CLIL Appeals to How the Brain Likes Its Information: Examples From CLIL-(Neuro)Science

Yen-Ling Teresa Ting, The University of Calabria (Italy)

Abstract
CLIL is revealing itself as far more than merely a means of combining language and content learning. In giving equal importance to both content and language learning (Marsh and Marsland, 1999), CLIL advocates a 50:50/Content:Language CLIL-equilibrium where the 50:Language component refers to the learners’ language. In doing so, CLIL automatically changes classroom dynamics: rather than downloading information onto passive learners, teachers guide learners towards deep-level understanding of concepts through interactive knowledge-construction processes. Such active learning processes are coherent with how the brain learns. This paper first presents a 50:50/Content:Language activity which enables the reader to acquire science-knowledge through language use. The efficacy of approaching science through CLIL is then explained by the fact that memory formation does not occur in isolation but is tightly linked to the neurobiological processes of fear, motivation and executive control. Finally, the activity is dissected into the operational components of sustained deep learning - an essential state underlying successful academic pursuits - concluding with a discussion of why such a CLIL-Science approach enables both language and content teachers to work within their comfort zones - an essential condition for mainstreaming CLIL. Ironically, science illiteracy is an ailment befalling those born into our scientifically advanced high-tech modern society since science education is failing to equip learners with a secure grasp of concepts underlying natural everyday phenomena. The 50:50/Content:Language CLIL-Science equilibrium provides a pragmatic solution to this problem, and if done well, will enable individuals to discern fact from fiction rather than drowning or unconditionally swallowing the inundation of information appearing with a click-of-the-mouse.

Keywords: Science education – learning, fear, motivation and executive control – neurobiological states of learning – CLIL-science – mainstreaming CLIL
1. Introduction

In linking CLIL to neuroscience one risks being accused of jumping on the “neuro-seduction bandwagon” (Skolnick Weisberg et al, 2008), where affixing “neuro” onto almost anything ups the resale value1. In fact, at first glance, there appears to be little coherence between neuroscience research, intended as controlled laboratory investigation of rat brain slices and neuronal cells in Petri dishes, to CLIL, intended as a means to provide additional foreign language (FL) learning. Neuroscience is grounded in the positivistic sciences, the “crowning achievement of Western Civilization” (Denzin and Lincoln, 1998) which, through research methodologies that are reproducible and generalizable, have replaced witchcraft and alchemy with the objective understandings underlying modern-day medicine, technology and science: anti-malarial medication which works for one works for all and energy-saving light-bulbs reduce consumption for everyone everywhere. CLIL, by contrast, is grounded in education, an arena which has attempted to render itself positivistic, seeking generalizable solutions “much like the biomedical sciences” (Hargreaves, 1996; Smeyers, 2008; Ting, 2005), but struggles since both teaching and learning, the basic processes of education, are idiosyncratic: no two lessons, let alone learners are identical like cancer cells in a Petri dish.

That said, in this paper, I suggest that there can be a very clear link between CLIL and what is known about how the brain processes information and learns. This belief is based on two sources of professional knowledge: that gained 1) during my former role as medical school instructor of “Human Neuroanatomy” and 15-plus years as neurobiology researcher (of rats) and 2) in my current role as an EFL CLIL-Science instructor (of Italian humans). Here, I would like to discuss why some very basic understandings regarding how the brain processes information promotes CLIL as a didactic approach that can overcome serious lacuna of 21st Century education (Section 2). In particular, I propose that CLIL-Science at the upper-secondary level can go far beyond merely “content plus language” if it ventures beyond the confines of reading comprehension into a constructivistic modality. A mini-lesson (on neurones) which adopts such a modality is presented in Section 3, demonstrating how scientific knowledge can be constructed through CLIL-based activities. This section goes on to summarize understandings from four areas of brain research which have clear implications for education: memory formation, fear, motivation and executive control. Section 4 discusses how, done properly, CLIL-Science can become a mainstreamed approach which allows teachers, be they science or language teachers, to function within a “transdisciplinary comfort zone”.

2. Two requests of 21st century education

Compared to science, technology and medicine which have evolved dramatically since the turn of the 20th Century, the stasis of education is rather depressing. While doctors in the early 1900s debated whether hand-washing increased post-partum maternal survival, today, ca. 100 years later, the debate is whether gene therapy is ethical: from ridding bacteria, we now manipulate genes. Education, by contrast has evolved little: when opened to the masses in the early 1900s, knowledge was equated to memorized encyclopaedic facts. Given the inaccessibility of information before the era of WWW, this is not surprising. However, with the advent of the Internet, knowledge is no longer about amassing information but discerning, from the inundation of text appearing with a Googling click, that which is valid from that which is not.

