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Fortnightly Mailing

Useful terse articles by Itiel Dror about the science of learning

Updated 19/3/2007 , 11/4/2007, 23/5/2007

Sheffield's Learning Light (a not for profit company set up with Government and EC funding to serve as a "centre of excellence in the use of learning technologies in the workplace and in organisational learning best practice") has published some interesting 3-4 page briefings by Southampton University's Dr Itiel Dror about the science of learning. Currently these are freely available, and it will be a shame if they are removed from public view, not least because their production has been publicly funded.

Note: Copies of the five documents follow.

- It is not what you teach, but what they learn that counts!;
- Shall I Remember? How learning technologies should facilitate, but too often hinder, memory;
- The architecture of human cognition paves the way to efficient and effective learning;
- The three C's of learning: Control, Challenge and Commitment - this is the one to read if you've only time to read one of them ;
- Meta-cognition and Cognitive Strategy Instruction - when I first looked (12/3/2007) there were some errors in an illustrative quiz in this document which reduced its impact somewhat - (19/3/2007) all but the "mootest" has now been corrected.
- Cognitive awareness [<70 kB PDF] (link added 23 May 2007).

Posted on 12/03/2007

It is not what you teach, but what they learn that counts!

By Itiel Dror

If learning demands supersede cognitive capacity, then learning is doomed for failure even before it takes off. In my first article in this series ("The architecture of human cognition paves the way to efficient and effective learning"), I have elaborated on this issue and how to deal with it by using quantitative and qualitative approaches. However, making sure your learning does not overload the cognitive system does not mean that the learners will actually learn what is intended and needed. Accounting for cognitive load and capacity enables learning to take off, but does not guarantee where it will go; it is necessary but not sufficient for learning.

The question is what does the learner take from the learning? What knowledge will be acquired? What will be remembered? And what will be used? It is naïve and would be a mistake to think, let alone take for granted, that the learner is in fact learning what was intended. Much of what the trainees take away from learning depends on how the learning material is constructed rather than the content itself. It is not the actual material that is critical as much as the way it is presented and delivered to the learner. It is essential that the material be designed in a way that the learners get out of it what is needed. Thus, learning programs may miss their target not because of overloading the capacity of the cognitive system, but because the learners do not 'take away' what is intended.

To design learning in a way that the recipients do indeed get out of it what the learning is supposed to convey, we first of all need to be clear ourselves --as learning designers, developers, evaluators, deliverers, etc.-- what we want to achieve via the learning. These 'learning objectives' are too often meaningless words and phrases that serve no purpose in terms of actually enhancing the learning. Learning objectives need to be taken seriously, properly considered and specified in detail.

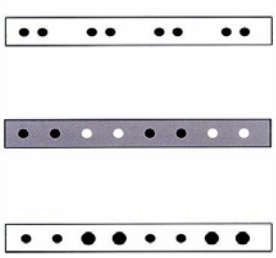
Getting the learning objectives right is crucial; not in order to justify the learning within the organisation hierarchy, nor in order to present them to the learners themselves. Understanding the learning objectives in a deep way is critical so as to guide and constrain the design and delivery of the learning so it actually promotes achieving these goals.

Ultimately it is not what you teach, but what is learned that really counts. How the learners interpret, understand and internalise the learning material (and what they will remember and use) is what the focus should be on. There are many factors that affect what the learners gain from the learning. To consider these issues we first of all need to transform our approach, shifting our viewpoint and emphasis from the learning materials to the perspective of the learners themselves. This shift represents a different cognitive outlook, rather than solely relying on the bottom-up cognitive processes that emphasise the information itself, to considering and emphasising the top-down cognitive processes that take into account the learners' active, inevitable and central role in the learning process.

Cognition and learning are dependant on two distinct processing mechanisms. The bottom-up processes are controlled by the information coming into the cognitive system. These processes are driven by the information itself and the mind is relatively passive. In contrast, top-down processes rely on the person him/herself and what is in the cognitive system already. For example, what they already know, what they expect, their mental state, previous experiences, motivation, and so forth. Such top-down factors play a major role in how information is processed, and determine the outcome of many cognitive operations involved in learning.

