Neurosciences and the Human Person: New Perspectives on Human Activities
Pontifical Academy of Sciences, *Scripta Varia* 121, Vatican City 2013
www.casinapioiv.va/content/dam/accademia/pdf/sv121/sv121-battro.pdf

Homo Docens and the teaching brain

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A Socratic Dialog revisited

> ἔχεις μοι εἰπεῖν, ὦ Σώκρατες, ἆρα διδακτὸν ἡ ἀρετή; ἢ οὐ διδακτὸν ἀλλ᾽ ἀσκητόν; ἢ οὔτε ἀσκητὸν οὔτε μαθητόν, ἀλλὰ φύσει παραγίγνεται τοῖς ἀνθρώποις ἢ ἄλλῳ τινὶ τρόπῳ;

Plato founded his famous Academy in Athens two thousand and four hundred years ago where many of the brightest minds of Greece were educated. They were "doing philosophy together", *sumphilosophein* (Berti, 2010). Socrates, the great teacher, was the master figure in the Platonic dialogs. He excelled in the way he presented the questions and negotiated the answers but, paradoxically, Socrates himself, the master teacher, tried to show that *he was not teaching at all, he was just helping the others to unfold their own knowledge*. Today we are "doing science together" even if we are separated by great distances. Teamwork in the digital era has distance 0 and no borders. In this context we can ask two questions: could we use a Socratic dialog today as an effective pedagogical tool with large populations of students online? Could we identify the brain processes of the teacher and the student involved in such a quest? The following considerations will hopefully suggest some answers.

Plato in *Meno*, a dialog about virtue, showed one of the examples of Socrates' peculiar way of "teaching" in great detail (see the *Meno* dialog in www.perseus.tufts.edu). Meno asked Socrates "whether virtue is acquired by teaching or practice; or if neither by teaching nor practice, then whether it comes to man by nature, or in what other way". In the search for an answer to this crucial question Socrates presented a detailed proof of his peculiar theory of teaching by giving a "lesson" on geometry to an ignorant boy who was Meno's slave: the problem was to double the size of a given square.

"Attend now to the questions which I ask him, and observe whether he learns from me or only remembers," said Socrates to his friend Meno when he started his lesson about the duplication of the area of a square. But Socrates also wanted to prove a cognitive thesis, a most controversial one: "Do you observe, Meno, that I am not teaching the boy anything, but only asking him questions..." And he insisted that he was not teaching at all: "Mark now the farther development. I shall only ask him and not teach him, and he shall share the enquiry with me: and do you watch and see if you find me telling or explaining anything to him, instead of eliciting his opinion". The dialog ended with the solution of the geometrical question by the slave. And then Socrates asked Meno: "What do you say of him, Meno? Were not all these answers given out of his own head?" "Yes – answered Meno – they were all his own". This lesson became a classical paradigm of Socratic pedagogy for centuries. In fact, it is perhaps the first time in history that somebody recorded in detail all the questions and answers of an exchange between teacher and pupil on a very precise topic. I think that this is one of the most beautiful pieces of pedagogy ever done.

Seven steps in search of the teaching brain

I will now follow several steps of the long path we have taken to understand this particular model of teaching. The question is: can we really teach how to think? (Battro, 1977).

1) Inspired by Meno

I became interested in *Meno* since the very beginning of the introduction of computers in education, in the early eighties, using *Logo* as a digital tool (Papert, 1981; Battro, 1998). In fact, most of the answers of the "slave/student" dialog were given by yes or no, a very convenient outcome to analyze with the help of a computer. Thirty years later our expectations were fulfilled (see the Sixth step).

2) The teaching brain

Soon we became aware that we were still lacking substantial support from the neurocognitive sciences to explain why all animals learn but only humans are so performing in the difficult art of teaching, even since early childhood (Strauss, 2005; Battro, 2010). Animals cannot teach in the way humans do (Caro & Hauser, 1992; Passingham, 2008), but until now most of the scientific effort in neuroeducation (Battro, Fischer & Léna, 2008) has been focused on the neural basis of learning, on the *learning brain* but not on the *teaching brain* (Battro, 2010). Fortunately we can correct this serious bias today using brain-imaging technologies in an experimental classroom setting.

3) Neuropedagogy

In order to establish a new field of knowledge we should take a "transdisciplinary attitude" (Koizumi, 2008). This is what happens in many laboratories of cognitive neurosciences today (see: IMBES, International Mind, Brain and Education Society; www.imbes.org). We may call *neuropedagogy* this new field of the theory and practice of teaching and learning.

4) A standardized Socratic dialog

At the Laboratory of Integrative Neurosciences of the University of Buenos Aires directed by Mariano Sigman we decided to explore *Meno* as a classical "lesson" of relevant significance in the story of Western pedagogy. The *Meno* dialog was translated into a standard format of 50 questions (in Spanish) that repeated the Socratic master class with 58 high school and college students, in "one to one" teacher/student interactions using pen and paper to draw the figures (Goldin, Pezzatti, Battro & Sigman, 2011).

We first parsed the dialog in linear and conditional branches. Conditional branches diverge from questions in which the slave makes an error and are only transited if the participant makes exactly the same error. For instance, in Question 10, Socrates asks "This (side) is two feet long: what will be the side of the other (square) which is double in size?" Meno's slave responded: "Clearly, Socrates, double" which is an error because the new square would be four times the size of the given one.

The experimental results show a remarkable agreement between Socratic and empiric dialogs: "In 28 questions, the response of every single participant followed precisely the Socratic dialog, as Meno's slave did some two thousand four hundred years ago! In questions in which Meno's slave made a mistake, within an unbounded number of possible erred responses, the vast majority of empiric responses coincided with the error of the dialog" (Goldin *et al.*, 2011).