---

1 This paper is presented, in part, in the chapter entitled “CLIL and Neuroscience: what is the connection?”, Proceedings of the CLIL Symposium, Vitoria-Gasteiz, Spain, May 08-09, 2009.
When it comes to scientific information, especially that “designed” for the general public, the ability to distinguish facts from nonsense depends on a solid understanding of basic scientific concepts. How efficient then is science education which stagnates in the information-download mode, inundating learners with details? The American Association for the Advancement of Science (1989) and the National Research Council (1996) warn that, in “overemphasizing facts”, rather than helping learners cultivate a deep-level understanding of scientific concepts, science curricula inadvertently oblige teachers to download onto learners facts and formulas to explain odd-sounding terminology of phenomena that learners can neither see nor appreciate. Worse still, as these details are embedded in the “alienating language of science” (Halliday and Martin, 1993), children quickly come to believe that science is for the brainy few, propagating the opinion that “science is inaccessible and thus irrelevant for the general public”.

Given the enormous advancements of science which now enable us to opt for scientific explanations over witchcraft, it is ironic that “science illiteracy” is an ailment of modern-day education. Schmidt et al., (1997), in the Third International Mathematics and Science Survey criticised the US Science curriculum as being “a mile wide and an inch deep”. Such superficial science education is unfortunately an international problem. In the now oft-cited PISA-OECD 2006 survey, only 1.3% of the 400,000 15 year-olds surveyed across 57 countries had attained the highest level of science competency whereby school-science knowledge was transferable into an explanation of natural everyday phenomena. Transferability reflects successful science education (Cognition and Technology Group at Vanderbildt, 1997) and inability to do so limits our active contribution to technological and scientific innovation.

Another skill requested from 21st Century education is foreign language competence. Considering the time and resources invested in FL-education, the success rate, measured as communicatively competent FL-users, is low. Not only is FL-communicative competence an obvious requisite for professional success in today’s globalised economy, it is a necessary ingredient for tolerance and multiculturalism. That FL-learning takes so long, is so tedious and yet unsuccessful does little to make “others” and their “otherness” accessible (Ahmed, 2000; Bassnett, 2002): If the first thought is “despite 8 years of English I still don’t understand them and I have zero personality when I speak their language” the next thought is unlikely to be “let’s talk to these folks”. This shortcoming of FL-education may be attributed to the fact that the language learnt in traditional FL-classrooms is often unrelated to real-life communication: if input is predictable and output not spontaneous, how can we expect learners to be effective communicators if real-life communication is, just that, real.

Among the numerous concerns of 21st Century education, science (il)literacy and FL-communicative (in)competence are two which have motivated me to adopt CLIL-science. First of all, in advocating a 50:50/Content:Language ratio (Marsh, 2002), CLIL attends to both language and content. What is central to the success of CLIL is that it elicits language from the learner, not the teacher. If 50% of the learning time is devoted to developing learners’ language, it is clear that the era of teacher-as-talking-encyclopaedia must give way to more student-centred science-education: CLIL automatically advocates “learning by construction rather than learning by instruction” (Marsh, 2009). Secondly, as CLIL advocates content-learning not in a FL but through a FL (Marsh, 2005), educators are called upon to design activities in which language is used in an authentically purposeful search for understanding. Done right, CLIL-classrooms are thus student-centred and investigative, very much in line with “the neuroscience of learning”.

http://www.icrj.eu/13/article1.html
3. The neuroscience of learning

3.1. Implementing 50:50/Content:Language CLIL-Science: an example

Linking CLIL to “the neuroscience of learning” calls for a brief overview of the brain’s basic unit, the neurone. However, rather than an encyclopaedic presentation, the reader is directed to the CLIL exercise in Appendix A before reading further. The exercise demonstrates that activities respecting the 50:50/Content:Language CLIL-equilibrium can provide content learning through language: readers are obliged to scaffold through their knowledge of English grammar (i.e. use Language) to attain information about neurones (Content). In addition, as readers must overtly negotiate language, content knowledge is gained through cognitive language processing. Upon completing the exercises, the reader will have noted that question 5 of Part II actually provides the answers to questions 4 and 5 of Part I regarding the characteristics of inter and intra-neuronal transmission. The reason for leaving these unanswered until Part II are discussed below.

