Are We Having Fun? The Neuroscience of Learning: Does it Support Enquiry-Based Learning?

Gráinne Mulcahy, Gorey Community School and Tutor with Co. Wexford Education Centre

Abstract
I have always had a love of biology, the natural world fascinates me. The human body and especially the brain are areas of particular interest. When I returned to teaching Junior Cycle Science, I felt a refresher in-service would give me a kick start. I enrolled in the Teaching Enquiry with Mysteries Incorporated (TEMI) programme. It was informative and so much fun. It refreshed both my knowledge and practical skills. My break from science teaching was due to my appointment as acting Chaplain. I had done quite a bit of work on the neuroscience of happiness in relation to meditation, it seemed logical to investigate if the physiological structure of the brain had something to teach us about learning. I wondered if the use of enquiry based learning could benefit both student and teacher. If it did, then this might encourage teachers to embrace both enquiry based learning and the new Junior Cycle, which is heavily influenced by this teaching strategy.

Introduction
Where do you stand on the whole sugar versus sugar free debate? I thought I had it all worked out then Coke came out with Coke Zero and then this year Coke Life and I had to rethink the whole thing. Not the ‘which is better for you’ debate, but the ‘which will float’ debate. I did what any resourceful teacher would do when hit with a contemporary dilemma. I asked my students. They were only guessing, so we did an experiment. We dropped the cans one at a time into a tank of water, taking bets as to what would happen. Things got rowdy, competitive elements in the class began to emerge. ‘If we get it right do we get to keep the coke?’ Everyone was interested now. ‘Has it to do with weight can we weigh them?’ ‘Has it to do with what’s in them can we look at the labels?’ ‘Are they the same size?’ ‘Is there more air in one than the other’?

The other way to teach density and flotation is to learn that density is equal to mass divided by volume. Mass being the amount of stuff in something and volume the amount of space it takes up. And then teach that something will float if it is less dense than the liquid it is sitting in. But on this occasion I’d been inspired to do it a little differently. The coke experiment is well known among science teachers who have been using it for years. Traditionally I would pre-teach the terms mass, volume, density and flotation first. This year I returned to the Junior Science classroom after a three year absence. Feeling a little out of touch I attended an in-service. I went to a TEMI workshop. Teaching Enquiry with Mysteries Incorporated. So engaged was I that I enrolled in their project. “TEMI is a teacher training project with the aim
to help transform science and mathematics teaching practice across Europe by giving teachers new skills to engage with their students, exciting new resources and the extended support needed to effectively introduce inquiry based learning into their classrooms.” (TEMI 2015) it is being run here in Ireland by the National Centre for Excellence in Mathematics and Science Teaching and Learning, based in Limerick University. Armed with my TEMI experience I tried out my mystery and enquiry based learning strategy.

The Prevalence of Enquiry Based Learning

There is no shortage of evidence that interactive learning where the student is more responsible for their own learning is essential if we are to prepare our students effectively for the ‘real world’. A quick Google of the topic brings a plethora of research papers and articles on the subject. International and home based experts all concur on the value of teaching through enquiry. Its value is best summed up here.

“Inquiry ... requires more than simply answering questions or getting a right answer. It espouses investigation, exploration, search, quest, research, pursuit, and study. It is enhanced by involvement with a community of learners, each learning from the other in social interaction.”

(Kuklthau, Maniotes, Caspari, 2007).

Enquiry based learning or inquiry based learning, if you are American, has taken root in education systems worldwide. In Ireland we are connected to major European wide education strategies to promote enquiry based learning. PROFILES (Professional Reflection Oriented Focus on Inquiry based Learning and Education through Science) represented by the Eureka Centre, University College, Cork. PPEBL (Project, Problem and Enquiry-Based Learning) initiative at NUI, Galway. SAILS (Supporting Teachers in Adapting Inquiry Based Science) from DCU, Dublin. TEMI, already mentioned based at Limerick University. Much of the methodology is already incorporated in schools. Its presentation and assessment may be a little different, but most teachers will recognise the methodologies. There are three commonly used teaching strategies under the umbrella term of enquiry, problem based learning, small scale investigation, and project or research type exercises.

