006, p.260). Our analysis has shown that there is no substantive knowledge exchange (through citations) between the field of cognitive neuropsychology and that of educational psychology. Furthermore, the knowledge exchange between cognitive pychology and educational psychology is one-directional. Educational psychology cites cognitive psychology, but not the other way around. When considering the existing linkages between the subfields, it seems that cognitive psychology forms a better starting point for establishing new learning science than cognitive neuropsychology.

6 Research topics in the new learning science

In chapter 4 and 5 the question was whether we could find networks of journals that represent the field of a new learning science. We could not find any. At the level of journals a new learning science is not yet visible. However, many of our informants claim that research in new learning science is published in a broad range of journals. Consequently, it is difficult to pinpoint field-specific journals. In this chapter we focus on a lower level of aggregation, that of articles. If we can't find dedicated journals, than it may still be possible to find clusters of related articles that address topics in the new learning science. If that is the case, research activities exist, even if they are not yet visible as a research field with dedicated journals.

6.1 Method

Can we find clusters of related journal articles that represent the field of the new learning science? In this chapter, similarities between journal articles are calculated, based on shared word-reference combinations (Van den Besselaar & Heimeriks, 2006).[6] Two articles share a word-reference combination, when both articles share a title word as well as a reference. When two articles have a high similarity it indicates that they are close to each other both in terms of the knowledge they use (indicated by the sharing of references) as well as in terms of subject matter (indicated by the sharing of title words).[7] Articles that have a similarity above a certain threshold are linked to each other and so networks of similar articles are made that can be visually represented in a map.

Before calculating similarities we need to find the set of articles relevant for the new learning science. This was done through a 'topic search' in the Web of Science.[8] To find appropriate search terms we scanned a number of recent (policy) reports that have been published on transdisciplinary learning science (De Jong et al., 2009; Howard-Jones, 2007; Jolles et al., 2006; OECD, 2007; Stern et al., 2005). The exact combinations of search terms that were used to retrieve the articles are given in Annex 5. We searched the Web of Science for the period January 1st,1997 to December 31st, 2007 and found approximately 58,000 documents that matched our search criteria. From these we selected articles and reviews only, which narrowed down our dataset to 55,527.

Setting the similarity threshold at 0.05[9] we made two similarity maps, one for the period 1997-2002, one for the period 2003-2007.[10] Articles that have a high similarity cluster together in networks. After removing all unconnected articles 2147 articles remained for the first map (1997-2002) and 3607 articles remained for the second map (2003-2007). That means that almost 90% of the articles from the initial set of 55,527 articles do not reach the threshold of significant similarity. This is not unexpected, because - as we did not want to miss out on any relevant articles - we have used a large set of search terms of which some were very broad. This resulted in the initial inclusion of a large set of articles that have low or no similarity with any other articles in the set.

6 The Jaccard index was used as a similarity measure.
7 Stopwords were excluded from the title word list, before the analysis was made.
8 The ISI topic word search, searches all words that appear in title, keywords or abstract of an article.
9 To give an indication of what this threshold means: When two articles with both ten title words and 30 references have a similarity of 0.05 it means that they share 28 unique word-reference combinations, i.e. 2 title words and 14 references or 4 title words and 7 references.
10 The computer was not able to run the analysis on the data for the whole period of 11 years.

The two similarity maps that remain after removing all the unconnected nodes consist of a set of different article networks representing different research themes (see fig.5 as an example of an article network). Some of these networks contain only a small number of articles and can thus not be considered as representing a research front. Since our analysis is aimed at finding research fronts that maybe indicative for the emergence of a new learning science, we have focused the further analysis on the larger article clusters. In the first map (1997-2002) we disregarded all article networks which contained less than 5 articles. In the second map (2003-2007), which as a whole contained more articles, we disregarded all article networks which contained less than 7 articles.

Because many of the search terms used were rather general, many of the articles clusters were not relevant for a new learning science. In order to select out these irrelevant article clusters we manually inspected the network map and the article titles. In this way we selected those clusters of articles that seemed related to a new learning science.

Articles that dealt solely with disabilities or impairments (e.g. dyslexia or ADHD) were not selected because of their limited direct impact on educational practice. However, if combined with other relevant topics (e.g. teaching strategies, see the last cluster 1997-2002) the clusters were considered relevant. Clusters of articles that addressed the teaching of (cognitive) neuroscience or neurotechnologies (fMRI) were also left out of the analysis. We selected article clusters when title words were found that referred to different types of learning, types of memory that are associated with learning (e.g. working memory), types of teaching strategies, skills associated with learning (e.g. mathematical skills), different directions of education (e.g. language or mathematics) and finally clusters that were about intelligence. A short overview of the findings is presented in the next section.

6.2 Results[11]

1997-2002

We limited our search to clusters containing at least 5 articles. Within this set, we found 87 clusters that contained at least 5 articles. From these, only 8 clusters dealt with research topics which were somehow relevant. They are listed below, starting with the largest clusters. The number of articles in the cluster is given between brackets, followed by the names of the subfields in which the articles in the cluster are published.

- Implicit (sequence) learning (16, Cognitive psychology and Cognitive neuropsychology)
- Multimedia learning (12, Educational psychology)
- (Short-term) working memory and language (10, Cognitive psychology)
- Perceptual learning (10, Neuroscience and Physiology)
- Sleep and Learning (9, Neuroscience and High-impact review)
- Verbal working memory and language impairment (6, Psycholinguistics)
- Working memory and reading disabilities (6, Learning disabilities)
- Teaching strategies and learning difficulties (5, Educational Psychology)

11 More details can be obtained from the authors (F.Merkx@rathenau.nl).

2003-2007
The dataset for 2003-2007 is far larger than the dataset for the previous period. After removing all unconnected nodes a total of 3607 articles remained. Clearly, there is a large increase in the number of articles published in this period compared to the period 1997-2002. Given the large number of clusters in this period we searched for clusters that contained at least 7 articles. This yielded a total of 43 clusters of which 13 were somehow relevant. In order of size:
- Sleep and memory/learning (40, Neuroscience)
- Working memory and intelligence/memory span/memory capacity (31, see figure 5)
- Nonword repetition and language impairment/working memory (22, Psycholinguistics)
- Working memory and reading disabilities/mathematical skills (20, Educational psychology and Developmental psychology)
- Cognitive load and multimedia learning/instruction (19, Educational psychology and Cognitive psychology)
- Sequence learning (16, Neuroscience and Cognitive psychology)
- Category learning (14, Cognitive neuropsychology)
- Neural efficiency and intelligence and cognitive information processing (11, Cognitive neuropsychology)
- Perceptual learning (9, High-impact review and Physiology)
- Cortical regions and cognitive tasks (8, Developmental psychology)
- Working memory and mathematics (8, High-impact review and Cognitive neuropsychology)
- Brain activity and intelligence (7, Physiology)

The topics we found for the two periods are very similar. Different forms of learning such as sequence learning, multimedia learning, and perceptual learning are present in both time-periods. Category learning is only present in the period 2003-2007 indicating that this might be a relatively new line of research. By far the largest cluster in the past 11 years is the cluster on sleep and memory/learning. The cluster contains 9 articles in the period 1997-2002 and 40 articles in the period 2003-2007.

The size of the journal clusters equals an average of 1 - 3 articles a year in the first time period and an average of 1 - 8 articles a year for the second time period. For most clusters we observe that they consist of articles that are published in journals from one or two of the subfields only. The articles on sleep and memory/learning for example were predominantly published in journals within neuroscience and in general science journals such as Nature and Science. We only found a few clusters of articles which are published in a broader range of journals and these clusters mostly relate to working memory or sequence learning. These clusters combine research from neuroscience, cognitive neuropsychology, cognitive psychology and even developmental psychology and experimental child psychology (see figure 5). However, in none of the clusters did we find research from both ends of the spectrum: educational research and neuroscience.