As an “encyclopaedic”, traditional way of “teaching” undoubtedly requires less effort, I will resort to “encyclopaedic” to check the readers’ answer and complete the remaining unanswered question in Part II. Briefly, intraneuronal signals are electrical and move, or, in neurobiological terms propagate in only one direction, from the soma (body) to the terminal dendrites to finally reach an inter-neuronal gap called the synaptic cleft (fig. 1). This inter-neuronal synaptic cleft is only ca. 20 nanometres wide and separates the “pre-synaptic” neurone from the “post-synaptic” neurone. As neurones are in series, much like a relay race, a neurone can be “pre-synaptic” or “post-synaptic”, depending on the synapse of reference: a baton-“receiver” becomes the baton-“passer”, depending on which baton-“passage” we are referring to. So, how do the two communicate? Returning to the electrical signal propagating along the pre-synaptic neurone, when this electrical signal reaches the terminal dendrites, it changes the trans-membrane potential (i.e. the difference in electrical charge measured across – inside-vs.-outside – the neuronal membrane) of the pre-synaptic neurone, prompting small membrane vesicles (i.e. packages) containing chemical molecules called neurotransmitters to move toward the inner surface of the pre-synaptic membrane (fig. 1b). Upon fusing with the membrane, the vesicles turn inside-out, releasing neurotransmitters into the synaptic cleft. Therefore, an electrical intra-neuronal signal in the pre-synaptic neurone is thus transformed into a inter-neuronal signals which is chemical (answer to question 5, Part II). Diffusing across the synaptic cleft and reaching the post-synaptic membrane, neurotransmitters act like keys upon “locks” - protein receptors - located on dendritic spines which are knobby protrusions on the surface of the post-synaptic neurone. As with locks, receptors have a specific three-dimensional shape and “unlock” with the right key, i.e. neurotransmitter. Only when a sufficient number of post-synaptic receptors have been “chemically unlocked” by neurotransmitters is a post-synaptic electrical signal generated within dendritic spines, subsequently restarting another electrical intra-neuronal signal which propagates into the dendrites, soma and down the axons towards the terminal dendrite.

Those interested are directed to excellent texts such as Blakemore and Frith (2005) and Scientific American (2003) which render neuroscience accessible to a non-expert audience and Kandel (2003) is a must for anyone fascinated with how the brain works and especially how that of a great neuroscientist reasons.
3.2. Memory formation
And how would learning and memory occur within this recurrent chemical-electrical circuit? In 1949, Hebb postulated that memory reflects the strengthening of inter-neuronal connections: “neurones that fire together are wired together”. Therefore, in a simplistic one-synapse model, intense repetitive pre-synaptic electrical activity would permanently alter the intensity of the post-synaptic response (Hebb, 1949). Once this memory engram is formed, even a smaller pre-synaptic trigger would evoke an intense post-synaptic response. Interestingly, this hypothesis well preceded the technical means to test it. In fact, only in the 60s did Kandel (Nobel Prize in 2000; see 2006) demonstrate “Hebbian learning” within the simple neuronal circuits of Aplysia, a marine mollusc and only in 1973 did Bliss and Lømo confirm that continuous intense pre-synaptic electrical activity permanently change the intensity of post-synaptic electrical responses in mammalian brain tissue, calling this phenomena “long-term potentiation” (LTP). Subsequent studies have demonstrated that blocking LTP-formation at the molecular level prevents learning, confirming Hebb’s hypothesis that functional modifications in inter-neuronal circuitry underlie memory formation.

3.3. Fear, motivation and executive control
Learning and memory ensure species adaptation and survival: The young monkey who recalls the physiological response of nausea after eating a luscious but semi-poisonous fruit-x will avoid fruit-x in the future and have a higher chance of passing on both nausea-discerning genes as well as genes which support the encoding of “emotional/physiological” memories (e.g. Anderson et al., 2006). The counterpart primate who has difficulty forming such memories may very well intoxicate on fruit-x before reaching mating age. Not surprising, brain regions involved with physiological/emotional memories necessary for species survival are similar across animals. In humans, these more primitive brain regions also maintain physiological homeostasis such as body temperature, hunger, thirst, etc., and coordinate emotion-driven behaviours such as the fight-or-flight response to danger. The structures involved form the limbic system (figure 2a), lying below the more evolved cerebral cortex (fig. 2b). The cerebral cortex processes
information along a continuum from simple to complex. At the simple end of information processing, we have two levels of processing: the first is “primary”, involving the five senses of vision, touch etc., which occur in the primary sensory areas and that of the primary motor cortex for executing voluntary movements. Damage to the primary motor cortex, e.g. a stroke, would compromise voluntary movements on the side of the body opposite the lesion. Likewise, patients with damage to the left primary visual cortex, would, despite an intact eye, retina and pre-cortical anatomical structures, report not seeing an object presented in the right visual field even if they can reach out and touch it. Beyond this primary level of information processing, things become very interesting. For example, patients with damage to secondary visual areas may see an object but are unable to say what it is or may be unable to perceive motion. Likewise, for other types of sensory input, higher levels of sensory processing go beyond perception and become more “cognitive” and “interpretive” in nature.