Top-down processes take part in almost all human activities, and in fact much of intelligence is characterised by the use of top-down processes. Since top-down processes determine how people perceive, interpret, memorise, and use information, they are critical for learning. It is important to consider how to utilise these cognitive processes for enhancing learning, or at the very least not to ignore their affects on learning. Not taking these cognitive mechanisms into account leads to tunnel vision that will result in poor learning at best. To understand better these top-down processes and their relevance to learning, I will illustrate them and how they affect learning. It is important to note that bottom-up and top-down processes are not independent, they interact and are highly intertwined, affect one another, and work closely together.

Perceptual phenomena pertain to the initial encoding of incoming information. Although as a first stage of information processing perception is highly bottom-up data driven, still other factors come into play on how this incoming information is encoded. These factors are important because they affect what the learner is going to perceive. Their perception is not solely dependant on the 'objective' information that is presented in the training, 'perception is far from perfection' because it depends on the mechanisms that encode the information and on many top-down processes. As we perceive and encode information we automatically (and mostly without consciousness) impose order on the information, grouping and conceptualising it in certain ways. For example, if we see dots, we will use their relative proximity, colour, or size to organise and group them. In the illustration below we use these factors to perceive each of the eight dots as four pairs.



Thus, one must consider how the learning materials will be perceived and conceptualised by the learner. Learning materials must be constructed so their encoding by the learner will correspond with and promote the learning objectives.

Beyond the actual organisation and presentation of the information, the interpretation of the information (the bottom-up incoming information) will highly depend on context. For example, if you look at the letters below, you will most likely see the letters A, B, and C:

If I show you the numbers below, you will most likely see the numbers 12, 13, and 14:

However, the fact of the matter is that the information I showed you in the middle is exactly the same, and you interpreted it as the letter B, or as the number 13, depending on the context in which it was presented:

This demonstrates how important it is to present the learning material within the correct context. ‘Correct context’ means the context that fits the learning objectives. These examples and illustrations pertain to the encoding of the information as it is initially perceived. At higher levels of processing, top-down processes play an even greater role.

To illustrate top-down processing at this stage, try to count the number of times the letter ‘F’ appears in the text below:

FINISHED FILES ARE THE RE
SULT OF YEARS OF SCIENTI
FIC STUDY COMBINED WITH
THE EXPERIENCE OF YEARS...

Most people will see 3 or 4 occurrences of the letter ‘F’ in this text, when in fact it appears six times. As we read, we do not only engage in the bottom-up processes that are driven by the actual text, but the top-down processes affect how we read, what we see, and what we understand and remember. In this case, people simply ignore and skip what the cognitive system regards usually as relatively meaningless words, such as ‘of’ (and hence in the text above miss the three occurrences of the letter ‘f’ within the ‘of’s). Thus the reading of the text, scanning it for ‘f’s, depends on many factors and not only on the actual text/appearances of the letter ‘f’. This clearly demonstrates that one cannot ignore the learners’ perspective. Designing and developing learning material by itself, in isolation from the learners and how they interact with the material would be a big mistake.

The illustration above also exemplifies another key cognitive mechanism: Selective Attention. People selectively attend to only a small subset of the material they are presented with (and thus ignore the rest!). That means that learning must be constructed in a way that attention is guided in the correct way, i.e., corresponds to the learning objectives. Selective attention is guided by both bottom-up and top-down cognitive mechanisms, and both need to be utilised to make sure the learner is attending properly to the information.

Beyond the perceptual and cognitive mechanisms of the learners, their mental state affects if and what they learn. These mental states refer to things such as motivation, expectation, engagement, and involvement. Some of these can be created and harnessed within the learning, so as to utilise the top-down processing to help fulfil the learning objectives. For example, giving the learner the correct control (or even the illusion of control), self-enhancing feedback, challenge, reward, and expectation will maximise these cognitive phenomena to achieve the learning objectives. Other mental states that affect learning --such as attitude-- are harder to create and manipulate within the learning; in these cases one must at least take into account their existence and impact on the learner and design the learning accordingly.

Learning does not occur in a vacuum. The learning material is provided to the learner, but then the learner is active in how (and if) it is taken on board, remembered and used. Too many learning programs focus solely on the bottom-up cognitive processes that are driven and dependant on the information itself. The top-down cognitive processes that the learners bring to the learning process are too often ignored. These cognitive processes play a major

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and critical role in learning, and therefore must be taken into account and utilised to promote efficient and effective learning. To read more about top-down cognitive processes and their role in learning, see http://www.ecs.soton.ac.uk/~id

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Shall I Remember?

