# Insight Quotient (InQ): How to discover what it means to have learned something

**Panos Lazanas**
*Department of Electrical, Electronic, and Computer, Engineering, Cape Peninsula University of Technology, South Africa.*
lazanasp@cput.ac.za

Abstract: In engineering education, students often pass exams without actually learning something. This is evidenced by the fact that when they come back the following semester most of them seem to have "forgotten" the work that was covered in the subjects that they had passed. Further, the examination process can allow students to pass on submissions that have no actual meaning for the students themselves. This two-way arrangement colludes in creating a culture of "passing" rather than learning in many higher education departments. At present we don't have a way of knowing if each student's knowledge is embedded in long-term memory and if this information is sufficiently cross linked in a student's brain to give it significance. This results in students "passing" at lower levels only to find that they don't have the underlying knowledge for the higher levels, instead of actually learning properly from the beginning. In order to get around this problematic state of affairs a new approach is put forward which is based on the findings of neuroscience. This new approach involves the development of the Insight Quotient (InQ) of students and lectures alike. The purpose of this approach is to bring to conscious awareness what learning actually consists of (as far as this is possible), by eliciting the ***subconscious*** underlying elements that make up the knowledge of things. In this way both students and lecturers can have a way of determining the presence or absence of learning. Most importantly, by having a means to scrutinise the structure and content of their learning, students can become responsible for the levels of learning they achieve.

## Introduction

One of the key difficulties in education is to know whether the student has internalised the knowledge being assessed. Most often students engage in rote learning which just gets then to pass an exam and is of no further use. This type of apparent learning is mostly structured in short term memory, only "loosely" related to deeper brain structures if at all (Doidge 2007, Swaab 2014), and generally disappears after exams are written. In Engineering Education environments where knowledge is developed sequentially from the first year level to the levels above, the internalisation of preceding work is a must for the more advanced material to have a foundation. Given the common Oxford dictionary definition of learning below, we can observe that the words "acquisition of knowledge" is the key term used to define learning, followed by the means of acquisition.

Learning: The acquisition of knowledge or skills through study, experience, or being taught. (Oxford dictionary)

In this paper the term acquisition will be made explicit by reference to findings in neuroscience, in such a way that both the student and the lecturer can be consciously aware of the presence or absence of the long term memory subconscious associations which we refer to as "acquisition of knowledge". Another factor that must be considered is the plethora of published material on human cognition. This development makes it very difficult to get past all the individual research findings to the point of being able to actually use them in engineering education. To overcome this problem the author has made use of experts, as listed in the references, who have provided overviews of the state of the art in human cognition studies. This gives us the opportunity to use their overview perspective to draw conclusions which find application in the material covered below, which we can use in the classroom.

## The background to the Problem

The key term to be clarified is the term "acquisition". How do we know that knowledge has been acquired? Normally we try to find out what students know by means of examinations, assignments, practical assessments in laboratories, etc. The problem with this approach is that by setting a single question in an exam, which is put to all the students, we have no way of knowing how the question is interpreted by each student's brain (particularly with second language learners). More importantly we don't know whether the response is simply short-term memory (rote) based or not (Swaab 2014). This is often the case with many students who may be able to repeat a definition or solve a calculation problem, but they are doing so without being able to explain the meaning of the words of the definition, or by simply memorising the sequence of steps for the problem calculations without actually understanding the significance of all the elements involved (Swaab 2014). One could argue, as most students do, that there is no time, given the density of most engineering curricula, available to understand everything that is covered, but that does not eliminate the problem above. In fact it makes it worse as what we get is the illusion of learning, supported by the illusion of assessment, when we accept rote answers and award "pass" marks for them, particularly for core concepts in the lower levels. It is not suggested that all learning and assessment processes are in vain, far from that. What this paper is saying is that we are not quite sure (in the context of Engineering Education, not science as a whole) how to actually find out if a student's brain has been sufficiently altered in terms of new synaptic connections, for us to declare that they have in fact learned something (Swaab 2014). This is a very complex problem which has many facets such as psychological, socioeconomic, linguistic, etc., which will not be discussed here at all. However, at the level of brain function it may be a lot simpler to deal with, if only one could access that level.