The most complex and highest level of cognitive processing is called executive control, that which distinguishes humans from primates. Of no surprise, this highest level of cognitive processing is managed by the most evolved of all brain regions, the prefrontal cortex: “This region lies at the top of the information-processing hierarchy, receiving highly processed information from all five senses” (Passingham, 2006: 620), accounting for ca. 30% of human brain mass compared to less than 10% in dogs (Goldberg, 2001). Evidence that the prefrontal cortex is the seat of behaviours which distinguish “humans from animals” come from the famous case of Phineas Gage, a railway foreman, who in 1848, due to an accidental explosion, received massive damage to his frontal cortex. Amazingly, Gage survived the accident, apparently losing only his left eye. However, it soon became evident that Gage had lost more: while Gage had been a responsible husband, worker and citizen prior to the accident, damage to his pre-frontal cortex rendered Gage irresponsible, irascible, rude and insensitive to social norms, leading to excess swearing and outrageous, socially unacceptable behaviours which eventually cost him his job and family. Subsequent studies have confirmed that the prefrontal cortex is indeed necessary for “executive control” (see Funahashi, 2001), coordinating the complex human behaviours which have less to do with species survival and more to do with what Homo sapiens sapiens social living is all about: smile rather than strangle, give a kiss in greeting rather than a kick in the groin, sweat and panic but nonetheless sit through a 1h exam, speak to your FL teacher in the foreign language even if you both speak the same L1 and suffer personality deficits in the FL etc. The prefrontal cortex provides us the “executive control” necessary to behave in ways which even our Homo erectus predecessors would find bizarre.

The Limbic System

Figure 2a. A median view highlighting the Limbic System which is a network of numerous sub-cortical brain regions (from

---

3 That the 2009 Society for Neuroscience in Chicago will host ca. 32,000 participants attests to the complexity of brain research: a two-paragraph attempt at “how the cerebral cortex works” can only hope to not do injustice to the discipline.
Although we pride ourselves in higher intellect and university degrees, when we let our guard down, species survival behaviours predominate. Imagine, for example, a peaceful stroll along the narrow via of a quaint Italian paesino. As you are admiring the wrought-iron balconies, an endeavour which does little for species survival but probably fulfils a higher cognitive aesthetic pleasure (Jacobson et al., 2006), a car suddenly careens around the corner, driven by a teenager with an immature prefrontal cortex (discussed below). Our first response would be identical to that of any animal: jump out of the way. Such a flight response is essential for species survival and more “instinct” than “cerebral”: we jump before we realize what we have done. This is thanks to a limbic structure called the amygdala which directs the incoming visual of “careening car” towards other sub-cortical structures such as the hypothalamus which increases heart-rate and blood flow so relevant muscles needed for jumping in the right direction can do so. Such rapid reactions illustrate the amazing velocity by which the electrical-chemical circuitry in the brain is coordinated. What is relevant here is that, in activating a flight response, the amygdala turns off higher-level cognitive processing. Therefore, it is only after the fact do we become consciously aware of our rapidly beating heart, sweaty palms and the coincidental fact of having, involuntarily, jumped into a street-side café. At this point, one might very voluntarily take advantage of this and order something to drink. Retrieving from memory that the stimulating effects of coffee would probably not benefit a rapidly beating heart, we may opt for a camomile or even a shot of whiskey rather than an espresso. In addition, we will hopefully, in this moment of cerebrally-grounded reflection, learn that one should keep to the side of vías no matter how quaint and quiet the paesino. Storing such pro-survival-knowledge in memory has evolutionary benefits.

Are we, however, evolutionary programmed to sit through auditory inputs (alias “lessons”) about topics for which real-life applications and relevance are not immediate? While boredom undoubtedly also afflicts our primate ancestors and other animals, refraining from escaping but obliging oneself to sit through such unpleasantness requires executive control. Such control comes from the prefrontal cortex, as per Phineas Gage. Therefore, while the primitive Limbic System supports rapid fight-or-flight behaviours, in non-life-threatening situations, such as a science lesson, emotive responses are governed by the prefrontal cortex which enables us to muster up enough “cerebral etiquette” to sit upright, look interested (maybe), hope for a good grade and plan for a brighter and better future, even if the relation between [current agony] and [brilliant future] is unclear. Unfortunately for education, the prefrontal cortex also manages short-term working memory which enables us to attend to new input long enough so it has a chance...
to become long-term memory. However, if the prefrontal cortex is busy mustering up etiquette to not flee the classroom, working memory is compromised. That executive resources are limited has been demonstrated in experiments whereby people who are dieting go off task sooner than those who are not, implicating that dieting requires a constant level of self-supervision that compromises executive attention even when the task is not food-related (e.g. Kemps et al., 2005). Likewise subjects who must not only resist chocolates but also eat radishes instead quit tasks earlier than those tempted by only chocolates, while participants without food enticements stay on-task longest (e.g. Baumeister et al., 2007).