How learning technologies should facilitate, but too often hinder, memory

Dr Itiel Dror

Memory is probably one of the most important dimensions in learning, but nevertheless it remains highly neglected. This is due to the difficulties and challenges involved in getting it right. The aim of the vast majority of learning is to convey knowledge to the learners so they *retain and remember* it. Learning can be seen as quite useless if the knowledge gained quickly fades away to oblivion and cannot be recalled. Indeed, research shows that most often 70-80% of the acquired information decays and is forgotten within 24 hours of learning (the rate of decay depends on many factors, such as the structure and complexity of the knowledge, the way it is learned, and how memory is tested and measured).

In fact most programs do not even test (and thus know) if and how well the learned knowledge is remembered. Usually testing occurs right after acquisition and thus totally fails to examine memory, i.e., the rate of retention/decay over time. Any learning program should be designed to take into account (and validation should examine) critical issues that pertain to memory.

In my first two articles in the series *The Science of Learning* I have addressed a variety of issues that directly pertain to memory. In the article “The architecture of human cognition paves the way to efficient and effective learning” I have covered issues of making the information more meaningful and cognitively engaging, and chunking/compressing, so it is easy to encode and later retrieve. In the article “It is not what you teach, but what they learn that counts!” I explicated on the affects of contextual encoding, cognitive representations, mental states, and top-down information processing. To avoid repetition I will not discuss these factors again here, and refer the readers who are interested to the two aforementioned articles.

Learning needs not only to avoid superseding the capacity of the cognitive resources, but must allow the learners to memorise the material. *Depth of processing* refers to the level in which the learners engaged with the material. As depth of processing increases, the material will be better remembered. Depth of processing is not achieved by mere repetitions. As the learners interact with the material in more cognitively meaningful ways, as they consolidate it with other information in their memory, they are going to remember it better. For example, rather then repetition, having the learners make judgements about the material, will make them process it more actively. As the judgements are more complex, depth of processing will increase. If learners are studying a list of items, then repetition is a very superficial interaction. Alternatively, if the learners are required to decide whether the first letter in each item is a vowel or a consonant, then this will increase their depth of processing. However, even such active participation of the learners is only minimal. If the learners are to process the material deeply, they need to engage with it at deeper levels; for example, to determine whether each item in the list is animate or not. Determining whether a letter is a vowel or consonant only requires cognitively superficial examination and processing of the first letter; however, determining

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whether the item is animate or inanimate, not only requires paying attention to the entire word, but also involves accessing semantic memory to determine meaning.

As we encode items, as we increase the links to the new information, the easier it will be to recall them later. This can take shape in the form of connecting the items together in a meaningful way (e.g., a story). Even a superficial addition, such as intonation, will increase memory (e.g., this is why we can recall songs so well). Adding visual imagery is another way to cognitively enrich items so they are remembered better. Such multiple encoding and representations play an important role in determining how well information can be recalled later.

Furthermore, matching the context of encoding to the expected retrieval in the future will further enhance memory. Specificity of encoding makes retrieval easier when it is in a similar context. Thus, the learning environment should be as similar as possible to that back at the workplace, where the learners are expected to recall the information and to modify their behaviour. This does not only pertain to context, but also to how items are learned. Items should be learned and connected in the way that they will need to be recalled and used later. The initial encoding of the information determines if, and how, it will be later retrieved. For example, it is quite easy to recall the months of the year: January, February, March, April, etc.; however, try to recall the months by alphabetical order… I bet that you cannot do that! Try it. This illustrates that for effective recall and usage of information, it must be initially learned and encoded in the proper way.

Enhancing memory does not only focus on better encoding, which I have discussed until now, but also making the retrieval process more effective. Although retrieval is to a very large extent a function of how the information was initially encoded, still one can enhance retrieval by addressing it direct. For example, rather than having assessment at the end of learning, with the sole purpose of measuring success in acquiring the information, assessment should be dispersed throughout the learning and in a way that facilitates memory. Active recall exercises that follow newly established information can further enhance its later recall. This will not only strengthen the memory, but also enable the learners to detect and correct any mistakes and omissions in their learning (strike while the metal is hot).

E-learning and other learning technologies can hinder memory by their very nature and merit. One of the appealing elements of technology is its ability to provide information in a very effective way; many times by taking the burden off from the learners. However, if not done properly, reducing the effort and work involved in learning is not necessarily good. It may promote 'spoon feeding' the material, which makes the learners more passive and decreases their depth of processing, leading to reduction in retention and memory of the learned material!