## Problem statement

Having acknowledged that this problem has many facets, here is what will be addressed in this paper: How does each student and the lecturer know if information (this term includes all the learning experiences presented to a student) is embedded in long term memory and is this information sufficiently cross linked in a student's brain to give it significance (Pinker 1997, Swaab 2014) and depth (Chomsky 1965)?

In order to resolve this problem the difference between subconscious and unconscious processing will be defined, and an introduction to the method used to access the subconscious representations of experience will be demonstrated in the following section.

## Literature Review to establish the Proposed Solution

To address the problem above it is imperative that we clearly define what learning acquisition is, in order to be able to identify if it has happened or not. To come up with a workable definition, I propose we turn to neuroscience. In this context the computational model of the mind arising in a brain is a well-accepted model of how the mind arises and works (Pinker 1997, p. 21). In this model a brain is regarded as a set of operators interacting with a set of information components, Pinker calls them "demons" and "notices" on a board (1997, p. 69). As an example, let us consider how a written word is recognised and then given meaning. In this model, the meaning or significance of words (or any other learning experience) is developed in layers from unconscious processing, to qualia, to words, to sentences, to the experience (as a combination of all the sensory modalities) (Damasio 2010) of actually knowing something. These "notices", the individual components listed above, are acted upon by various "demons" in order to arrive at some meaning or action, along the different layers of processing in a brain.

Quale 'kweil': noun, the internal and subjective component of sense perceptions, arising from stimulation of the senses by phenomena. Qualia: plural (Oxford dictionary)

Layers of processing are activated in a person's brain when perception and learning take place. According to Pinker (1999, p. 87) in order to identify a word, the shape of the constituents of the letters of the word are recognized first, then the shape of the word itself, then the sound of it, and finally its ultimate meaning by means of very fast parallel cross-referencing in many parts of the brain at once. This type of activity cascades across brain regions through the limbic system and up to the neo cortex mostly unconsciously, then subconsciously, until conscious experience arises. Waves of brain activity access the whole brain as required in order to put together the different components of stored information (such as images, sounds, sensations, etc.), which make up all the associations with that word, within the background context in which it is placed (the sentence etc.) (Damasio 2010, Pinker 1997, Ramachandran & Hirstein 1997). All this is taking place in an individual brain, based on its previously acquired and stored (in long term memory) associations (Pinker 2017, Swaab 2014), along different hierarchies, and structures, which are activated unconsciously and subconsciously to finally create or arrive at the meaning of the particular word or concept. Other writers like Noam Chomsky (1965), a linguist, alluded to this when he distinguished between deep structures and surface structure in linguistic expression. The key difference between short term memory (rote learning) and long term memory (actual learning) as demonstrated by Nobel laureate Eric Kandel (Doidge 2007, p. 218) is this: When information is stored in short term memory neuron synapses in the brain are simply exited, whereas when actual learning or long term memory storage takes place new synapses are formed. The brain changes its structure when learning takes place.

Ramachandran and Hirstein (1997) state that the absence of qualia-rich structures is what they regard as the distinguishing criterion between words repeated without deep meaning (in rote fashion), and actual knowledge. Words repeated in such a (rote) fashion are by definition **not** associated with deep structure components and therefore are qualia-poor. Learning, which we refer to by the term "acquisition of knowledge", is associated with qualia-rich, spontaneously arising, cross-linked subconscious experiences, which give meaning to words, associated to long term memory structures (Damasio 2010, Doidge 2007, Pinker 1997, Swaab 2014). Short-term memory, as mentioned above, simply excites the amplitude of synaptic potentials so that when the excitation is lost so is the information, whereas long-term memory involves new synaptic connections so that information is retained and can be reported on. Thus the arising of the experience of qualia as a function of new synaptic connections is another very significant distinguishing factor between proper learning and rote learning.

This then is our criterion of knowledge acquisition: Knowledge acquisition is said to be in place when the structure and content of long-term memory embedded, spontaneously arising qualia-rich representations (in all five modalities such as hearing, seeing, feeling, etc.) (Damasio 2010, Doidge 2007), arising in the minds of students, are compared with the representations in the assessor's mind (who is the expert in a particular field by virtue of him/her having a rich subconscious store of such representations) and are found to be in accord with another.