Unlike the motivation prompting us to seek water now, the motivation to lose weight, like that for learning a foreign language, the periodic table etc, draws heavily upon executive attention as fulfilment is “down the road”. While the fulfilment-now type motivation involves, not surprisingly, sub-cortical brain structures governing physiological homeostasis, it is, interestingly, also linked to the prefrontal cortex via a bundle of axons called the median forebrain bundle (MFB) which originates in sub-cortical structures and project to the prefrontal cortex. Electrical stimulation of the MFB of laboratory rats will put rats into such a “high motivation” frenzy that they forego water, food and even mating so to manically press a lever to self-administer electrical stimulation to the MFB (Olds and Milner, 1954). As electrical transmission releases neurotransmitters at the terminal dendrites, the astute reader will realize that motivation is a state by which the sub-cortical primitive structures governing emotional/physiological homeostasis modulate the evolved prefrontal cortex governing executive control. Abnormal functioning along this circuit is in fact associated with the disruptive obsessive-drug-seeking motivational state of drug addiction. Be it sleep, drug addiction, depression, schizophrenia or an attentive student, brain chemistry underlies affective states (e.g. Benes, 2009, Wise, 1998).

3.4. An ideal learning state?

More complex than fear, motivation is an affective state supporting species survival, prompting us to seek conditions in which hunger is satiated, thirst is quenched and even cerebral states such as “emotional contentment” associated with nurturing our young and even play, are satisfied. However, is there obvious survival value, physiological benefit and emotional contentment for students streamlined within compulsory education where “completing the curriculum” is prioritized above and beyond “learning”? Few youngsters would say “I hate food (in general)” but too many say “I hate school (in general)” (Bransford et al., 1999). Observing toddlers exploring their surroundings and finding fascination in a rolling ball, one realizes that, somewhere along the line, we have muted our genetic predisposition to “explore and understand” (Blakmore and Frith, 2005). As human children explore, so do young animals driven by curiosity to understand the world around them. However, while young animals continue to roam and learn, young humans enrol in schools to sit and learn. There are certainly inhumane zoos as well as insightful teachers who promote learning through discovery, however, few would deny that information-download is a general trend in education, even when well-meaning educators venture into African villages to set-up schools so youngsters can sit and learn (Chimombo, 2009).

Sitting may not, however, be bad at all if the “food later” motivational state is operational, or, in neurobiological terms, the prefrontal cortex should be:

1) adequately motivated - the MFB should be ON because something gratifying is happening (we teachers probably need not fear the state of excessive MFB stimulation) and;

2) directing its limited resources onto working memory rather than “calming the amygdala” – fight-or-flight should be OFF.

http://www.icrj.eu/13/article1.html
Finally, given the apparently central role of the prefrontal cortex in enabling learning, it is interesting that only until quite recently was the belief that the human brain attained its final anatomical organization by early childhood refuted by a longitudinal study on intelligence where unexpected dramatic changes were found in adolescent brains (Shaw et al., 2006). Various structures, but especially the prefrontal cortex, achieved their final functional and anatomical adult-like organization around the early 20s. This may explain why adolescents may sometimes lack that far-sightedness needed to sustain “responsible” behaviours aimed at achieving long-term goals (see Goldberg, 2001, Blakemore, 2008). These findings have clear implications for why compulsory education must provide naturally motivating learning contexts: while university degrees and foreign language competence may help find food, they do so only in the long-run (hopefully).