We can conclude from the analysis that there is no broadly interdisciplinary cluster of articles in this set that display a high degree of similarity. This indicates that there is not yet an inter-disciplinary research front in new learning science visible in the literature. Still, new learning science might be in an emerging form and currently only show low similarity levels. To check for this, we repeated the analysis, but using a much lower similarity measure of 0.002. As expected, the retention of articles was much higher. After excluding all clusters with less than 5 nodes, 5030 articles remained for the first period (1997-2002) and 9325 articles remained for the second period (2003-2007).

Visual inspection of the article maps showed that articles published in different journal categories were not evenly distributed over the network. Neuroscience articles cluster together with other neuroscience articles and mixed interdisciplinary articles cluster together with other mixed interdisciplinary articles. The proportion of educational articles in the entire network is relatively low (4.8 % in the first time period and 4.4 % in the second time period). The educational articles also tend to cluster together, especially during the second time period.

We extracted from the network all educational nodes as well as all nodes that are immediately linked to these educational nodes (k=1 neighbourhood network). This resulted in a 1754-node network for the first time period and a 3919-node network for the second time period. We visually inspected these networks and found similar research topics to the ones we found when using a higher threshold. A few topics showed a mixed composition of articles published in both neuroscience journals as well as educational journals: Sleep disorders; Working memory; Phonology and memory; Aging and cognition; ADHD; Intelligence; Implicit learning and memory; Sleep and learning; Cognition and Memory; and Language and learning. This indicates that an emerging new learning science might be developing that is focused on these topics.

Furthermore, when we focus on the educational articles and the immediate neighbourhood network of the educational articles, we see some interesting trends. Between the first and the second period, the number of articles in this network grows by a factor of 2.2 from 1754 to 3919. However, the growth is not evenly distributed over all article categories. The relative number of educational articles remains quite stable (11.6 % (1997-2002) to 10.6 % (2003-2007), whereas the relative number of neuroscience articles in this immediate neighbourhood increases from 16.6% to 24.8%.[12] This indicates that over time, the neighbourhood of the educational articles in this set is more neuroscience-related.

Parallel to the increase of network nodes over time, we see an increase in network linkages. The relative growth of the number of linkages between the nodes also differs between journal categories. Over time we see a relative increase of mutual linkages between educational articles in the network. In the first period (1997-2002) 16.9% of all linkages in the immediate neighbourhood of the educational article network are between educational articles. In the second period (2003-2007) the percentage of mutual linkages between educational articles has increased to 20.6 %. This indicates that, in relative terms, similarity between educational articles increases in comparison to the level of similarity to other article categories in the set. Interestingly, there is also an increase in the relative number of linkages between educational articles and neuroscience articles. It increases from 10.3 % in the first period (1997-2002) to 12.4 % in the second period (2003-2007). So the similarity-above-threshold between educational articles and neuroscience articles is increasing as compared to the similarity-above-threshold between educational articles and articles from other journal categories.[13] This may be seen as a modest indicator of the emergence of a new learning science.

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12 This relative increase is not due to an increase of the share of neuroscience articles in the overall network. In the first period (97-02) the share of neuroscience articles is 36.3%, in the second period the share of neuroscience articles is 36.7% (0.002 threshold, including clusters of 5 nodes or less).

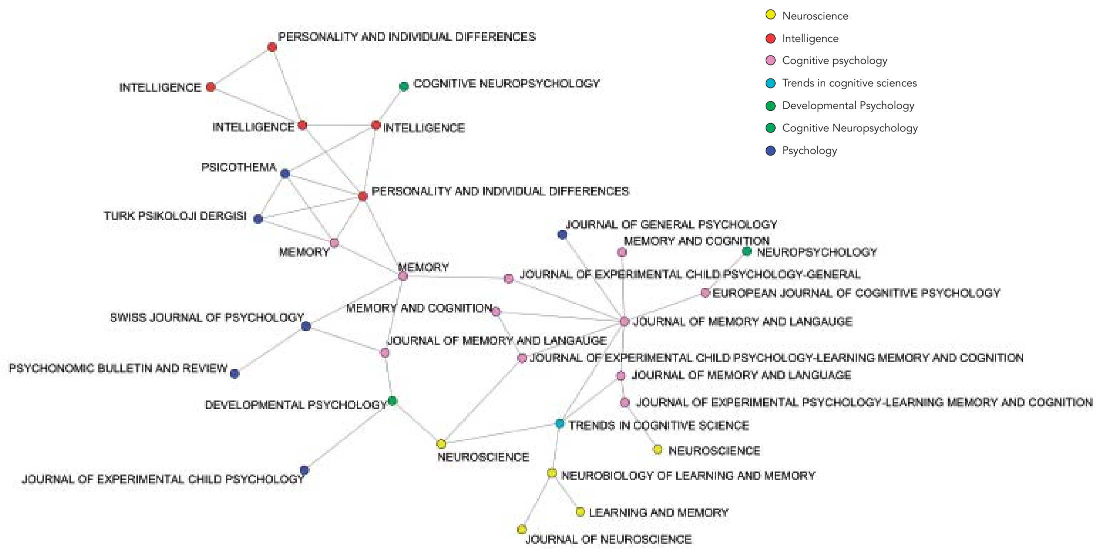
13 It should be noted that whereas the number of nodes and linkages in these networks grows over time, the relative interconnectedness of the networks decreases: Network density decreases from 0.0033 in the first period to 0.0023 in the second period.

6.3 Conclusion

When using a high similarity threshold (0.05) we found a few clusters of articles that were of some relevance, but the clusters were generally rather small. Additionally, we did not find any clusters of papers that were published in both educational as well as neuroscientific or cognitive neuropsychology journals. Most of the identified research themes are still quite fundamental and do not contain publications from educational research. Only a few themes address teaching practice. Generally, the identified topics stay within disciplinary boundaries rather than transcending them. This indicates that there is not yet a strongly developed interdisciplinary research front in new learning science.

Using a low similarity threshold (0.002) does not significantly change this conclusion. We do find however a few topic clusters of articles published in both neuroscience journals as well as educational journals. Furthermore, over time we see a modest increase in similarity between educational articles and neuroscience articles. This might form a first indication for the emergence of new learning science on these topics. However, as was the case when using a high similarity threshold, we did not find an orientation towards teaching practice.

Figure 5 Articles on 'Working memory'



Nodes represent articles, with the node label being the journal name in which the article was published. Links represent similarity in terms of word-reference co-occurrences (above threshold). Colours indicate the different subfields.

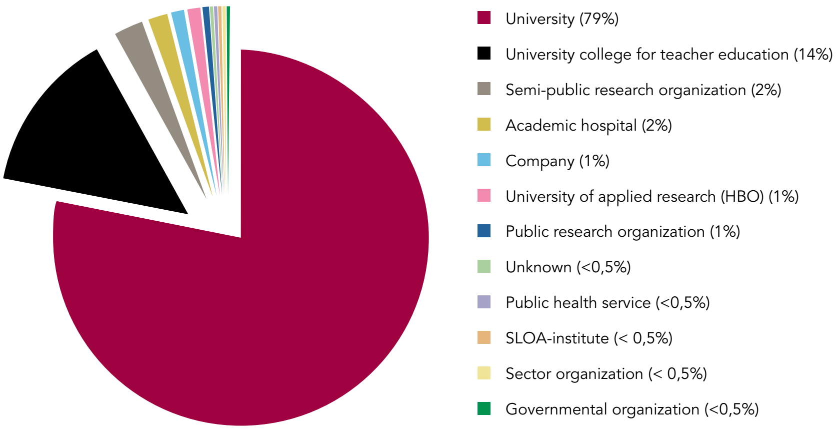
7 Transdisciplinary collaboration between educational research and practice

What is the institutional affiliation of Dutch authors that publish in the international educational journals? What is the distribution over universities, public research institutes and private research institutes? And, are researchers and practitioners from institutes for educational services and advice visible? Finally, do we find collaboration and co-authorships between researchers and practitioners? The answer to that question indicates whether Dutch educational research is transdisciplinary: do collaborative networks exist between different types of research and practice?