Although challenging to achieve and to validate the longer term memory of the acquired material, it is an essential corner stone of learning. Will the learners remember what they have learned? Will they be able to retrieve it and use it? Has learning technology been utilised properly to engage the learners in deeper levels of processing and to construct multiple traces and representations of the learning material? Or has technology been used in ways that do not promote good learning and perhaps even used in ways that hinder memory? The longer term success, or failure, of learning modules highly depends on these factors.

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The architecture of human cognition paves the way to efficient and effective learning

By Itiel Dror

To achieve objectives in learning and to maximise its potential one must consider the workings of the human cognitive system. At the end of the day it is the learners' cognitive system that acquires the information, stores it, and retrieves it later for use. Thus, understanding the human cognitive mechanisms involved in learning should underpin any and every aspect of learning. A good fit between the learning and the learners is critical for success and promotes efficient and effective learning. By efficient learning I mean that maximum knowledge is learned with minimal investment (both from the learners' perspective and also from the point of view of learning development). By effective learning I mean that the learning material is retained well over time (there is little use in a learning program in which the learners acquire the information --as perhaps reflected by an assessment at the end of the program-- but that the information acquired during the learning is forgotten and cannot be recalled later). Effective learning does not only mean that the information is remembered, but that it is also usable, makes an impact on the learners, and modifies their behaviour (there is little use in a learning program in which the learners acquire the information and can remember it, but still do not use it and it has no impact on their behaviour).

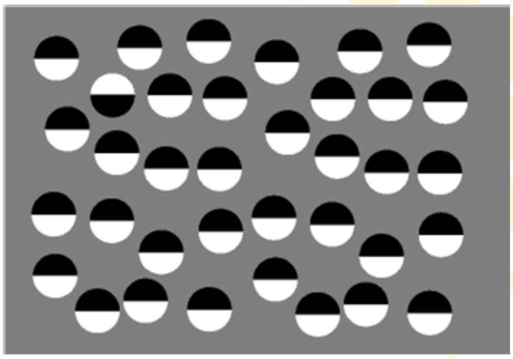
The efficiency and effectiveness of learning depends mainly on if and how well the learning conforms to the mechanisms and constraints of the cognitive system of the learners. Understanding these mechanisms that underlie learning is critical for all aspects of learning. But the complicated and tricky step is how to connect and translate this understanding to practical implications in learning. In this and in future articles I will introduce different aspects of the human cognitive system and bridge the theoretical and academic information to practical issues in learning.

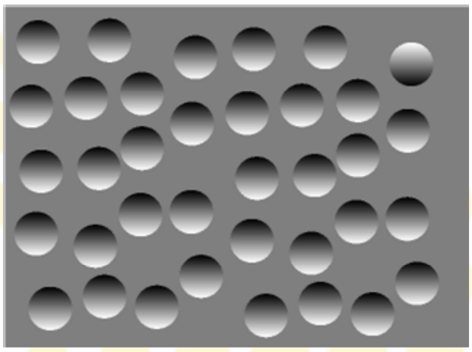
In this first article I will address the issue of cognitive capacity. A corner stone in understanding cognition and learners is that the underlying cognitive system is limited. It has limited capacity for processing, acquiring, and storing information. Understanding and acknowledging this constraint means that any learning program must carefully consider issues of cognitive load.

Dealing with cognitive load at a rudimentary and superficial (but still important) level requires minimising the amount of information the learners are exposed to and are expected to acquire at any one time. This quantitative approach entails eliminating any information that is not needed, so as to enable the learners to focus their limited cognitive resources on the most important and relevant material. One should consider not only excluding all irrelevant information, but really focusing the learners on the most critical information by also excluding relevant information that is not actually that important. During development, evaluation, or/and when a learning program is ready to be deployed, it is essential to go over the entire program and consider, piece by piece, if anything can be taken out.

At a more complex and deep level, cognitive load can be dealt with by a qualitative approach. The qualitative approach, in contrast to the quantitative approach, deals with the efficiency in which information is conveyed rather than the amount of information per se. Thus, using this approach, limited cognitive capacity does not necessitate reducing the amount of information the learners are exposed to and are expected to learn at any one time. One can considerably reduce cognitive load by tailoring the learning to the architecture of cognition. For example, due to limited cognitive capacity the cognitive system has developed attention and selection mechanisms which focus processing on a subset of the information available. Thus, making the important information more salient directs cognitive resources to the most valuable and critical learning material. This can be accomplished by simply emphasising this information, for example, through correct use of colour, animation, and dual modality encoding (using a balanced and integrative combination of visual and auditory information).