With the advent of the Junior Cycle the emphasis on enquiry based learning has taken a shift into overdrive. The reasons for this change were clearly articulated in a recent paper by Eilish McLoughlin, Odilla Finlayson and Sarah Brady whose research was undertaken as part of the “pan-European FP7-funded project ESTABLISH (2013) has led to the development of teaching and learning materials as well as educational supports for both in-service and pre-service teachers designed to promote the use of Inquiry based approach at second level.” (McLoughlin, Finlayson, Brady, 2013) They are based at the Centre for the Advancement of Science and Mathematics Teaching and Learning at DCU. Their paper referring to the European Future Skills-Biotechnology project 2009-2011 concluded that “Top Transferable Skills sought by Biotech Employers in Europe were: Oral Communication; Listening; Continuous Improvement and Excellence; Teamwork; Personal Strengths; Written Communication; Personal Organisation and Time Management.(McLoughlin, Finlayson, Brady, 2013) The paper also cited Patte Barth Director, Centre for Public Education at National School Boards Association, Washington, who found that many of today’s employers had identified that “high school graduates were deficient in skills such as problem solving and critical thinking”. (Barth 2009)

It is evident that the ‘Principles for Learning’ outlined in the new Junior Cycle have been informed by the requirements of third level institutions and of industry. The teaching
strategies that come under the general heading of enquiry based and problem solving are evident throughout the new curriculum. These principals outlined in ‘A Framework for Junior Cycle’ published by The Department of Education and Skills, include: Quality; Creativity and innovation; Choice and flexibility; Engagement and participation; Inclusive education, every level of learner can engage; Continuity and development, learning enables students to build on their learning to date, recognises their progress in learning and supports their future learning. Learning to learn, developing greater independence in learning and in meeting the challenges of life beyond school, of further education, and of working. Wellbeing, the student experience contributes directly to their physical, mental, emotional and social wellbeing and resilience. (NCCA 2012)

The Neuroscience of Learning
The biologist in me was somehow not satisfied with this vast array of evidence, I had to understand why. If like me, you like to be convinced by evidence you might like to know if science is firmly behind enquiry based learning. An area of fascination for me has always been neuroscience. What’s going on in our heads? The field of neuroscience and its implications for enhancing learning is where I decided to look for evidence to support the theory of enquiry based learning. ‘The Neuroscience of Learning: A New Paradigm for Corporate Education’ a white paper compiled for The Maritz Institute brings together much of the current research in the neuroscience of learning. The process of learning, according to James Zull biologist, author and neuroscientist, has been identified in a process he calls the learning cycle. “The cycle begins with gathering information followed by reflection, creating and active testing. Each step of the cycle is associated with a different region of the brain”.(Zull 2002) The first phase, gathering, involves the sensory cortices that receive input from external stimuli. This is the brain’s first exposure to the new material, and therefore allocates most of its focus and energy during the learning cycle to ensure the raw materials are properly gathered. The second phase of the learning cycle, reflection, is when the individual takes time to reflect, analyze, and understand the sensory information obtained. The third phase of the learning cycle is creation, where the learner takes received and digested information and extrapolates to create ideas, symbolic representations, and plans. The final phase of the learning cycle is active testing, which involves conveying information into physical events. Examples of active testing include engaging in a discussion or debate about the learned material or designing an experiment to test a concept. (Hendel-Giller 2010) These are four separate stages; each must be completed for learning to be retained. Appropriate time must be given to each stage.

How Learning Happens
Essentially learning happens when one nerve cell makes a connection with another. We do something, we reflect on it, testing its value or otherwise. The more we create and reinforce pathways between nerve cells, the stronger that memory becomes. The more of ourselves we engage in an activity the more of the brain we use, so the more neurons, brain cells, are working together. In his book ‘The Art of Changing The Brain’ James Zull suggests that a better understanding of brain function will promote a more flexible and varied approach to learning. The extraordinary capacity of our brain has only recently been truly explored. With the advent of high quality brain imaging major advances in neuroscience have been made. A statistic that gives us some idea of the extraordinary potential of our brain, and emphasises the importance of understanding its workings is quoted in Zull’s book. “A human brain has about 100 billion neurons (eleven zeros). And estimates range as high as 10,000 connections per neuron. That comes to a total of a thousand trillion connections (that’s fifteen zeros) in an average human brain. There are ten to a hundred times more connections in our brain than there are cells in our body.”( Zull 2002) The enormity of these numbers is difficult to picture. “It is equivalent
to the brain having more connections in it than there are stars in the universe. A piece of brain tissue the size of a grain of sand contains 100,000 neurons and 1 billion synapses, all "talking" to one another." (Payne 2014)