7.1 Institutional background of educational researchers

To determine the answer to this question we selected data from all articles published within our journal set (see table 6, chapter 4) that have at least one Dutch author. Per article all contributing authors and their institutional addresses were taken into account. Foreign addresses were removed from the dataset, since we were interested in Dutch contributions and collaboration only. This resulted in a dataset of 642 unique Dutch author-address combinations good for 461 unique papers. The addresses were then manually checked and homogenized, since the ISI-database often uses different denotations for the same addresses. This homogenization took place in two steps. First, the addresses were homogenized on organizational level (university names, company names, etc.). In a second step we homogenized the denotations at a lower level, that of departments and research groups. The 642 unique Dutch author-address combinations could be assigned to 35 different organizations which were then categorized as belonging to 12 different types of organizations (see figure 6).[14]

Figure 6 Distribution of (Dutch) publications over types of organizations



University based researchers form the largest group (79%), and another 14 % of the authors work at a university college for teacher education. Together they account for 93% of the addresses. Only a very small number of publications are written by researchers working at institutes that carry out applied or mission-oriented research (e.g. at universities of applied research, private companies, national pedagogic centers and public research organizations).

14 In some cases it was difficult to distinguish between University college for teacher education, and university. Such was the case for the Freudenthal institute at the UU, which educates mathematics teachers. The Freudenthal institute was categorized as a University college for teacher education.

The number of non-university research groups publishing in the international academic literature is very low. Compare, for example, the results of this analysis with a similar analysis we made for the field of coastal engineering research where the share of university research is only 51 % and 40 % of the journal articles are (co-)authored by researchers working at public and semi public research organizations, that are more mission-oriented. Furthermore, private companies, NGOs and governmental organizations (co-)author almost 10 % (Merkx & Van den Besselaar, 2008, p.13).

Table 11 Number of co-authored publications between Dutch educational research organizations

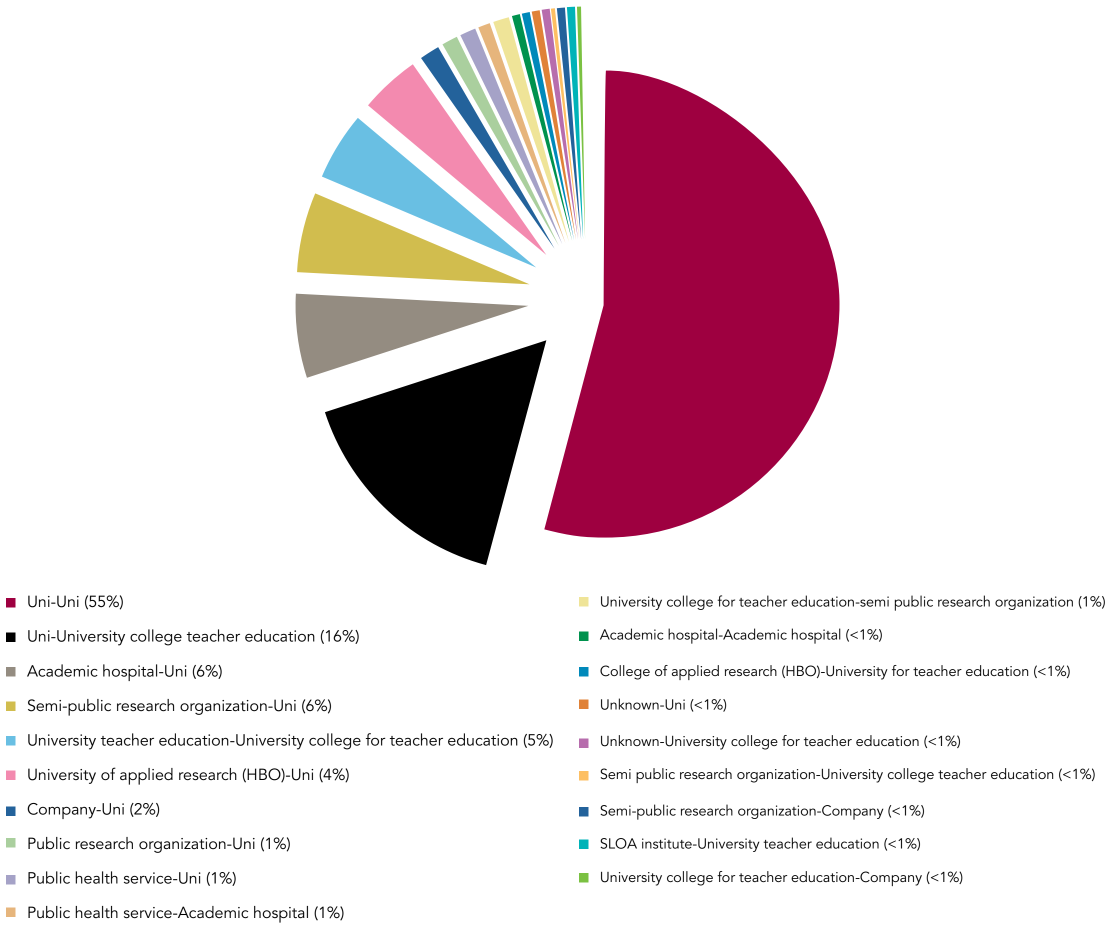
Co-authoring institutes		Number of co-authored publications
Open University Heerlen	University of Maastricht	11
University of Amsterdam	University of Leiden	7
Erasmus University Rotterdam	Open University Heerlen	6
University of Utrecht	Institute for Teachers Education	5
University of Amsterdam	University of Maastricht	5
Centre for Teachers Education Leiden (ICLON)	Freudenthal	4
Institute for Teachers Education (ILO)	Free University Amsterdam	4
University of Maastricht	Erasmus University Rotterdam	4
University of Utrecht	Open University Heerlen	4
University of Utrecht	University of Amsterdam	4
Free University Amsterdam	University of Leiden	4
Erasmus Medical Centre	Free University Amsterdam	3
Institute for Teachers Education (ILO)	University of Leiden	3
Kohnstamm Institute	University of Amsterdam	3
Radboud University Nijmegen	Univeristy of Utrecht	3
Radboud University Nijmegen	University of Amsterdam	3
Radboud University Nijmegen	University of Twente	3
University of Groningen	University of Amsterdam	3
University of Tilburg	Technical University Eindhoven	3
University of Utrecht	Free University Amsterdam	3

7.2 Transdisciplinary co-author relationships

A next question is whether we find collaboration between academic educational researchers, applied researchers and practitioners, indicated by transdisciplinary co-authorships. In order for education and the educational system to benefit from research, a transdisciplinary approach to research is necessary. Collaboration between different types of research groups in terms of co-authoring scholarly papers forms a strong indicator for transdisciplinary research. We were therefore interested whether, and on what scale, co-authorship relations exist between different types of research groups and between academic research groups and more practice oriented groups in The Netherlands. A co-author analysis was done on the obtained dataset, at the level of the organizations with collaboration within organizations not being included[15]. For each article we manually checked whether institutions were mentioned only once. From the 194 collaborations at organizations level, the 20 most-often occurring are presented in table 11. The highest number of co-authorship collaborations is between the Open University Heerlen and the University of Maastricht (11).

The top of the table shows mostly collaborations between universities (14 out of 20). Other types of collaboration in this table are between university and university colleges for teacher education (4), between academic hospital and university (1) and between a university and its applied educational research organization (1) (University of Amsterdam and Kohnstamm Institute). This indicates that research collaboration between universities and other types of organizations hardly occurs. This is also visible in figure 7, which shows the distribution of the different type of collaborations as a percentage of the total number of collaborations. About 82% of all collaborations are between universities or between university related research organizations (e.g. university colleges for teacher education and academic hospitals).