In this way (by direct comparison) we can establish whether the students have mentally embedded the new knowledge in long-term memory, at the subconscious level, in such a way as they can use it to make meaningful decisions (Damasio 2010). This approach is quite different from the current method of written exams, where one question is given to all students, and no feedback on the individual interpretation or the presence or absence of complex equivalences is explored for each student, and it is easiest implemented for projects. This does not mean we do away with exams, what this paper proposes is that we should supplement what we already do with this new approach in preparation for exams. Having established a significant difference between knowledge acquisition (as defined above) and rote learning, at the brain level, we will now see how we can identify this sort of difference in an individual student's mind.

The method(s) used to elicit the presence of the existence of such spontaneously arising, qualia-rich, subconscious structures, is based on techniques from Neuro-Linguistic Programming (NLP) (Bandler 1989), which when applied correctly by a trained lecturer can help a student reveal what he *actually* knows, by means of revealing to the assessor the presence of complex associations (in the form of qualia representations in the five modalities, visual being the most significant), and other long-term memory subconsciously embedded (Bandler 1989; Damasio 2010) references. These NLP questioning techniques make possible the elicitation of the qualia-rich structure and the content (Bandler 1989) of students' subconscious references of learning, which we established (above) to be the criterion of learning acquisition. A student's ability to report on their subconscious experience is then defined as their Insight Quotient (InQ).

### The Method Used

At this stage we need to establish the meaning of terms like unconscious, subconscious and conscious experience as used in this paper.

The term “Unconscious” in the context of this paper refers to events of which we have no conscious access to. For instance the neural processing of information between our brain regions right now is and will remain outside our awareness (Damasio 2010, Swaab 2014). Such processing is the foundation on which our conscious experience and ideas are based. This is like saying that an image appearing on a computer screen will never become aware of the individual transistors firing in the central processor which make its very existence possible. This definition is different from the Freudian unconscious.

The term “Subconscious” refers to aspects of mental experience, which can be brought to conscious awareness but are not initially conscious (Swaab 2014). For instance your memories are subconscious until you actually bring them to awareness.

The term “Conscious” refers to the content of one’s awareness at this moment (Damasio 2010). It consists of sensations, thoughts, and feelings which one is fully aware of in what we call this moment. It is the awareness of all conscious experiences, as the brain generates them, while they are processed up through the layers of processing to conscious awareness (Doidge 2007).

Unconscious processes are outside the realm of conscious access (Damasio 2010, p. 151; Swaab 2014, p. 329), so they will be excluded in this discussion. The process of bringing the subconscious representations existing in the brain of a person to conscious awareness will be discussed next. This will be done by illustrating how one can ask questions in such a way as to elicit the structure and the content of the internal subconscious images in a student’s brain. This is achieved by assisting the student to divert their focus from the normal conscious level to the subconscious domain by turning their attention to it. These subconscious images arise in response to properly chosen questions, which direct a student’s attention to subconscious phenomena. In other words, as shown by Bandler (1989) and Lazanas (2012), it is possible to report (provided that the skill of observation and the necessary vocabulary are present) on the subconscious qualia-rich images that give meaning to our experiences and which constitute evidence of learning in the context of this discussion. As the type of questions used are simple, of the kind that require descriptive answers about viewed (or other modality) experiences, students with English as a second language do very well in answering them.

To demonstrate this method, let us consider the following example of a student describing the layout of a Western Cape distribution network that he works with on a daily basis. This is something that he is very well acquainted with, for which he has qualia-rich references as evident in the description below.

Student talking: …so the bus bars I will be looking at are at Bluedown and at Khayelitsha … is 132, ... then at Spine, … so that the 66kv substations around N2, ….

As the student is saying these words the following can be observed:

His gaze is turned out into the distance as if he is looking at a mental picture, and with his right hand he is making gestures pointing to an imaginary landscape from left to right. His hand pauses to indicate each substation as he mentions the substation names, Bluedown (to his left,) – Khayelitsha (almost in front of him at about chest height) – Spine (to his right and up higher then the other two, presumably because Spine is at a different voltage level).