A Canadian psychologist Donald Hebb in 1949 proposed a way that learning might exist at the level of synapses, the place where two brain cells meet. His discovery led to the well-known phrase “neurons that fire together wire together”. Which in layman’s terms means, brain cells that are used at the same time become linked. Learning has happened, and is reinforced by engaging in and repeating that same or a related activity. Ronni Hendel-Giller in ‘The Neuroscience of Learning’ describes a vast network of brain cells, just like a road network. “There is a neuronal network in the brain for everything we know. Every fact we know, every idea we understand, and every action we take assumes the form of a network of neurons in our brain”. (Hendel-Giller 2010) It has been said that we remember ten percent of what we read, twenty percent of what we hear, thirty percent of what we see and hear, seventy percent of what we say and write and ninety percent of what we do. Essentially the more of the brain you engage the more you are likely to remember.

Pat Wolfe, an educator and neuroscientist tells us that there is no such thing as a brain not paying attention. As a teacher I know I have met many students not paying attention, his comments give me cause to think teaching through enquiry might be the way to go.

"The brain is designed to immediately filter all incoming sensory stimuli and select only those that are relevant at that moment so as to encode them. There is actually no such thing as a learner who is not paying attention: the brain is always paying attention to something, although it may not focus on relevant information or on what the instructor intends. It drops information that doesn’t fit easily into an existing network. It “forgets” information that it does not find useful and important. By necessity, the vast majority of sensory data is not encoded—the brain simply cannot pay attention to all the incoming stimuli—so it ignores information that, in terms of existing neural networks, is meaningless. In designing learning experiences, we must discover ways to quickly, effectively and powerfully grab the learner’s attention.” (Wolf 1998)

Understanding the biology of the brain we can tailor teaching strategies which appeal to learners because they appeal to the brain. Two further interesting neuroscience discoveries are the brains response to novelty and the brains heightened ability to learn new facts when connected to prior knowledge. We all perk up when presented with something new or unexpected. New or novelty information increases production of dopamine, a chemical in the brain linked to pleasure and reward, encouraging us to take notice of our environment. All of which validates the TEMI use of mystery in motivating learning. On the other hand we learn best when we can link new information to one of our existing pathways. Teachers link new information to pre-taught material or existing knowledge all the time. It is worth insuring you link your new material well to existing knowledge, including revision at this stage reinforces, and promotes learning. Appreciating that the brain likes to add information to an existing network helps us to put in good foundations for future teaching. Awareness of this when planning what material we are going to be teaching next is a useful technique to maximise learning potential. “Novelty helps the brain initially attend to a stimulus—then, once attended to, connections must be made for the information to take root. So, while the brain needs to make connections, it also likes things that are new.” (Hendel-Giller 2010) Understanding how our brain receives, processes and stores information can inform good teaching practice.
Neuroscience and Social interaction

Humans are social beings; in fact we are designed that way. “Like every living system, from single neurons to complex ecosystems, the brain depends on interactions with others for its survival. Each brain is dependent on the scaffolding of caretakers and loved ones for its survival, growth and well-being . . . The brain is an organ of adaptation that builds its structure through interactions with others.” (Cozolino 2006) In a learning context we function better in a social environment. It has even been suggested by Matthew Lieberman, a Social Cognitive Neuroscientist at UCLA that current understanding of the social nature of the brain challenges Maslow’s pyramid, suggesting that social needs are at the bottom of the pyramid, more basic than food and water. It is also clear that we learn better from people than inanimate devices. It may not be a good idea to replace teachers with ipads. “People learn from one another, sometimes without even realizing that they are doing so. With the increasing shift from face-to-face meetings and events to virtual and digital formats, careful thought must be given to how we build human interaction into learning solutions.” (Hendel-Giller 2010) As social beings emotions play an enormous role in cognition. As practising teachers we understand that there is a balance to be achieved in a classroom. The Coke cans for example, there is a fine line between being educational and being out of control. Betting on the outcome of floating or sinking cans with the exuberance of an all Ireland final is engaging but only educational if tomorrow they know what density has to do with floatation. Again from Cozolino who “calls the ideal emotional state for learning one of “safe emergency”—in other words, there is a high level of attention, without the negative impact of anxiety.” (Cozolino 2006) Similarly, research has shown that stress in the learning environment, negative memories from prior learning, or stress in the broader environment can negatively impact the potential for learning. The creation of a safe and social learning environment will maximise the learning potential of your students.