There are more sophisticated cognitive ways to achieve this qualitative approach, such as making the information more meaningful, cognitively engaging, involving deeper cognitive processing, and making it ‘pop-out’. For example, in each of the two figures below there is an ‘odd circle’ that is different from the rest (try and see if, and how easily, you can find them).





This piece of information is relatively hard to detect and notice in the left figure, but it readily ‘pops-out’ in the right figure. This is because the right figure presents 3-D information to the cognitive system whereas the left figure is only 2-D. Of course, both figures are 2-D, but by changing from white to black gradually in the right figure (rather than all at once in the left figure) the cognitive system is engaged and actively interprets this as a 3-D image. This is only one example, just to illustrate that rather than reducing the number of circles in the left panel so as to enable easier perception of the ‘odd one’, one can achieve this heightened perception by correctly engaging the cognitive system. There are many other ways to cause ‘pop-out’ effects, to direct visual search, and to grab the attention and resources of the cognitive system.

Rather than competing for the attention and resources of the cognitive system which was illustrated above, one can construct learning materials in ways that are less cognitively demanding and taxing on the cognitive system. This expansion of the qualitative approach further optimises the efficiency and effectiveness of how information is conveyed to the learner, which in turn enables the learners to acquire and memorise more. One way this can be achieved is by chunking and compressing information together. This way all the information is still present and processed, but it is more economical in cognitive terms. We are all familiar with such a technique when we perceive and memorise telephone numbers; rather than processing them as a set of single digits, we try to compress them into chunks (such as area codes that we perceive and memorise as a single entity rather than three separate digits). This reduces the cognitive load without eliminating any information.

There are many ways to facilitate and enhance learning, both in terms of the efficient acquisition of information and in terms of the effective retention and use of the information. However to achieve such efficiency and effectiveness the learning must be tailored to utilise and take advantage (as well as take into account the constraints and limits) of the way humans learn, remember, and use information: The human cognitive system. In future articles I hope to cover additional aspects of the cognitive system and what they mean in practical terms to learning. More information and detailed scientific literature on these issues can be found at: http://www.ecs.soton.ac.uk/~id

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The three C's of learning: Control, Challenge and Commitment

Dr Itiel Dror

When the learning material is simply presented to the learners, then they are passive and learning is minimal. In contrast, when learners are active and motivated, when they are involved, participating, engaged, and interacting with the material, then learning is maximised. It is maximised because it activates and correctly taps into the cognitive mechanisms of learning, such as attention, depth of processing, and other cognitive elements that I have discussed in the three previous articles in the series *The Science of Learning*.

Given the great importance of achieving the active participation of the learners, how can this be accomplished? The answer is the correct utilisation of the three C's: *Control*, *Challenge*, and *Commitment*. Each of these are not easily achieved, but the gains and benefits from each of them make it worthwhile. The shift from merely exposing the learners to the material to utilising the three C's transforms the learning to a higher level and quality. This new level of learning is more sophisticated, superior, and can achieve short and long term objectives that otherwise are not possible. In what follows, I discuss each of the three C's, not only pointing out why they are so crucial, but also elaborating on how learning can be practically constructed to incorporate them.

The learners' *control* can take many forms and can be viewed as a continuum. At one extreme end, control is totally surrendered to the learners, giving them full freedom to do (or not do) as they please. At the other extreme end of the of the continuum, the learners have no control at all, the learners blindly (and passively) follow what is determined and dictated by the learning program.

Since giving the learners control supports and promotes learning, it therefore follows that learning programs should maximise the learners' control. However, giving them control can also be detrimental to learning. Thus, it is important to understand why and how it fits (or not) into your learning program and carefully consider this issue. Before explicating practical ways in which control can be shifted from the learning developers to the learners, I want to draw attention to some potential weaknesses.