Figure 7 Distribution of inter institutional co-publications in Dutch educational research

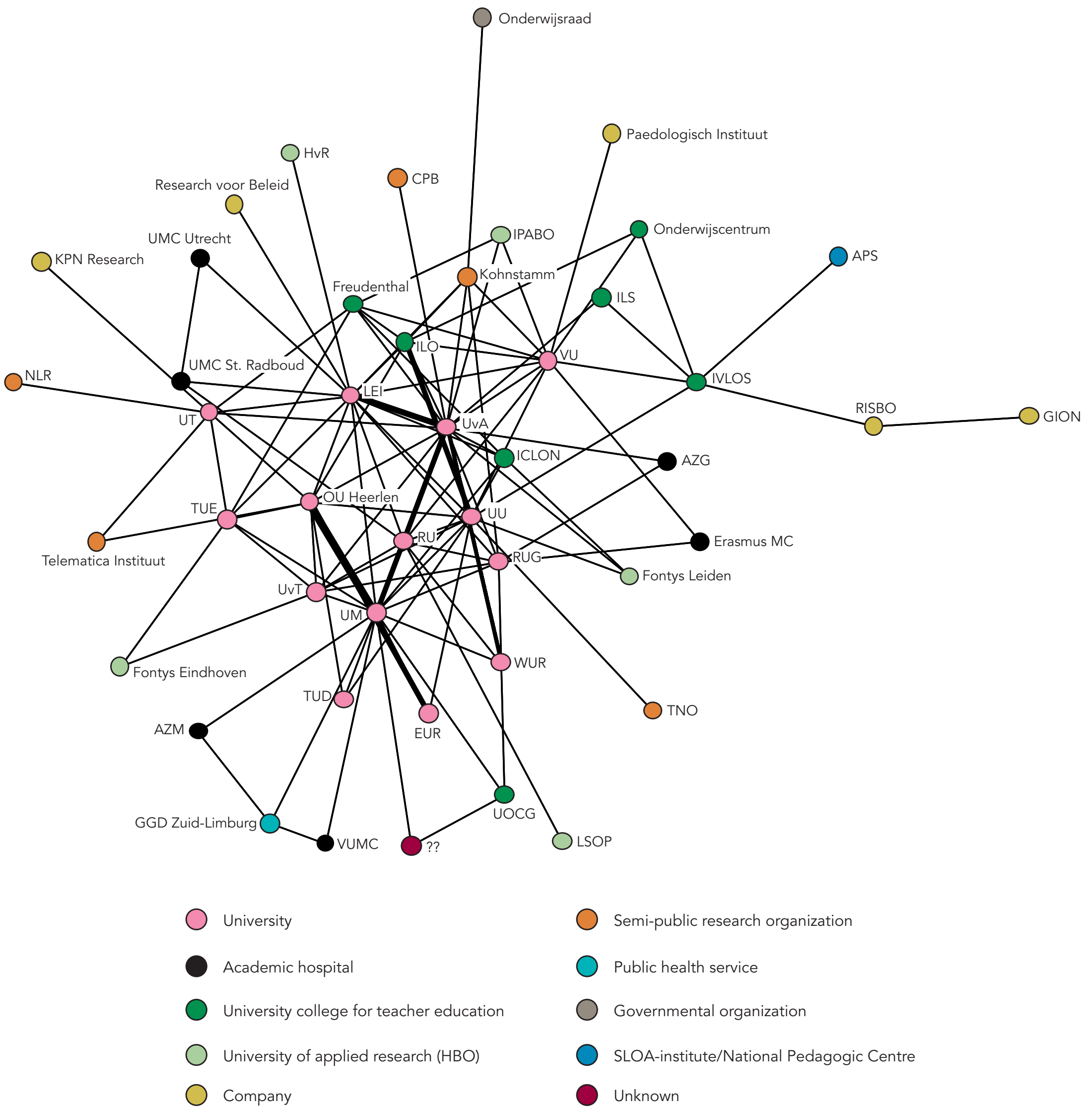


In figure 8 the same relations are depicted in a network structure. The thickness of the lines represents the number of collaborations between the different institutions. Clearly the universities (pink dots) form the core of the network and the other institutions are distributed around that core. Apart from collaborations between universities, there are strong collaborations between universities and university colleges for teacher education (dark green dots) and between universities and university related research institutes for applied research

15 By this we mean that a paper written by two authors of the Vrije Universiteit and one of the Universiteit of Amsterdam counts as one co-author relation between the two universities.

(orange dots, e.g. Kohnstamm). Other institutions have far fewer co-authorships, usually only one or two over a long period of time and often with the same university. The question marks (red dot) depict the unknown addresses. Note that the national pedagogic centres (LPCs), where a large part of short term applied and commissioned research is carried out, are almost invisible. Only one is in the margin of the network (APS in figure 8).

Figure 8 Network of inter-institutional co-publications in Dutch educational research



7.3 Conclusions and discussion

The low share of non-university research in the scholarly literature and the low percentage of research collaborations between universities and public research organizations seem to reflect the distance between educational research and educational innovation. According to (Jochems, 2007), this is related to the manner in which educational research and educational innovation are funded in the Netherlands. Until 1996 educational research was funded through the Institute for Educational Research (SVO). Since 1997 mid-term and long-term educational research is funded through the National Research Council (NWO/PROO). The budget for short-term customer-driven research went to the National Pedagogic Centres (LPC's) and short-term policy oriented research became directly funded by the Ministry of Education. Jochems estimates the yearly budget for long-term and mid-term academic educational research to be between 20 and 30 million Euros and that of short-term customer driven research by educational research organizations (National Pedagogic Centers and other SLOA institutes) to also be between 20 and 30 million Euros. Apart from this, there is a large innovation budget of an estimated 500 million Euros - without any relation with research.

The call for transdisciplinary educational research is not unique to the developments that relate to neuroscience and cognitive neuroscience, and is in fact more general. It is made in relation to the paradoxical situation that educational research in the Netherlands is of high quality according to international academic standards, yet has failed to have any significant impact on actual educational practice (Onderwijsraad, 2003). Broekkamp and Van Hout-Wolters (2006) give an extensive overview of the many problems, causes and solutions. Over the last five years transdisciplinary educational research has been propagated as a solution for the low impact of academic educational research on educational practice (AWT, 2003; Onderwijsraad, 2003). But it is also recognized that a large number of institutional factors make it difficult to accomplish transdisciplinary research in education. However, the newly developed “academic schools”, funded by the Ministry of Education, may open up new perspectives. Here, teachers and academic researchers collaborate in researching and improving teaching and educational practice.

8 A new journal and its knowledge base

In chapters 4 and 5 we have analyzed the fields of neuroscience, cognitive neuroscience, cognitive psychology and educational research on the aggregated level of journals. We did not find a cluster of journals as early representation of the field, nor did we find any targeted multidisciplinary journal. It was also concluded that the citation linkages between the fields of educational research and that of the neuroscience and cognitive sciences are generally quite weak or absent. In chapter 6 we focused the analysis on the level of journal articles. No substantive clusters of articles were found that can be considered as a representation of new learning science. Finally, in chapter 7 we have shown that transdisciplinary connections between educational practice and educational research are nearly absent. In other words, the often announced emergence of transdisciplinary learning sciences is not visible yet in the academic literature.

However, in 2007 a new journal Mind, Brain and Education was launched, which focuses specifically on transdisciplinary learning sciences. The journal specializes in "basic and applied research on learning and development, including analyses from biology, cognitive science, and education."[16] It was established by the International Mind, Brain, and Education Society (IMBES), whose mission is "to facilitate cross-cultural collaboration in all fields that are relevant to connecting mind, brain, and education in research, theory, and/or practice".[17] Being a new journal, MBE is not (yet) processed in the ISI journal citation reports. Therefore it is absent in the analysis of the previous chapters. To compensate for that, this chapter presents a brief analysis of this journal.

Firstly, we analyzed the cited references of all MBE articles in the first six issues of MBE (April 2007 until June 2008), as these form the knowledge base of MBE. This helps to answer the following questions: What fields of research constitute the knowledge base of MBE, and what is the thematic focus of the MBE knowledge base? Secondly, the content of the articles published in MBE were analyzed, as this shows the focus of the research published in the journal.

