Learning Sciences and Brain Research:
Summary of the 2nd Literacy and Numeracy Networks Meeting,
held in El Escorial, Spain, from1 – 3 March 2004.

For the second time the OECD-CERI Literacy and Numeracy networks met in a joint meeting which was hosted by the Spanish Ministry of Education, Culture and Sports. The meeting was held in El Escorial (about 40 kilometres outside of Madrid), an appropriate setting, next-door to the imposing Monastery of San Lorenzo built by King Phillip II.[1] The purpose of the meeting was to update on the research work in the field of literacy and numeracy by the scientific networks members; to develop interconnected activities that would link intervention training techniques to specific cognitive and brain imaging research; and to foster the bridge-building activity that the OECD-CERI is striving to achieve in this project between neuroscience and education by coming up with ideas and positive suggestions on how to go about how to make this knowledge accessible to a global audience of educators and policymakers. This meeting marked a milestone, not only in the cementing the collaboration between the two networks, but by proving that they could work in a transdiciplinary fashion with the educationalists present at the meeting. The conviction that the OECD-CERI project has instilled in the parties present at the meeting, demonstrated that these two networks are ready to help concretely towards impacting directly on education.

These two networks have been working closely in tandem for some time, and for this reason it was decided to meet together so that scientists in the two fields could cross-fertilise and exchange ideas on their work and how they might be able to impact education. They were invited to El Escorial from 16 countries to come together to compare their different studies on brain areas activated in problems with math and reading problems, and hypothesise on the impact of these for education. There were 25 educators present (including 6 from the Spanish Ministry). The programme was very ambitious, with 37 presentations in 3 days (the first day focussing on literacy, the second day with sessions from both fields and such topics as looking at numerical and literacy skills in a knowledge society, and the final day dedicated to numeracy).

As opposed to the third OECD-CERI Brain and Learning Science project network on Lifelong Learning, these two networks are looking more at children from preschool - when language and counting skills are formulating in their brains - to the ages where they have mastered and are fluent at these skills.

In history, reading was considered as a luxury, whereas being able to count was a necessity to survive. One-sixth of the world still remains illiterate. The challenge for

[1] This monastery houses the very first Arabic literature library with around 50 000 original volumes and where amongst the other philosophies, arithmetic has been elevated to celestial heights depicted on the painted ceiling amongst the other philosophies and even including some calculations.

these two networks within the OECD-CERI project on Brain and Learning sciences is to show how findings in brain science (by looking at the fundamental problems underlying learning disorders such as dyslexia and dyscalculia, and bringing to attention existing interventions that work), can develop a new synthesis of basic and lifelong skills in order to survive and meet the challenges we are now faced within the knowledge economy. CERI, by holding such a meeting, is putting together neuroscientists, psychologists, educationalists, and policy-makers in a melting pot so that its overall goals to gain sounder basis for the understanding (and, over time, an improvement) of learning and teaching processes and practices, notably in the areas of reading and mathematics might be achieved.

The Literacy Exchange

Reading has no evolutionary base. It is a relatively recent code which was founded by the Phoenicians. There is therefore no rooted step in our brains for written language. For the Literacy Network, one of the main ideas is that if we can know the deeper underlying processes of reading, we could design more effective learning-to-read and remedial reading programmes for reading disorders. This is however a somewhat dream goal and can be considered as the "bridge" metaphor to which John Bruer has referred to as being a little too far. CERI will endeavour to take the findings from this meeting and the continuous input from this network in order to help diffuse information, especially by way of its website, in order to prepare and update teachers and practitioners and to assist therapists in their jobs.

This meeting highlighted that the time is now ripe for a more bottom-up approach whereby better ownership from teachers as well as parental involvement are necessary.