4. So, why CLIL?

Calling for radical change would be unrealistic. However, sensitizing educators to the need for learning contexts which are more brain-aware is feasible. We need to remember that “food-later” motivation is an evolutionarily new way of being and more volatile than the primitive “food-now” type motivation. Learning something that has little apparent immediate real-life relevance requires what Scherer (1988) calls sustained deep learning. Unlike the learning of physiologically-driven behaviours required for species survival, “sustained deep learning is never inevitable and therefore is highly dependent on affect, emotion and motivation” (Schumann, 1998: 35). These states in fact underlie the subconscious act of stimulus appraisal, a filter separating “input” and “learning” (ibid). Scherer (1988) presents five modes of stimulus appraisal and, applying this to CLIL-Science, we may conceive of a stimulus appraisal unit comprised of five sequentially stacked filters:

1) the novelty filter: is this information new?
2) the pleasantness filter: is this input enjoyable?
3) the relevance filter: what does this have to do with my goals – do I need it – is it significant?
4) the cope-ability filter: can I understand this?
5) the self/social-image filter: will knowing this make me ‘cool’?

Sustained deep learning is possible if information flows smoothly across each filter, through the entire unit. The 50:50/Content:Language CLIL learning environment can easily accommodate these filters and promote a brain-compatible science-learning environment which is investigative and interactive. Science-teaching based on terminology and details will probably not send Johnny’s median forebrain bundle into a frenzied high-motivation state. On the contrary. If learning is downright intimidating, we may even activate Johnny’s amygdala. In receiving the “flee now!” message from his life-saving primitive brain structure, Johnny’s prefrontal cortex is unable to sustain working memory and maintain “food later” motivation as it is too busy marshalling up “etiquette energy” to prevent (sometimes not totally successfully) him from just screaming out in despair or behaving in an unscholarly manner. Conditioned-fear response can be seen in rats which have learnt that an otherwise neutral auditory signal is followed by a painful electrical foot-shock. Conditioned-fear rats freeze upon hearing the auditory stimulus while non-conditioned rats continue normal exploratory behaviour. In fact, the auditory stimulus elicits a frenzy of neuronal activity in the amygdala of conditioned rats prior to, i.e. in anticipation of, the painful foot-shock. Recent studies using fMRI in humans have also found amygdala activation associated with conditioned-fear (LaBar et al., 1998). Finally, prolong exposure to even mild environmental stress disrupts the executive functioning capabilities of the prefrontal cortex (Arnsten, 2009). Take together, the damage caused by unpleasant learning contexts upon the developing adolescent brain may be deeper and more far-reaching than we would like to imagine. A milestone study carried out by Klüver and Bucy (1938) found that ablating the
amygdala of monkeys rendered them extremely docile and unresponsive to otherwise innate fear-inducing stimuli such as snakes: Either we perform amygdalectomies like tonsillectomies so that Johnnys don’t hinder curriculum completion, or we reconstruct the learning environments so that classrooms are more brain-aware, revving up the median forebrain bundle and enabling the prefrontal cortex of the average Johnny.

4.1. The dynamics of science through CLIL

CLIL may bypass the need for amygdalectomies. As mentioned above, unlike immersion bilingual education where content is learnt in a foreign language (FL), with CLIL, content is learnt through a FL (Marsh, 2002; 2005), via the 50:50/Content:Language ratio which attends to both content-learning and FL-learning. The foreign language competence we are interested in is clearly not that of the teacher acting as a FL-speaking-encyclopaedia but that of the learners as they use the FL language to obtain content information and construct understandings. Therefore, CLIL-teachers should automatically be asking “How do I get students to use language?” As an EFL teacher adopting CLIL with Italian science students, I am obliged to consider “Who will be talking? What will they be talking about? How much talking will take place and by whom?” In attending to learner language, CLIL automatically calls for learner-centred classroom dynamics. For science-education, this presents a significant step in the right direction. And as the learning of content must be achieved without a walking-talking encyclopaedia (alias “traditional teacher”), CLIL also calls for the learning process to evolve from a passive explicit-information-absorption format into an active you-work-it-out-using-language format where knowledge is gained implicitly (Ting, 2007; Parise and Ting, 2010). A 50:50/Content:Language equilibrium automatically promotes, therefore, a learning environment which activates learners’ innate needs to satisfy curiosities, i.e. understand.

4.2. Dissecting a 50:50 CLIL-science activity

The first step, then, is to establish curiosity. While the CLIL-neurone exercise in the Appendix is certainly (and hopefully) not the most curiosity-provoking exercise to date, it establishes motivation by harnessing pleasure from puzzle-solving. Although modern-day crosswords may have limited species-survival value, “solving” is what evolution is about, thus accounting for that sense of satisfaction we derive from Sudoku and crossword-puzzles (Davidson and Sternberg, 2003). Puzzle-solving can acknowledge the “pleasantness filter” of appraisal for sustained deep learning. In fact, the entire neurone exercise is founded on the belief that solving puzzles is gratifying, instigating, therefore motivation to approach the topic. New topics do not, however, automatically fulfill the “novelty filter” if their presentation is not pleasant and cope-able. The first exercise is therefore a puzzle about neurones which is completely solvable through readers’ knowledge of the English grammar: the “cope-ability filter” is considered. However, learners are left with two unsolved questions regarding whether inter or intra-neuronal communication is electrical or chemical. These unknowns harness motivation from curiosity long enough for learners to continue seeking answers, not so much because they care about neurones but because they have already started a puzzle.