Please note that the thoughts in terms of words and other experiences, which this student is using in his description, are limited conscious aspects of the much richer subconscious associations to which these words relate. The student at this stage is not consciously aware of the subconscious representations behind his narration. As we observe the student's face, one can actually notice that the student's gaze is diverted. He is not looking at the persons he is talking to but out into the distance as if he is in another, mental, word. This diversion of his gaze takes place in order for him to mentally reference the arising of all the imagery etc. that their brain is accessing with respect to the words he is using (the substations at different voltage levels etc.). All this is taking place without him being aware of this initially as indicated by Bandler (1989), and Damasio (2010). The image of the network has spontaneously appeared in his mental landscape, just outside conscious awareness, and his narration is all about his view of it from the perspective he occupies, but can be brought to consciousness if required (Lazanas 2012). **The first step** of this elicitation process therefore, is to notice when the student starts to access the internal meaning-giving processes as they arise by observing the student's eye movements and other clues (in this case hand movements and eye accessing), in their physiology. Then, instead of allowing him to continue talking, his attention is now guided to report on the mental representations he is seeing.

When questioned about what he is looking at when his gaze is diverted, he replied as follows.

I see Khayelitsha in the middle ... with two transformers ... there is a line coming down from Bluedown .. Bluedown in a bit fuzzy I don't see it so clearly. I don't work with it very often. Then there is a line to Mpilo ...
Q. Where is Mpilo?
A. Lower down from Khayelitsha ...
Q. Then what?
A. Then there is Spine
Q. Where is that?
A. To the right. Khayelitsha is connected to Spine via Mpilo. Mpilo is down from Khayelitsha and Spine to the left of Mpilo.
Q. What kind of image is it? Is it photos of places, or lines you are seeing?
A. It's a schematic drawing
Q. Is it in colour or black and white?
A. Black and white.

**The second step** then is for the student to be made aware of, and then find the words to describe the content and structure of the mental processes that have arisen from somewhere in their brain. This level of description may take some time, but it can be as detailed as you wish it to be, as long as the words being explored (in this case his network) have meaning for him, and the person asking the questions is suitably trained. The student's ability to provide accurate, detailed, qualia-rich feedback on these mental images (sounds, tastes, smells, and other sensations could also be included), constitutes **the last step**. These three steps can be used to elicit the subconscious structure and content of what in this case is the description of a distribution network.

This form of NLP elicitation reveals information, which is consistent with Ramachandran and Hirstein's (1997) qualia criterion and Kandel's criterion of synaptic connectivity (as the two go together) (Damasio 2010, Doidge 2007, Pinker 1997, Swaab 2014), of long term memory embedded information. The presence of long term memory representations in a student's mind can be revealed in this way, and this is the evidence of what was defined above as actual learning. This is because if the arising of internal images etc. does not take place, in response to words used, there is no evidence of such words having been embedded in the long-term memory of the person using them. This means that actual learning has not taken place yet. A typical example of the absence of learning is when you ask a student to explain or describe the meaning of a word like "voltage", and they say "potential difference". But when you ask them to describe what potential difference is, they say voltage, looking at the lecturer to validate their reply as either right or wrong, instead of referencing internal representations of their own. This shows that the words used have not been associated with experiences in long-term memory and are just "floating" sounds in the student's mind. It also shows how terrible a habit they have acquired, which is to look for external validation in order to "pass". On the other hand if you asked them to describe in detail how they got to class they would not hesitate at all, nor look for validation. They would answer with confidence while reviewing the video of their actions as it plays out spontaneously on their mental screen.

The turning point in the whole process is the point when the student recognises the difference between rote and actual learning. In this respect the process of acquiring knowledge is made clear. Then the *context* in which it is to be placed and other uses of the knowledge are introduced in lab sessions etc. The best part of it is that the images, sounds, etc., arise spontaneously when everything is working at it should. The experience of this process is a tremendous boost for the student's self-confidence as they realize, for the first time perhaps, that they can gain control of the learning process. This has been the case with hundreds of students over the past twelve or more years at UJ and CPUT, both for theoretical and project based subjects. The students' ability to consciously recognize and report on subconscious phenomena will be discussed in the next section as the Insight Quotient (InQ).

## Insight Quotient (In Q)

A lecturer's efforts, therefore, should be directed at creating elaborate, interconnected, networks of imagery (including the other modalities as well) of the concepts being taught. This responsibility is to be shared by the students who in the process of continuously monitoring the presence or absence of subconscious representations with respect to the topic covered (Damasio 2010; Doidge 2007; Ramachandran & Hirstein 1997) must make sure that they are "learning".