5) Comparative studies

In order to compare these results with other cultures we asked our colleague Jiaxian Zhou of the Center for Educational Neuroscience, East China Normal University at Shanghai, to repeat the Socratic dialog with her Chinese students using our methodology. The results of the students of Buenos Aires and Shanghai were similar (Jiaxian Zhou, personal communication). This finding suggests that the cognitive process involved in the solution of the Socratic problem may be common to students of different cultures, but clearly we would need larger populations to show the "universality" of this neurocognitive process.

6) Meno online

We can now use the digital platform provided by OLPC, One Laptop Per Child www.laptop.org (Negroponte, 2007), to reach a large number of students online by using a software that automatically asks the Socratic questions to the student and can follow, guide and track the answers step by step in a digital version of the *Meno* dialog. By the way, this computer-based lesson on geometry "without teacher" could be understood as a metaphor of the paradoxical Socratic statement that a teacher doesn't teach (nor does a computer...).

7) Transfer of knowledge

It was a complete surprise for us to discover that almost 50% of the participants that reached the correct solution: "take the diagonal of the given square as the side of the square with a doubled area" *failed* when asked to double the area of a square of a *different* size! They couldn't *generalize* the geometrical construction to a square of any size… This transfer failure is amazing and suggests that the Socratic dialog per se is not enough to induce a student to overcome a cognitive bias (such as to double the length of the side in order to double the size of the square) and accept a stable and definitive solution that can be generalized to any square.

This typical regression to a former and erroneous state of knowledge clearly shows that the lesson wasn't understood and the new knowledge wasn't assimilated. This phenomenon has been recognized in many disciplines, for example in the teaching of physics where advanced students must "unlearn" the Aristotelian notion of force to simulate a landing on the moon using a computer program (diSessa, 1981). We can conclude therefore that the Socratic method per se, as shown in the *Meno* dialog, has a low pedagogical efficiency. This unexpected failure in the process of generalization is a major educational problem that needs further clarification. We decided then to explore this issue with the tools of the new neuropedagogy.

8) A dialog between brains

We started a new research using portable brain imaging equipment (functional near-infrared spectroscopy, fNIRS) on both teacher and student during the *Meno* dialog. As a control after the Meno experiment the teacher and the student read aloud a passage of Plato's dialog *Apology of Socrates*, taking respectively the role of Socrates and Meleto. The main result with *Meno* is that the left prefrontal area recorded in this experiment with 17 teacher/student couples showed significant differences of cortical activation between the students that could generalize the solution to any square in comparison to those that didn't generalize at all. The former showed a minimum level of activation – similar to the teacher's brain pattern – while the latter maintained a higher activation. Also, students that would later show a sound transfer of knowledge showed a drop in activity during the whole dialog while students that could not generalize showed sustained levels of activity during the entire dialog (Holper, Goldin, Shalóm, Battro, Wolf & Sigman, submitted to publication).

Another interesting finding is that specific brain activations during a given lesson *may predict the success of the learning process of the student*, in other words *we may predict the level of efficiency* of the learning processes of an individual, in this case if the student can generalize or transfer the knowledge just acquired to another situation. In *Meno* the level of brain activity of the teacher serves as a *standard of efficiency* for a given task. We absolutely need the records of both the learning brain and the teaching brain to understand the cognitive process involved during a lesson. Students that transfer show a positive correlation with the levels of cortical activity of the teacher, while a negative correlation occurred with the group of students that couldn't transfer.

After the middle of the dialog, Socrates shifted the focus of the arguments to the diagonal of the square and, with question 33, launched a new path in the geometrical reasoning that will end in the solution of the problem. We call that key question the *diagonal argument*. At that moment we observed a discontinuity revealing a small effect of student transfer in the teacher's NIRS signal. It seems that in such successful interventions student and teacher brains "dance at the same pace", but we need more evidence to affirm this.

A possible interpretation is that the geometric solution is correctly assimilated by the student only when the brain has reached a higher level of *efficiency* for this particular task, in other words "doing more with less" neural activity. This increase in efficiency is what we see in the reduced level of brain activation of the teacher during the dialog. Instead, when the student is unable to generalize, he or she still needs to sustain a higher level of neural activation. In this sense we agree with the recent statement of Bullmore and Sporns (2012) that "*the brain is expensive*, incurring high material and metabolic costs for its size – relative to the size of the body – and many aspects of brain network organization can be mostly explained by a parsimonious drive to minimize these costs". We believe that these costs can be reduced by a sound (neuro) pedagogy that enhances the efficiency of the neural networks in place. Of course our results are only a first and very modest step in the long way to understand what good teaching is.

In conclusion, we can expect that in the near future low-cost and high-performing wireless and portable brain imaging equipment will be common in experimental classroom settings and will, hopefully, help to transform the way we teach and learn. A whole new world will be then opened to education.

Acknowledgments

I wish to express my gratitude to my colleagues of our international team interested in the study of the "teaching brain", in particular to:

– Mariano Sigman, Andrea Goldin, Laura Pezzatti, Diego H. Shalom, Diego Fernández Slezak, and Matías López

– *Laboratorio de Neurociencias Integrativas. Facultad de Ciencias Exactas, Físicas y Naturales, Universidad de Buenos Aires.*

– Lisa Holper and Martin Wolf
Biomedical Optics Research Laboratory (BORL), University Hospital, Zurich.

– Jiaxian Zhou
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