The second exercise asks learners to match six answers to seven questions about neurone anatomy and, even if this is their first encounter with the subject, scaffolding again upon their knowledge of how the English language works, learners automatically learn how neurones work: content knowledge (new) is accessed through language knowledge (known). In completing this second puzzle learners automatically answer the two unknowns from Exercise I. In addition, reference to the big toe addresses the “relevance filter” and knowing this tid-bit may be “cool” enough to reinforce learners’ “science-self-image”. Exercise 3 asks learners to label parts of the neurone in figure 1, and, lo and behold, yes they can! Who said science was inaccessible? Classroom research using similar exercises showed that knowledge regarding
heart anatomy was transferable, enabling students to correctly infer heart physiology (Ting, 2007). This is the CLIL-content-potential. In addition, while CLIL does not do miracles, since the content knowledge of “poor” students often remained erroneous, such 50:50/Content:Language activities increased students’ confidence as English users since, after only three CLIL-Science lessons, even weak students opted to write in English under high-risk test conditions. This is the CLIL-language-potential, also noted by Dalton-Puffer et al., (2009).

4.3. Issues with student-centred 50:50 CLIL-science

While both the CLIL-language-potential and the CLIL-content-potential can be optimized through the 50:50/Content:Language approach presented here, several issues require attention. First of all, both the heart and neurone exercises were developed to fulfil the L1-science syllabus established for Italian Scientific Lyceum. Being L1-content-driven, the scientific content was not simplified for the sake of CLIL. This is an important point for two reasons:

1) for CLIL to be mainstreamed, it must provide an efficient and effective means to fulfil school curricula. CLIL-content cannot simply repeat what has already been covered in the L1-content class;

2) the content was not simplified into the comfort zone of a language teacher. To date, much of what calls itself “CLIL-material” is merely reading comprehension exercises that language teachers feel comfortable managing (Ting et al., 2006). However, rather than reading about when Coca-Cola was invented, the readings are about DNA, with statements such as “DNA is important because it contains all the genetic information that makes us what we are.” If students are already learning in their L1-science courses that “the DNA double helix is formed when hydrogen bonds pair the bases of adenine with thymine and guanine with cytosine found on adjacent sugar phosphate backbones”, expecting learners to be enthralled by the statement that “DNA is important...” is akin to expecting our mechanic to find the user manual of our car fascinating reading. It would be better to stay with readings about Manchester United or anti-wrinkle creams and just call these by their real names, “EFL-material” – nothing wrong with that.

Having said that, we must commend the great effort publishers make to render science content comfortable for language teachers (e.g. Fitzgerald et al., 2007). Since “science is intimidating” (Halliday and Martin, 1993; Cortese, 1999), asking language teachers to CLIL science content that fulfils the L1-curriculum may oblige them to work well outside their comfort zone (Ting, 2007, et al., 2006; see also Coyle, forthcoming). Interestingly however, language teachers are the primary force behind the “CLIL movement” and are therefore especially commendable in their ability to implement CLIL even if they must seek help from content colleagues and navigate beyond their comfort zone. Such enthusiasm must be harnessed before it peters out. In fact, as Coyle so rightly noted at the CLIL Symposium in Vitoria-Gasteiz (2009), “CLIL is at a dangerous moment”: being applied with few guidelines CLIL risks evolving into time-consuming but ineffective and thus frustrating experiences for otherwise eager teachers. Likewise, if commercial CLIL-materials continue to use the modern-day CLIL-veneer to cover olden-day reading comprehension exercises in which content has been dramatically simplified, CLIL will definitely become only “a passing fad” (e.g. see MacMillan “One-stop CLIL” for a discussion on this) and we will have missed the CLIL-potential.

A truly 50:50/Content:Language approach whereby new science-knowledge is gained through familiar English language-knowledge does not require teachers to “lecture” outside their comfort zone. In fact, it would be unwise to expect anyone to talk too much about something they are not thoroughly familiar with. To rev the CLIL-potential, we must support teachers with materials developed ad hoc so that even if content is outside a teacher’s comfort zone, the learning process is not. The neurone activity allows the language teacher to pause on why certain
matches cannot be, given what is known about English grammar, and the content teacher, with only minimal familiarity with English, can use the exercise as is since it addresses content within their expertise. The 50:50/Content:Language CLIL-Science equilibrium can instil a “transdisciplinary comfort zone.” However, for the teacher who cannot hear enough of him/herself talking, such exercises would be downright annoying. Compared to traditional teacher-centred information-download, CLIL-lessons call for teachers to graduate from mere science-informants to the more interesting role of science-knowledge-cultivators.