It is this ability of a student, or anyone else for that matter, to consciously access and provide detailed feedback on these mental processes as they arise, just on the edge of conscious awareness, that is now defined as "In-sight Quotient" (InQ). The higher a person's InQ, the better the person can interact with and report on the content and structure of the representations arising in their brain with respect to learning. As students realize that their subconscious domain can become available for observation, they can become responsible for the quality of their own learning. It is now their task to ask appropriate questions of the lecturer in order to make sure that their inner representations are complex and their learning both deeper and more satisfying (this has been indicated by students in lecturer review forms at UJ and CPUT).

This method of encouraging InQ in students has been applied with the author's students, and has enabled him to achieve pass rates of over 98 % in second, third, and fourth year electrical engineering projects and theory classes over the last twelve years. This is not to say that this is the only factor contributing to the high throughput rate. However since each student is interviewed individually (for project subjects) and the method of checking for qualia-rich learning evidence is the main method of assessment used (together with written reports), we can infer that the method is reliable and effective. Keeping in mind that if qualia-rich learning evidence is not found to be present a student will not be promoted. Therefore the results of using this approach are very positive since all the students were evaluated this way. The students are afforded numerous assessment opportunities *until* they satisfy this criterion, and they get interviewed over and over until they do. The student feedback has been excellent because they are in control of the assessment process, which depends on satisfying the criterion when they are ready rather than sitting for a fixed duration exam. For these efforts the author has been awarded teaching excellence awards at UJ (2013) and CPUT (2015). Similarly, with research conducted at the Eskom National Control Centre, this approach has revealed significant findings (Lazanas 2012) with Eskom staff that have developed very sophisticated mental structures (revealed by this method) in order to perfect fast, what others call intuitive, decisions. This approach has therefore been validated both in the classroom as well as in industry.

Based on all the above, teaching can be redefined as a process of modifying neurology (i.e. creating long term memory synaptic connections evidenced by qualia-rich descriptions). Lecturers are therefore, according to this definition, neuro-programmers, or as Doidge (2007, p 188) puts it "Neuroplastic surgeons", not orators who deliver random monologues. They should be seen as responsible for the "code" they instil in their students' brains using closed-loop feedback by means of a well-developed InQ. On the other hand, together with the lecturer's efforts, the students' ability to look "within" and report on the arising of the content and structure of their mental associations, with respect to the topic presented, closes the loop of the learning process. This then is to be verified at the final assessment stage in an appropriate way, perhaps different to the way it's done at present with written exams, so as to avoid the use of short term memory which is to everyone's detriment.

The promotion and development of InQ in students and lecturers provides a more substantial solution to the problem of human communication in general as meaning, in terms of its subconscious references, "resonates" between two individuals. As individuals share the actual underlying components of the words they use (so that eventually both parties see the same images), a better appreciation of the other's person's inner world arises as mirror neuron structures are activated (Damasio 2010, Swaab 2014). This in turn contributes to making all parties feel understood and appreciated, which can be a most satisfying experience.

## Conclusion

It is the position of this paper, that when the presence of qualia-rich subconscious associations in long term memory is verified, in response to a question, and only then, that we can say that a student has actually learned something. That is because it is the presence of complex subconscious associations, which arise spontaneously in the minds of learners, and are revealed by carefully structured questions that constitute the evidence of actual deep structure learning. This is the type of learning, the evidence of which is made clear to both the student and the lecturer, which can serve as the foundation for further learning development. This is a new approach of establishing the existence of and verifying the "acquisition of knowledge" or learning, in the field of engineering education.

Finally it must be made clear, as was said in the beginning, that this is a very complex problem with many facets, therefore it is not the intention of the author to make light of a difficult problem. The intention is to find a way to approach this problem that subsumes a lot of the complexity. That level is the level of information processing in a student's brain. Fortunately that dimension has been rendered accessible by the findings of neuroscience. The techniques of elicitation briefly mentioned above require considerable training and practice if they are to be mastered. This is because the required form of questioning is not something that most are familiar with, and it is imperative that the person doing the elicitation has first-hand experience with their own brain before they attempt to work with others.

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