Nearly all the presenters of this network highlighted the complexity of the English orthography. On a European Union gradient showing the complexity of orthographies across Europe, the Finnish, German, Greek, Italian and Spanish languages appear at the top of the scale, with English as the most complicated orthography at the bottom. As the phoneme level appears to differ enormously in languages, several researchers are pointing to the importance of phonemic awareness and how it should be taught, as the key to the door of learning to read. Prior to school, children are already aware of phonological units, but it is only at school that a new awareness comes with reading acquisition. It was shown that teachers who concentrate on letter/sounds have better impact on at-risk children. Today, as English is becoming the jargon for international communication on the worldwide web, the problems of learning a more challenging orthography as opposed to a shallow[2] language need to be thoroughly explored. Two hypotheses on this were sounded: one being that because of the higher complexity of the English language, when mastered it could fire more neurons and possibly help make brains more adept

[2] "shallow" languages have a one-to-one correspondence between letters and sounds (graphemes/phonemes). In English the reader has first to be able to make orthographic segmentation of multi-letter and often inconsistent graphemes (*thief - /th/ /ie/ /f/*) and where the knowledge of basic letter sounds does not suffice for being able to use the grapheme/phoneme (letter/sound) correspondences.

for learning other skills; or on the other hand, that it uses up so much learning space in the brain that it then blocks the learning of other skills.

Dyslexia has been a focal issue of this network from the outset and not least due to its reported prevalence in some countries. This is a common disorder in the phonological domain, which is why it helps us understand reading in general. Emphasis at the meeting was placed on predictors of reading problems such as dyslexia and that they should be explored more thoroughly. Some promising work on this is being undertaken in a longitudinal study in Finland whereby some very early measurement predictions which can point to at-risk children as early as six months of age. This kind of early diagnosis will help to get these at-risk children remediated before onset and problems are ingrained.

A lot seems to be going on prior to school, language, literacy, cognitive and social skills already emerge and stabilise before formal schooling begins, so that early variables are important. However, once a kid walks in the school door, instructional variables become vital, as these can then (notably if delivered by teacher-managed explicit higher order instruction) produce a dramatic turnaround effect in the early grades. It was shown that teachers who are sensitive to progress of children and programmes with child-by-instruction interactions work well.

It was stressed by speakers throughout the three days that the environment is also vitally important so that we always should keep larger context in mind. We should not forget that children’s brains are inside their bodies, so that there are also a lot of other biological and hormonal activities going on around the brain to consider as a whole.

One of the presentations highlighted the evolutionary lip reading system. It should be remembered that vision is important in reading instruction.

During the course of the meeting, it was made evident that various brain scanning research models which highlight different areas of brain use are shedding new light on how our brains process written language. One interesting research example was shown from data on an autistic child who represents the antithesis of a dyslexic person in that this young boy who is obsessed with reading. But, a word of caution, it should always be retained that fMRI studies are very much research tools and not yet diagnostic tools. We are far from wheeling in mobile units into the classroom to scan our children’s brains as routine.

It is not yet apparent if there can be considered to be a “critical period” per se for learning to read. A study was presented on kids who miss the cut-off date to go to kindergarten. The results show that where reading skills are concerned, these children seem to catch up just as easily as those who have a head start.[3]

---

[3] On the other hand, studies such as the OECD PISA Study [www.pisa.oecd.org/] have shown a marked difference in other aspects of schooling for children who have attended kindergarten.

The Literacy network is now looking towards developing some experimental edutainment intervention tools, which will be downloadable in the foreseeable future from the OECD website[4]. This network will continue to further explore the biological underpinning of reading and reading problems, and across language culture and schooling, in order to see how educational factors impact on this.

The Numeracy Exchange

The Numeracy network is very much connected with the work of the literacy network as after all maths involves reading, reasoning and working memory skills so that all of these need to be trained when considering improving or making education programs. As far as the brain is concerned, there are not as many studies in numeracy as in reading. In math problems especially the comprehension phase is vital as this requires a complex cognitive process which demands the activation of working memory resources. For example, storing operands and answers simultaneously requires the brain having to store three numbers at a time, so that the relationship between counting skills and subsequent retrieval of facts is not as straightforward as one might assume. The difficulty of the task is of course further accentuated with higher figures. The human brain is no good at doing sequential operations. Maths provides you with a whole set of conceptual tools for life.