If the learners control the learning (or even part of it), then this adds another cognitive task to their system. In addition to actually acquiring the learning material and encoding it properly so it is easily retained and used, the learners will need to exercise the control over the learning itself. This control may involve understanding and considering alternatives, making decisions (and sometimes needing to remember them), taking actions, and so forth. These processes are an additional burden on the cognitive system, which is (should be) involved and focused on the actual learning material, thus increasing the overall cognitive load. Furthermore, the learning material may have an inner structure, a logical way and flow in which it can be best learned. Therefore giving the learners control may also interfere and even conflict with the optimum way of delivering the learning. Nevertheless, shifting control to the learners is an excellent way to enhance learning and should always be maximised, whenever it is possible. However, as discussed above, one needs to achieve the correct balance, and consider when, where, and how it can have the greatest benefit. This brings me to examine some of the practical ways in which control can be given to the learners.

The ultimate way of giving the learners control is letting them determine if and what they need to learn. This may pertain to deciding which learning modules will be learned from a variety of available programs, or in deciding within a single module which elements will be covered. Such freedom may result in material not being covered and learned at all; however, the learning that is chosen will be learned effectively. Furthermore, if the learners are forced to 'learn' things that they do not need (or that they think they do not need), then they may 'shut down' and disengage, thereby not learning any of the material well. If control is given to such a major extent, it is important to provide the learners with help so that they will be able to use this freedom wisely. This first entails a clear understanding of the options and what is offered within each alternative. More important and critical is helping the learners 'know what they know' and 'know what they need to know'. Such knowledge about knowledge falls within the area of *meta-cognition*, and is an inherent part of learning (I will discuss this advanced topic in the next article in this series).

At a more basic level, rather than giving learners control of what they learn, they can have control over the order in which topics are covered. Sometimes this order is rigid because of inter-dependencies whereby one concept/content must be covered before the other. However, many times there are degrees of freedom that allow different sequences of learning. This flexibility can be used to increase the scope of control that is provided to the learners.

The learners can also receive control over the presentation format of the material. Because learners have different experiences, cognitive styles, etc., they may have preferences for the way the material is delivered (for example, visual vs. auditory, text vs. diagrams, etc.). Giving them control over the format of presentation not only gives them control but also optimises and tailors the learning to the individual learner. Finally, at the most basic level, learners can control the pace of learning (e.g., when to move on to the next item/page, and whether to repeat a section before moving on to the next).

Even the more basic levels of control give the learners some ownership of the learning. This significantly improves learning, both in terms of achieving the learning objectives and in terms of the learners' positive affect. Even the mere illusion of control (i.e., giving the learners a feelings that they control the learning when in fact they do not) can be a step in improving the learning outcomes.

For the learners to be further motivated, engaged, involved, participating, and interacting, the learning must be *challenging*. If the learning is deemed boring, as simply going through the motions, then learning is minimised. Learning is drastically enhanced when the learners find it challenging. Challenging does not mean making it unduly complicated and complex. Learning can be made challenging in a number of ways and on different fronts.

First, the learning material itself. The learning material can be made challenging if it is presented in an interesting way that requires the learners to think about it, to reflect and figure things out. If the learning feels more like a puzzle, a mystery that the learners solve, then it is challenging. If the learners feel that they have accomplished something, if they feel good about themselves, if they are proud, then the learning is challenging.

Learning can be made challenging not only by modifying how the material is presented and the role of the learners, but also by providing clear signs, measurements, and feedback about the learners' advancement and progression. These should be clearly laid out throughout the learning so the learners can see how well they are doing. As they advance and progress, they should be provided with a clear measurement of their success and receive positive self-enhancing feedback. The learners should not merely be provided with a progression measurement (e.g., how much they have gone through or/and how much they still need to do), but they should be given challenges to achieve certain levels of performance, or they should be encouraged to generate their own goals.

These types of challenges can be further encouraged and supported by external recognition and awards. Furthermore, depending on the context and the organisational culture, this type of challenge can also be extended across learners whereby different learners compete for the best performance achieved.

If the learners are not *committed* to the learning, then it is an uphill struggle (or a lost battle…). Commitment to the learning underpins many aspects of learning; however getting the learners to commit is not easy. As discussed, control and challenge contribute to commitment, but commitment is illusive and difficult to achieve. Although some learners come committed, others are only loosely committed, if at all.

Before considering further ways to improve the learners' commitment, we need to first ask ourselves if the organisation and the learning developers themselves are committed to the learning? If they are not, then we can quite confidently assume that the learners are not going to be committed. If the learners see the commitment of the organisation and the people involved in the learning, then they themselves are more likely to commit to it too. Although commitment is a personal trait to some extent, it can be enhanced by a strong commitment of the surrounding institution and learning developers.