8.1 Journal composition of the MBE knowledge base

The analysis in this section is based on the cited references of the first six issues of MBE (April 2007 until June 2008), which refer to journals processed in the Web of Science. We manually collected 757 unique records, which is between 70% and 80% of all cited references. HistCite was used to analyze the data. Table 12 shows the 23 cited journals which appeared at least 9 times[18] in the dataset. The table presents the research fields to which these journals belong.[19] As one would expect, the articles in *Mind, Brain and Education* refer to journals from a variety of research fields: neuroscience, cognitive neuropsychology, cognition, psychology, education, sleep research and genetics. Fields that concern mind and brain research clearly dominate for the top of the list and the whole of the list. Only two journals (9%) in this top list are related to educational research: *Child Development* and *Journal of Learning Disabilities*. Additionally,

16 Source: http://www.imbes.org/journal.html
17 Source: http://www.imbes.org/index.html
18 This is the number of unique records in the database. It does not indicate how often the unique records are cited by the articles in MBE.
19 To attribute journals to research fields we used the results obtained in previous chapters: the journal clustering and the attribution obtained from the informants. For the remaining journals, we used the journal title as an indication of the field.

slightly more than 12% of the references in the paper set are published in educational journals. [20] Given the issue domain of the MBE journal, it comes as a surprise that we find journals on sleep research and on genetic research in this journal list. However, this is related to the fact that out of the six issues of MBE, two had specific themes namely: ‘sleep and education’, and ‘genetics and education’. Journals with these specific topics are marked with a (*).

Table 12 Most frequently occurring journals in the knowledge base of Mind, Brain and Education

Journal	# of unique appearances	% of Total	Subfield
Science	41	5,4%	High-impact review
PNAS	19	2,5%	High-impact review
Neuron	18	2,4%	Neuroscience
Child development	17	2,2%	Developmental Psychology / Education
Trends in cognitive sciences	17	2,2%	Multi-disciplinary
Brain and Language	16	2,1%	Cognitive Neuropsychology
Nature	15	2,0%	High-impact review
Sleep*	15	2,0%	Other
Journal of sleep research*	14	1,8%	Other
Psychological review	14	1,8%	Multi-disciplinary / Psychology
Psychological science	14	1,8%	Psychology
Cognition	13	1,7%	Multi-disciplinary
J of learning Disabilities	13	1,7%	Education
Psychological bulletin	13	1,7%	Psychology
Am. J. of human genetics*	12	1,6%	Genetics
J of cognitive neuroscience	12	1,6%	Cognitive Neuropsychology
Nature neuroscience	12	1,6%	Neuro-science
Neuroimage	11	1,5%	Brain mapping / imaging
Brain	10	1,3%	Neurology, Neuroscience, Cognitive neuropsychology
Developmental neuropsychol	10	1,3%	Neuropsychology
Nature reviews neuroscience	10	1,3%	Neuroscience
Behavior genetics*	9	1,2%	Genetics
Intelligence	9	1,2%	Other

8.2 Thematic Focus of the MBE knowledge base

Using Histcite we composed a list of title words of the papers cited by MBE, which resulted in 2057 unique title words. ‘Children’, ‘dyslexia’, ‘reading’ and ‘sleep’ are the most commonly used title words in this dataset, in 79, 70, 69 and 57 cited articles respectively. Most words at the top of the list are more of a general nature (brain, development, children, cognitive, processing), as shown in table 13.

20 The educational journals were identified by using the following criteria:
- Used in the previous analysis to characterize the educational field.
- Contained one of the following (parts of) words in the title: Educ-, Learn-, School-, Read-, Writing-, Teach-.

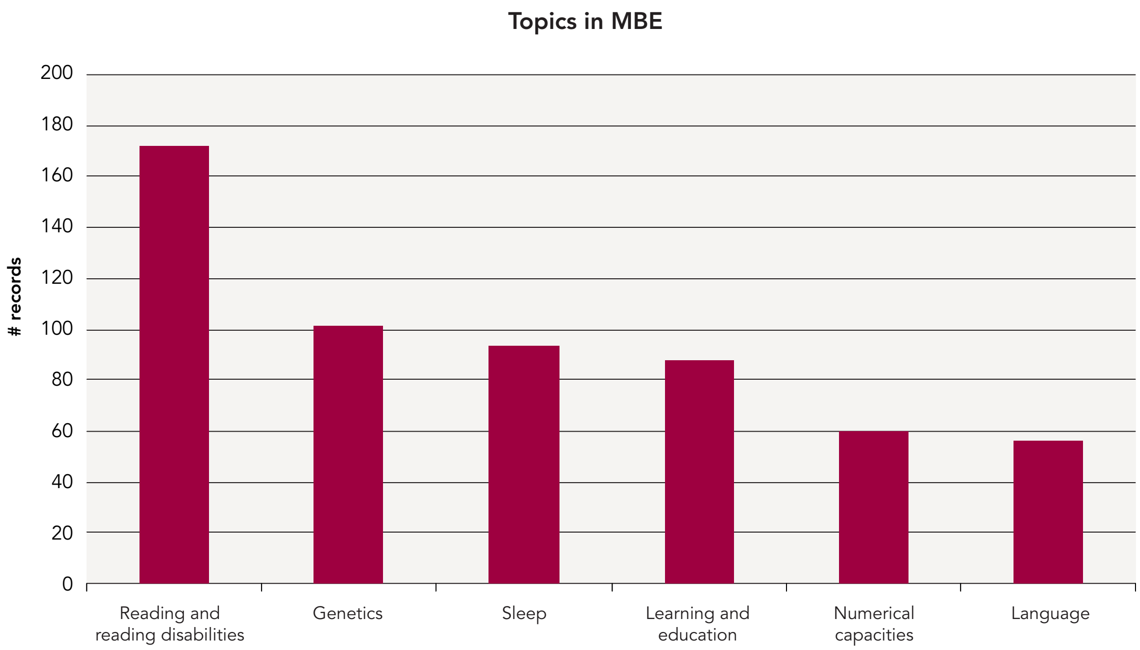
This resulted in a list of 27 journals with a total of 92 unique articles cited by MBE, which is equal to 12.2 % of the total number of unique records cited by MBE. The remaining 88 % is made up of journals with either a more neuroscience, neuropsychological, cognitive science or broad review character.

Table13 Top title words in the knowledge base of Mind, Brain and Education

title words	# records	title words	# records	title words	# records
children	79	development	45	performance	27
dyslexia	70	Human	45	learning	26
reading	69	Processing	38	number	25
sleep	57	Visual	34	cortex	24
brain	52	Evidence	33	disorder	24
developmental	48	Genetic	29	circadian	23
cognitive	45	Neural	27		

To further elucidate the research focus within the MBE knowledge base, we clustered title words[21] into specific research topics and counted the number of cited references belonging to these topics (figure 9). The most important topic in the MBE research is obviously reading and reading disabilities, with 23% of the cited references. Other important topics in the MBE knowledge base, are 'genetics', 'sleep', 'learning and education', 'numerical capacities' and 'language' with 13%, 12%, 12%, 8%, and 7% respectively.[22]

Figure 9 Focus of research in the cited references of Mind, Brain and Education



21 In the analysis we only took into account title words that occurred in at least three cited references. This resulted in 451 unique title words, which covered 610 out of the 757 cited references (81%).

22 Note that the topics are not mutually exclusive and that there may be overlap between the different topics.

8.3 Content analysis of the MBE journal

The reason of IMBES for launching the journal *Mind, Brain and Education* is to promote the integration of the various disciplines that investigate human learning and development and to bring together the fields of education, biology and cognitive science to form the new field of mind, brain and education. It is expressed in the first editorial of the new journal that there can be no direct transfer from knowledge obtained from laboratory studies to classroom practice and a plea is made for a transfer of knowledge to be mediated through a "joining of practice with research". The editors of the journal draw a parallel with the field of medicine in which this reciprocal process of development of biological knowledge and its practical application is the current standard. They state that doing research in the context of educational practice is the most important condition for developing knowledge on mind, brain and education.

Is this ambition realized in the first volumes of the journal? In the first year four issues of Mind, Brain and Education were published with a total of 20 articles. Seven of these present original research. The other non-research articles are often of a conceptual nature and describe where and how neuroscience, cognitive science, educational science and educational practice might inform each other. Out of the seven research articles only one presents research performed in a practical setting. The other articles are concerned with research in which output measures on education and learning are related to genetic or neuropsychological variables. Finally, two of the articles in the first four issues were written by a scientist with an educator background.