As with dyslexia, there also appears to be a high rate of children and adults with dyscalculia. However, this problem lacks official recognition and there are no standardised diagnostic tools available. It appears that the genetic component needs also to be more thoroughly examined. As numbers are renowned to inspire fear and frustration in all of us, we were also presented with a broader problem that was previously unheard of: math anxiety in children. The research presented was not able to prove yet what the exact cause of this is, whether it is due to the teachers themselves who instil it in their pupils or if it is a kind of phobia. But this indeed appears to be a real problem which needs addressing in the in the classroom, and specific remediation is necessary more in line with treatments for emotional stress disorders. This study brought to the attention the fact that we also need to focus on the role of the amygdala (which plays a crucial role in emotions/fear) when looking at the brain structures affected by maths.

Studies from infants with problems such as Downs and Turner syndrome were demonstrated which may also shed light on brain math disorders. As with all learning problems, in all three networks we have noted that the causes are due to a combination of genetics as well as environmental factors.

This network presented several applications recommendations for improving maths skills. One presenter pointed to the benefit of micro-genetic application math models – concentrating on the inborn internal mechanisms to perceive numbers - in order to observe and pinpoint change much more directly and specifically. In Austria, comparative brain scanning research is conducted with maths disabilities on behavioural measures (reaction times, accuracy) and on brain activation patterns in

[4] www.oecd.org/educ/brain

healthy young adults. Two groups are compared: one group being taught using step-by-step algorhythms, which teaches strategy, and the second group being taught by rote (repetition) learning. This study shows that learning by strategy leads to more stable results than learning by drill, and that different strategies lead to different brain activations.

Another presentation showed that children should be able to develop their talents in a more natural way and that math teaching should be adapted to contribute to today's society (some curricula are too probably traditional). It was suggested that perhaps evaluation across countries is needed and more onus should be put on the parents. There are already some existing interventions that do not brain scans to so that they work such as "Number Worlds" program in US based on Piaget's instructional principles. These are interventions in the form of games for teachers to implement and which provide a rich set of activities for children to train up their number sense. This kind of sensible hands-on approach could be reinforced by parents playing board games at home with their children, teachers should not be afraid games are too innovative. In the Netherlands "Rekenet" (Mathsnet)[5] is a good playground for kids to do math gymnastics in a fun on-line web setting and it also provides a support tool for primary school teachers.

A few of the speakers referred to children who rely on their fingers for counting and making calculations. Warning was sounded that whereas it is a natural prop, it should be encouraged to begin with, but that children should be weaned off it as it destroys mental calculation and they rely on it too much. However, there was no real consensus here, and clearly more research is needed

As with the literacy network, CERI is looking at intervention tools to be adapted for putting on their website. The advice of this network for the future to follow is that: rich representations for teaching mathematics should be further explored; existing good practice teaching tools that have been shown to work should be made accessible to a wide audience; and that when teaching maths information, it needs to be consolidated with the aid of auditory stimulation, by repetition and scaffolding.

Conclusions

Reading and arithmetic are very recent cultural inventions, so that the architecture of our brains has not had enough time to adapt to their specific constraints. The brain also has limitations due to the fact that it is laid down by genetic control. However, due to the plasticity of the brain, and as cultural inventions have a highly variable basis, we can work on those. Understanding how the brain works in literature comprehension and when undertaking numeracy computations can show how the architecture is constructed and point to how to capitalise this. It is difficult to take models as theoretical tools (very abstract and theory driven) and incorporate them into the classroom, but we can look at how they can be adapted and used in practical fields. The key is that we need to find the underlying processes as in

[5] http://www.fi.uu.nl/rekenweb/en/

cognitive models and learn from those, and way by clarifying the nature of learning we can begin to describe the learning processes.