Conclusions
Interpreted as a 50:50/Content:Language ratio in which “language” refers to that of the learner, CLIL can transform classroom dynamics into one which is learner-centred, constructivistic and motivating as it prompts learners to use language authentically to access information, gain understanding and formulate new content knowledge. As children explore, inquire, ponder and solve, so do learners in such CLIL classrooms. CLIL can go far beyond merely “teaching content and language simultaneously” and become highly coherent with the “neuroscience of learning”. Although teachers can neither implant electrodes in Johnny’s MFB nor perform amygdalectomies, being aware of how certain brain structures process input (or not) may contribute to more effective classroom practice. If nothing else, is what we are doing annoying the amygdala or enticing the MFB? Are the learners’ curiosity levels up or totally off and is working memory at optimal potential? In 1997, Bruer rightly warned against the overzealous transfer of neuroscience findings to education. However, less than two decades later, not only are academic brain research journals such as Cortex (2009) inviting neuroscientists to contribute to ameliorating education but renowned neuroscientists are taking the time to render their expertise knowledge accessible to educators (e.g. Blakemore and Firth, 2005).

Potentially, CLIL can open a new chapter in 21st century education, one which must provide learners with a deep-level comprehension of concepts rather than a myriad of facts. The challenge for (science) education today is not the inculcation of facts but empowering learners with a solid concept-base to discern trash from treasure. Science literacy is essential for social and economic progress (Halber, 2006) but merely completing the curriculum is insufficient if learners are confused only because questions on a test are not presented in the same order as chapters in the textbook (see Bransford, 1979; Mayer, 1998): covering the science syllabus with regurgitated facts and formulas is not science-literacy. Compared to the enormity of the problem, 50:50/Content:Language CLIL is noteworthy for its relative “simplicity”. Carried forth with the brain in mind, CLIL-Science provides a pragmatic means for changing classroom dynamics to overcome the lacuna of science-education: Raising the status of teachers from “encyclopaedia” to “Teachers” (capital “T”) may better accommodate the edgy amygdala, encourage the contemplating pre-frontal cortex and even elicit the motivating median forebrain bundle in the brains of our Learners (capital “L”).
References


http://www.icrj.eu/13/article1.html


Klüver H., Bucy P.: 1939, Preliminary analysis of functioning of the temporal lobes in monkeys, Archives of Neurology and Psychiatry, 42, 979-1000.


Appendix A. Learning about neurones using CLIL

I. Match the sections to form complete sentences:

<table>
<thead>
<tr>
<th>1. Neurones are capable…</th>
<th>A</th>
<th>…two types of communication in the central nervous system (CNS).</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Electrical signals…</td>
<td>B</td>
<td>…is electrical in nature.</td>
</tr>
<tr>
<td>3. There are…</td>
<td>C</td>
<td>…of generating electrical signals.</td>
</tr>
<tr>
<td>4. Intra-neuronal communication…</td>
<td>D</td>
<td>…is chemical in nature.</td>
</tr>
<tr>
<td>5. Inter-neuronal communication…</td>
<td>E</td>
<td>…travel in only one direction.</td>
</tr>
</tbody>
</table>

Figure 1. A neurone.

II. Match these 7 Questions to the 6 Answers given below:

1. Where is the nucleus, the central engine of a neurone?
2. Is the AXON the long extension emerging from the SOMA?
3. Does the AXON terminate as one single point?
4. What is the name of the numerous extensions near the SOMA?
5. How do electrical intra-neuronal signals become transformed into inter-neuronal chemical signals?
6. Why are MYELIN SHEATHS important for neurones?
7. What is the direction of propagation of intra-neuronal electrical signals?

ANSWERS (6):
A. Because these form an insulation around the long axon, like the plastic cover on electrical wires.
B. In the SOMA, the ‘body’ of the neurone.
C. No it doesn’t. It ends in small ramifications called the TERMINAL DENDRITES.
D. They are called DENDRITES.
E. From DENDRITES to SOMA along the AXON to TERMINAL DENDRITES.
F. Yes it is. The longest axon in the human body is the sciatic nerve, running from the base of the spinal cord to the big toe!

III. Now label the parts of the neurone in figure 1.