Multisensory Stimulation

From the brief information I have outlined it would seem obvious that the brain would like multisensory stimulation. The novelty value, the potential for pre-knowledge and the firing of many neurons in different parts of the brain at once. This is indeed the case. “Research in neuroscience strongly supports what is already considered a best practice in learning design—engaging multiple senses. It also demonstrates the unique power of visual images and suggests that using rich images and asking learners to engage visually—and through visualization—increases learning.” (Hendel-Giller 2010) There is a particularly strong response to visual stimulation. Images have an extraordinary impact in the human brain. According to Eric Jensen, Brain Based Learning The New Paradigm of Teaching. “Our eyes are capable of registering 36,000 visual messages per hour. Between 80 and 90 percent of all information that is absorbed by our brains is visual. In fact, the retina accounts for 40 percent of all nerve fibres connected to the brain.” (Jensen 2008) The mechanism and the brains response to visual image is complex and intriguing but beyond the scope of this paper. The much quoted adage “A picture is worth a thousand words” is something to keep in mind when you are trying to get your point across. Which reminds me of the image of coke cans floating, or not, in a tank of water.

Neuroscience and Happiness

There is one last fact from neuroscience I’d like to share. Using strategies in our classroom that appeal to the physiology and chemistry of the brain, like enquiry based learning are engaging and fun. Dopamine a chemical reward produced in our brain is released when we do things that promote our survival, such as learning. Happy brains learn better. Happy teachers
teach better, and happy people live longer and have better lives. There is a vast amount of research on the benefits of positive psychology. They have even located the happiness centre in your brain. It is located in the left prefrontal cortex. This is perhaps the most convincing argument for engaging with enquiry based learning. Our brain is an extraordinary organ, the more active and creative we keep it the healthier we are. It is not just about what is best for students, it can be better for teachers too. Shawn Achor, an authority on the science of happiness and author of the ‘Happiness Advantage’ writes

“If you can raise somebody’s level of positivity in the present, then their brain experiences what we now call the happiness advantage, which is, your brain at positive performs significantly better than at negative, neutral or stressed. Your intelligence rises, your creativity raises, your energy levels rise. In fact we’ve found that every single business outcome improves. Your brain at positive is 31% more productive than your brain at negative, neutral or stressed.” (Achor 2010)

Conclusion

I set out to find out if the latest discoveries in neuroscience would support enquiry based learning. If understanding more of the brain processes involved in teaching and learning would lead to a better quality learning environment for both students and teachers. “Knowledge is power and the more you know about your brain the better equipped you’ll be to have a better life - isn’t that what we all want” (Amen 2014) I have been encouraged by the plasticity of my own brain, the ability to change old habits. My return to teaching junior science afforded me an opportunity to examine my own teaching practice. TEMI provided me with a different perspective and skills allowing me to change my approach to introducing and teaching new material. I enjoyed teaching science, I look forward to the class because we are having fun. I am happy to conclude that in my experience and from my research into the neuroscience of learning, enquiry based learning does indeed give an improved learning experience for both student and teacher.

If you are wondering what happened with the coke cans, then enquiry based learning has worked for you. On many levels it has stimulated your curiosity, grabbed your attention and caused you to look for answers. But more, it will cause you to ask even more questions. You have neurons lighting up and firing all over your brain. What did happen with the cans? The ordinary red coke sank, the others floated but not all exactly to the same extent. Diet coke has no sugar so it is less dense than ordinary Coke, which has thirty five grams of sugar. The new Coke Life has twenty two grams of sugar, less dense than ordinary, it floats. Coke Zero has no sugar, but it does have salt, almost a gram, not enough to sink it but it is slightly denser than Diet. Which is better for you? That is a whole other debate. One my exuberant class were well up for. And we had only begun; diet versus ordinary mayonnaise was next. What about their summer exams? They are a mixed ability group and only a small sample, but virtually everyone knew what density had to do with floatation and could work it out. They may also give more consideration to their choice of soft drink in the future.
References


Hendel-Giller, R., The Neuroscience of Learning: A New Paradigm for Corporate