The second volume started with a special issue on sleep, circadian rhythms and education. It was the result of a conference held by IMBES on the same topic. Most of the papers were review articles. Most articles again addressed how measurements of educational and learning performance give insight in the effects of certain physiological conditions, such as sleep deprivation and shifts in the sleep-wake cycle. In the latest issue of MBE that we analyzed a different approach was taken. An article that was published in one of the earlier MBE issues is reviewed and taken as an entry point for a cross-disciplinary discussion to facilitate the development of a transdisciplinary dialogue that is, according to the author, currently lacking. A number of authors with different disciplinary backgrounds - ranging from educational practice to neuroscience - comment on the article from their specific perspective and discuss possible implications for education. These commentaries are followed by a reply from the author. In this way a multidisciplinary discussion is facilitated. The last part of the sixth issue contains some articles of (again) a conceptual nature in which both preconditions and some possibilities are sketched for genetics and cognitive neuropsychology to inform educational practice.

The content analysis of the early issues of the MBE journal gives a mixed impression. Positively, the journal indeed tries to facilitate the much needed dialogue between educators and scientists from different disciplines. However, apart from the one last issue in which this dialogue is facilitated, almost none of its content is *joining practice with research*, one of the main goals of the journal. Apart from one of the cross-disciplinary review articles in the last issue all articles are written by university-based researchers with practice-based studies still missing. This may be due to a lack of practice-based research in the broader field of educational research. This would be in accordance with our results of the characterization of the Dutch educational research landscape.

Secondly, differences in educational or learning performance are often described as the possible result of certain genetic, anatomical or (neuro)physiological conditions. How, and in what way, these research results are relevant for the practice of education and teaching is often not, or only vaguely, expressed. Possibly these studies might form a starting point for more practice-based research in the near future. Furthermore, most of the studies focus on learning disabilities or on the impact of certain disorders on learning abilities. Although these studies may be informative for developing strategies to combat learning disabilities it is unclear whether these studies are also relevant for general teaching practice. In terms of medical research, 'translational' research, which links bench to bed, in this case from the laboratory to the classroom, is missing.

8.4 Conclusion and discussion

From the bibliometric analysis of the knowledge base of the MBE journal we learn that the articles in this journal predominantly focus on research on dyslexia and reading disabilities. From the distribution of cited references over different journals we can further conclude that the knowledge base of MBE is dominated by journals in cognitive neuropsychology and that educational journals only make a modest contribution. Research that is published in MBE does not build on a pre-existing transdisciplinary learning science.
From the analysis of the MBE journal we conclude that this journal clearly plays a role in the attempts to establish transdisciplinary learning science, but that transdisciplinary learning science does not yet form a substantial subfield of research. This is indicated by the low number of original research papers and the high number of conceptual papers that are published in the journal.

One of the associate editors of the MBE journal confirmed our analysis and conclusions. He also pointed out a mechanism which impedes the development of a new and transdisciplinary journal like MBE. This mechanism is related to individual researcher's publication strategy. Researchers select journals for publication not only because of the research focus of a journal but also for strategic purposes. High impact journals with a longer history are preferred over newer journals, which are not yet processed by ISI or which - because of their recent existence - have not yet been able to build up a high impact score.

9 Conclusions

The promise of transdisciplinary learning science is flourishing, both internationally as well as in the Netherlands. Over the last five years the OECD has been trying to stimulate the development of the field and within several countries research centres were set up with the aim of crossing the boundaries between educational practice, educational research, and cognitive and neuroscientific research. In 2007 the first journal was established, specifically dedicated to this field. In the Netherlands education is being proposed as one of the focal domains of application within a national research initiative on Brain and Cognition.

In this study we have used a variety of bibliometric methods to investigate if and where transdisciplinary learning science is emerging and becoming visible within the academic literature. Our analysis shows that there are three main issues related to the development of transdisciplinary learning science. These concern the developmental stage of the field, the patterns of knowledge exchange between the involved academic subfields, and the patterns of collaboration between educational research and educational practice.

The new learning science: stage of development
The claim of the recent OECD report that there is "now a global emergence of educational neuroscience"[23] seems premature (OECD, 2007). Although there are many agenda setting activities and several research institutes in educational neuroscience have been established over the last ten years, within the academic literature we have found no indication that educational neuroscience (or new learning science) is emerging as a new research specialty. We did not find any interdisciplinary or multidisciplinary cluster of journals on this topic. On a more fine-grained level, we also did not find substantial clusters of research articles representing this new research field. The content analysis of the new journal *Mind, Brain and Education* pointed in the same direction. In other words, a formal communication network of researchers building on each other's work has not developed yet.

That is not to say that there are no research lines from which new learning science may develop. The word-reference co-occurrence analysis did result in some small clusters of research that may be relevant and we found an increasing number of relevant articles in more recent years. Furthermore, at low-similarity-thresholds we see an increase in linkages between educational articles and neurosciences articles over the years. This reflects the widespread interest in the subject and the international efforts that are made to develop this field. However, the promise of a new learning science still remains predominantly on a programmatic level.

Knowledge exchange in new learning science
The new learning sciences explicitly aim to make brain and neurocognitive research relevant for educational research and practice. However, collaboration between researchers in different fields is not yet visible. Such research collaborations are not easily established. Collaboration may be difficult as different fields of research use different paradigms, methodologies and theoretical assumptions, which may be difficult to reconcile. Several authors have addressed the paradigmatic conflicts that make interdisciplinary collaboration between the different fields of the neuro and cognitive sciences difficult (e.g. Van Dijk et al., 2007).

23 The report uses the term neuroscience very broadly "to encompass all overlapping fields, including neurobiology, cognitive neuroscience, behavioral neuroscience, cognitive psychology" (p.21).

We mapped knowledge exchange between the main fields of research that seem relevant for the development of transdisciplinary learning science: e.g. neurosciences, cognitive neuropsychology, cognitive psychology, educational psychology and educational and teaching research. It appeared that there is indeed some knowledge exchange between these subfields, but the relations are still weak. The field of educational psychology for example only uses cognitive psychology as a knowledge base, and none of the other subfields. Conversely none of the fields of the neurosciences, cognitive neuropsychology or cognitive science uses educational psychology as a knowledge base. Cognitive psychology may form a bridge between the fields of educational psychology at one end and cognitive neuropsychology at the other.

Transdisciplinary collaboration between educational research and educational practice
The new learning sciences should be transdisciplinary: crossing the borders between different academic disciplines as well as between academic research and educational practice. Our analysis of institutional authorship and cross-institutional co-authoring relations has shown that the educational academic literature is very much dominated by researchers that work for university research departments and university colleges for teacher education, and that there is hardly any research published by authors working for non-academic research organizations. The National Pedagogic Centres[24] for example, which have a task in applied educational research, only account for 0.5% of all publications. Research collaboration between the National Pedagogic Centres and university departments is also very low (<1%). More generally the impact of academic educational research on educational practice is considered to be very low. We expect this to be a barrier for developing transdisciplinary learning sciences. On a positive note, initiatives are being developed to improve the situation, for example by establishing academic schools. This may form the basis for strong translational research in the educational field.

Implications
As we are not experts ourselves in the fields presented here, with our study we are not implying a judgment on the viability of the new transdisciplinary learning sciences. Such judgments should be left to knowledgeable experts. The brief overview of the debate amongst these experts shows that a broad consensus on the viability of transdisciplinary learning science does not yet exist.

Szúcs and Goswami (2007) for example tune down the expectations on the short- and mid-term practical implications of neuroscience research in education. They argue that "one major reason for skepticism within the educational community has been the inadequate definition of the potential role and use of neuroscientific research in education. (…) (and) that there is a fundamental difference between doing educational neuroscience and using neuroscience research results to inform education." They argue that "while educational neuroscience may be able to address applied questions in the long run, current educational neuroscience research must focus on basic science" and they suggest that educational neuroscience should not be seen as an emerging transdisciplinary field but instead as an emerging discipline, provisionally defined "as the study of the development of mental representations".

24 In Dutch: 'Landelijk Pedagogische Centra'.

Other experts argue - in line with the OECD report - that transdisciplinary learning science is a promising new research field. However, they claim that it is too early to find this new development in the formal literature, as it takes time before radically new approaches are adopted and accepted by a broad group of researchers. This may explain why hardly any citations exist between the neuro/cognitive fields of research and the field of educational research.

Our findings accommodate both views. Firstly, it is clear from our analysis that new learning science is in a very early stage of development. The field exists more as a program for future research (and application) than as an existing research practice. This does not preclude that it will become so in the future. And secondly, our analysis also shows that transdisciplinary collaboration between researchers and practitioners does not yet exist on a substantial scale. This may prevent transdisciplinary learning science (if it develops further) from becoming relevant for the educational and teaching practice.

If the expectations put forward by proponents of new (and transdisciplinary) learning science are perceived as promising, programs for stimulating the field should reflect the stage of development of the field, and at the same time not only support laboratory based neuro-cognitive research on learning and teaching, but also support ‘translational research’ that bridges the gap between the laboratory and the classroom.

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Annexes

Annex 1 List of informants neuroscientific and cognitive research

- Prof. dr. P.G.M. Luiten, University of Groningen
- Prof. dr. Christian Keysers, University of Groningen
- Prof. dr. Arjen Brussaard, Free University Amsterdam
- Prof. dr. Eco de Geus, Free University Amsterdam
- Prof. dr. H.B.M. Uylings, Free University Amsterdam
- Prof. dr. Guus Smit, Free University Amsterdam
- Prof. dr. Jelle Jolles, Free University Amsterdam
- Prof. dr. Edward de Haan, University of Amsterdam
- Prof. dr. K.Richard Ridderinkhof, University of Amsterdam
- Prof. dr. Jeroen Raaijmakers, University of Amsterdam
- Prof. dr. Marjan Joëls, University of Amsterdam
- Prof. dr. Fernando Lopez da Silva, University of Amsterdam
- Prof. dr. Peter Hagoort, University of Nijmegen
- Dr. Miranda van Turennout, University of Nijmegen
- Prof. dr. Niels Schiller, University of Leiden
- Prof. dr. Ron de Kloet, University of Leiden
- Prof. dr. Rolf Zwaan, Erasmus University Rotterdam
- Prof. dr. Pieter Roelfsema, Netherlands Institute for Brain science (NIH)

Annex 2 List of informants educational research

- Prof. dr. Jeroen van Merriënboer, Open Universiteit Heerlen
- Prof. dr. Fred Paas, Open Universiteit Heerlen
- Prof. dr. Ton de Jong, Universiteit Twente
- Prof. dr. Jan van Driel, Universiteit Leiden
- Prof. dr. Adriana Bus, Universiteit Leiden
- Prof. dr. Rob Martens, Universiteit Leiden
- Prof. dr. Monique Volman, Vrije Universiteit Amsterdam
- Prof. dr. E.C.D.M. van Lieshout, Vrije Universiteit Amsterdam
- Prof. dr. G.T.M. ten Dam, Universiteit van Amsterdam
- Prof. dr. J.H. Hulstijn, Universiteit van Amsterdam
- Prof. dr. A.L. Ellermeijer, Universiteit van Amsterdam
- Prof. dr. Cees van Vleuten, Universiteit Maastricht
- Dr. Diana Dolmans, Universiteit Maastricht
- Prof. dr. Paul Kirschner, Universiteit Utrecht
- Prof. dr. Marc Vermeulen, Universiteit van Tilburg
- Prof.dr. B.P.M. Creemers, Rijksuniversiteit Groningen
- Prof. dr. Victor van Daal, Universiteit Stavanger, Noorwegen

Annex 3 Journals on neuroscientific and cognitive research (informant based)

Journal	Times mentioned	Journal	Times mentioned
Nature Neuroscience	13	Brain research reviews	1
Journal of neuroscience	11	Brit. J. Educational Psychology	1
NeuroImage	10	Child Development	1
Nature	9	Cortex	1
Science	9	Developmental Neuroscience	1
Cerebral Cortex	8	Developmental Psychology	1
Journal of Cognitive neuroscience	8	Developmental Science	1
Neuron	8	Early Childhood Education Journal	1
Brain Research	7	Educational Psychology Review	1
Nature reviews neuroscience	7	Educational Researcher	1
Proceedings National Academy of Sciences	7	Experimental Brain Research	1
Brain	6	Frontiers in Neuroendocrinology	1
Trends in Cognitive science	6	Infant Behavior and Development	1
Trends in Neuroscience	6	Infant Mental Health Journal	1
Human Brain Mapping	5	Int. J. Behavioral development	1
Psychophysiology	4	Int. J. training & Development	1
Current opnion in neurobiology	3	International journal of Psychophysiology	1
European journal of neuroscience	3	J Amer. Acad. Child & Adolescent Psychiatry	1
Psychological Review	3	J of Neurochemistry	1
Behavioral and brain sciences	2	J of Neurophysiology	1
Brain and Cognition	2	J of Undergraduate Neuroscience education	1
Brain and Development	2	Language Learning	1
Cognition	2	Mind Brain and Education	1
Cognitive Brain research	2	Molecular Psychiatry	1
Cognitive, Affective & Behavioural Neuroscience	2	Neurobiology of Aging	1
Current Biology	2	Neurobiology of Diseases	1
Hippocampus	2	Neurobiology of Learning and Memory	1
Learning and Memory	2	Neurology	1
Neuropsychologia	2	Neuropsychopharmacology	1
Public Libary of Science (PLOS) Biology	2	Neuroscience	1
American Educator	1	Neuroscience and Biobehavioral Reviews	1
Ann. N.Y.Acad. Sci.	1	Neuroscientist	1
Annual review of Neuroscience	1	Progress in Neurobiology	1
Arch. Pediatrics and Adolescent medicine	1	Psychological Science	1
Biological Psychiatry	1	Psychology Bulletin	1
Biological Psychology	1	Sleep	1
Brain and Language	1	Teachers College Record	1

Annex 4 Journals educational research (Informant-based)

Journal	Times mentioned	Journal	Times mentioned
Learning and Instruction	8	Cognitive development	1
Journal of Educational Psychology	8	Developmental neuropsychology	1
Review of Educational Research	6	European journal of cognitive psychology	1
Instructional Science	4	Gender and education	1
Journal of the Learning sciences	4	Harvard educational review	1
Child Development	3	Journal of computer assisted learning	1
Developmental Psychology	3	Journal of Early Childhood Literacy	1
Journal of Experimental Child Psychology	3	Journal of exp. psychology:applied	1
Cognition and Instruction	3	Journal of Literacy Research	1
Contemporary educational psychology	3	Oxford review of education	1
Educational Psychologist	3	Research in Science Education	1
Science Education	3	Review in higher education	1
Journal of research in science teaching	3	Teaching and learning in medicine	1
Academic medicine	2	Journal of research in reading	1
Applied cognitive psychology	2	Scientific studies of reading	1
British journal of educational psychology	2	Quarterly journal of Exp psychology	1
British journal of sociology of education	2	Cognitive psychology	1
Curriculum Inquiry	2	Journal of child psychology and psychiatry	1
Early Education and Development	2	Brain and language	1
Educational psychology review	2	Behavioral and brain sciences	1
Journal of curriculum studies	2	Cognitive neuropsychology	1
Journal of learning dissabilities	2	Educational research review	1
Medical education	2	Studies in Second Language Acquisisition	1
Medical teacher	2	Bilingualism, Cognition, and Language	1
Memory & Cognition	2	The Modern Language Journal	1
psychological bulletin	2	Language Testing	1
Reading and Writing	2	Second Language Research	1
Reading Research Quarterly	2	Applied Linguistics	1
Teaching and teacher education	2	Educational Evaluation and Policy Analysis	1
American Educational research journal	2	Sociology of Education	1
Computers in human behavior	2	American Sociological Review	1
Computers & education	2	IJST International Journal of Science Teaching	1
Apllied psycholinguistics	2	American Journal of Physics	1
Language learning	2	Physics Education	1
International Journal of Science Education	2	Journal of Chemical Education	1
Advances in health sciences education	1	International Journal of Mathematical Education in Science and Technology	1
British educational research journal	1	Communications of the ACM	1
Cognition	1		

Annex 5 Keyword combinations for word-reference co-occurrence analysis

The search terms were divided in four different categories:
- General neuroscience words
- General education words
- Specific neuroscience words
- Specific educations words

In the ISI-database these words were combined with the Boolean operators OR (within the category) and AND (between categories) to create the dataset. Because the search engine accepts a total maximum of 50 search terms the categories were further divided (see below) and the following searches were performed:
- 1 AND 4, 1 AND 5, 2 AND 4, 2 AND 5, 3 AND 4, 3 AND 5
- 1 AND 7, 2 AND 7, 3 AND 7
- 4 AND 6, 5 AND 6 10 AND 6

This resulted in a combined dataset of more than 41000 documents of which we only used the review and article type documents. This yielded a total of 39318 records.

A second dataset was created by combining the general neuroscience terms with specific words on *literacy* and *numeracy*, two important focal points of educational research. The following searches were performed:
- 6 AND 8, 6 AND 9

This resulted in almost 17000 records of which we again only took de review and article. This resulted in a second set of 16209 records.

Specific Neuroscience search terms

1) fMRI OR EEG OR PET OR "Cognitive load" OR "Metacognitive processes" OR "Cognitive system" OR "Episodic buffer" OR "Phonological loop" OR "Visuo-spatial sketchpad" OR "Modality effect" OR "Encoding strategy" OR Multimodality OR "Brain correlates" OR "Neural correlates" OR "Selective attention" OR "Memory load" OR "Activation pattern" OR "Neural efficiency" OR "Neural mechanism" OR Neurogenesis OR "Cognitive processing" OR Cortical OR P600

2) N400 OR Sleep OR ERP OR ERN OR "Executive control" OR "Executive functions" OR "Brain maturation" OR "Brain development" OR "Mirror-neuron" OR "Neural circuit" OR "Affective processes" OR Limbic OR "Near infrared spectroscopy" OR NIRS OR Lesion OR Imaging OR HIPS OR "Magnocellular deficit hypothesis" OR Plasticity OR Synaps OR "Synaptic pruning" OR "Synaptic density" OR "Synaptogenenis"

3) "Critical period" OR "Sensitive period" OR "Enriched environment" OR "Deprived environment" OR Myelineation OR Hemisphere OR Neurofeedback OR "Working memory" OR "Short term memory" OR "Long term memory" OR "Procedural memory" OR "Declarative memory" OR "brain region" OR "Magnetic resonance imaging" OR Electroencephalography OR "Positron emission tomography" OR "Supervenience model" OR MEG OR Magnetoencephalography OR "experience-expectant" OR "experience-dependant" OR "central executive" OR "brain-computer interface"

Specific Education search terms

4) "Learning environment" OR "Self-directed learning" OR "Learning material" OR "Implicit learning" OR "Explicit learning" OR "Informal learning" OR "Self-regulated learning" OR "Self-regulation" OR "Collaborative learning" OR "Multimedia learning" OR "Verbal learning" OR "Inquiry learning" OR "Life-long learning" OR "Whole-task learning" OR "Social learning" OR "Observational learning" OR "Imitational learning" OR "learning from expert models" OR "Learning style" OR Semantics OR Intelligence

5) "Educational performance" OR "Insight problem solving" OR "Knowledge acquisition" OR "Implicit knowledge" OR "Explicit Knowledge" OR "Instructional design" OR "Problem solving" OR "Information acquisition" OR "Information processing" OR "Teaching method" OR "Self-management" OR "Brain gym" OR Neurofeedback OR "Developmental change" OR Didactic OR Classroom OR chronoeducation OR "privileged learning" OR "non-privileged learning" OR "conditioned learning" OR "Insightful learning"

10) "Dual coding theory" OR "Modality effect" OR "Redundancy effect" OR "Multiple representation" OR "Conceptual change" OR "Feelings of knowing" OR "Dual route model" OR "Orthographic depth hypothesis"

General Neuroscience search terms

6) Neuro* OR Neural OR Brain* OR Cortical OR Cortex OR Synap* OR lobe OR Memory OR gyrus OR sulcus

General Education search terms

7) Educat* OR Learn* OR teach* OR school OR classroom OR literacy OR numeracy

Literacy

8) "Language instruction" OR "Second language learning" OR Reading OR "Alphabetic principle" OR "Phonemic awareness" OR "Oral reading fluency" OR Vocabulary OR Comprehension OR "Phonics instruction" OR "Word reading" OR "Pseudoword reading" OR rhyming OR syllables OR orthographic OR logographic OR "linguistic-visual processing"

Numeracy

9) Numerosity OR "Analogue magnitude system" OR "Realistic mathematics education" OR "Mathematical process*" OR "Number processing" OR "Mental number line" OR Multiplication OR Subtraction OR Mathematics OR Arithmetic OR "Math fact fluency" OR Ordinality OR Algebra

Recent Science System Assessment reports:

0701 Anouschka Versleijen, *Nulmeting IOP selfhealing materials*. Den Haag, Rathenau Instituut, maart 2007

0702 Barbara van Balen, Peter van den Besselaar, *Universitaire onderzoeksloopbanen: Een inventarisatie van problemen en oplossingen*. Den Haag, Rathenau Instituut, juli 2007

0703 Anouschka Versleijen, Barend van der Meulen, Jan van Steen, Robert Braam, Penny Kloprogge, Ruth Mampuys, Peter van den Besselaar, *Dertig jaar publieke onderzoeksfinanciering in Nederland (1975-2005): historische trends, actuele discussies*. Den Haag, Rathenau Instituut, juli 2007

0704 Femke Merkx, Anouschka Versleijen, Peter van den Besselaar, *Kustverdediging: wetenschap, beleid, maatschappelijke vraag*. Den Haag, Rathenau Instituut, augustus 2007

0705 Peter van den Besselaar, *Een kaart van communicatie- en media-onderzoek*. Den Haag, Rathenau Instituut, september 2007

0706 Femke Merkx, Inge van der Weijden, Anne-Marie Oostveen, Peter van den Besselaar, Jack Spaapen, *Evaluation of Research in Context; a Quick Scan of an Emerging Field*. Den Haag: COS/EriC, june 2007

0707 Peter van den Besselaar, Loet Leydesdorff, *Past performance as predictor of successful grant applications - a case study*. Den Haag, Rathenau Instituut, december 2007

0808 Jan van Steen, *Informatievoorziening over wetenschappelijk onderzoek*. Den Haag, Rathenau Instituut, juli 2008

0809 Edwin Horlings, Anouschka Versleijen, *Groot in 2008; momentopname van grootschalige onderzoeksfaciliteiten in de Nederlandse wetenschap*. Den Haag, Rathenau Instituut, november 2008

0910 Edwin Horlings, *Investeren in onderzoeksfaciliteiten; prioritering; financiering, consequenties*. Den Haag, Rathenau Instituut, januari 2009

0911 Femke Merkx, Reinout van Koten, Thomas Gurney, Peter van den Besselaar, *The development of transdisiplinary learning sciences: promise or practice?* Den Haag, Rathenau Instituut, Juni 2009

0912 Peter van den Besselaar & Thomas Gurney, *Regenerative medicine, an emerging field*. Den Haag, Rathenau Instituut, juni 2009

0913 Inge van der Weijden, Maaike Verbree, Robert Braam, Peter van den Besselaar, *Management en prestaties van onderzoeksgroepen*. Den Haag, Rathenau Instituut, augustus 2009

F&F1 Jan van Steen, *Universities in the Netherlands - Facts and Figures 1*. Den Haag, Rathenau Instituut, september 2008

F&F2 Jan van Steen, *Public research institutes in the Netherlands - Facts and Figures 2*. Den Haag, Rathenau Instituut, march 2009

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