Another way commitment can be achieved is by correctly introducing the learning. Proper induction can play an important role in constructing commitment. In addition, having a clearly laid out overall curriculum (rather than unconnected bits and pieces) that is clearly integrated and intertwined with the everyday work, will strengthen the commitment and attitude to the learning. Finally, personal commitment contracts can further help establish the commitment to the learning. The commitment of the individual learners is a difficult topic to tackle, but nevertheless it plays a big role in learning and should not be ignored (as is often the case).

The three C's of learning: Control, Challenge, and Commitment, help to establish active and motivated learners. They bring about engagement, involvement, participation, and interaction. These are all critical ingredients for achieving effective and efficient learning because they maximise many of the cognitive mechanisms that I have discussed in previous articles in this series. Otherwise, passively exposing the learners to the material undermines the very objectives of learning. The three C's are not independent or exclusive, they effect one another and there are additional ways to support active learning. The three C's are an illustration of a way of thinking, of an approach to what learning should be all about. Having active and motivated learners will better achieve learning objectives and every learning program should be constructed to incorporate them as much as possible.

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Meta-cognition and Cognitive Strategy Instruction

Dr Itiel Dror

The science of learning has two fronts: the first deals with the learning material, and the second deals with the learners. Although they are interdependent to some degree, they comprise a host of different issues and solutions. In the first two articles in this series I focused on the former; how to make the content and presentation of the learning material more effective. How designing the material to fit the architecture of cognition enables it to be conveyed more efficiently, making sure not only that it is more likely to be learned, but also to be retained over time and to be used back at the workplace. In articles three and four I shifted attention to the learners. Emphasising issues of the learners' **C**ontrol, **C**hallenge, and **C**ommitment ("The three C's" of article four) I was able to further develop the idea that "It is not what you teach, but what they learn that counts" (article three).

Understanding the role of the learners is a step forward, but what determines their success? Getting them 'on board' is great, but will they live up to the challenge? And most importantly, how can learning designers and developers help the learners achieve their goals? The learners' cooperation and motivation are critical, but are far from sufficient. So, what are the missing pieces?

At the most basic level, the learners need to have the cognitive capacity to grasp the concepts and skills. However, as learners become more active (e.g., more involved, engaged, control, as already discussed in the previous articles), no less important is the learners' ability to know and be adept in higher cognitive functions, specifically to:

1. Know what they know, and know what they do not know… (*meta-cognition*)
2. Know how to best learn (*cognitive learning strategies*)

Knowledge about knowledge, meta-cognition, is reflecting and being aware of one's own knowledge. To illustrate this concept, it is best to experience it yourself. I encourage you --the reader-- to test and understand your own meta-cognitive skills. To do so, please answer the following 11 questions, marking your answers on this paper by circling the correct answer (1 of 4 alternative options). For each question you answer correctly, you will **receive 1-point**, but for each incorrect answer you will receive a penalty of **minus 2-points** (you get zero points for unanswered questions), thus, do not guess!

1. What is the meaning of the musical term "allegro"? A. loud, B. soft, C. quick, D. slow.
2. In Greek Myth, who is the God of wines? A. Demeter, B. Hestia, C. Artemis, D. Dionysus.
3. How many years was Margaret Thatcher Prime Minister? A. 9, B. 10, C. 11, D. 12.
4. What was Lady Chatterley's first name? A. Eleanor, B. Constance, C. Margaret, D. Elizabeth.
5. What year was the Lockerbie disaster? A. 1986, B. 1987, C. 1988, D. 1989.
6. London's population (2001) is approximately, in millions: A. Seven, B. Eight, C. Nine, D. Ten.
7. What is the most common element on Earth ? A. Oxygen, B. Nitrogen, C. Iron, D. Hydrogen.
8. There is <u>no</u> Nobel Prize in? A. Physics, B. Chemistry, C. Biology, D. Medicine.
9. What year was John F Kennedy shot? A.1962, B. 1963, C. 1964, D. 1966.

10. What countries does Luxembourg have borders with ? A. Belgium, Holland, Germany; B. Germany, Switzerland, Belgium; C. Holland, Belgium, France; D. Belgium, France, Germany.
11. What was the last album the Beatles recorded together? A. Let It Be, B. Rubber Soul, C. Magical Mystery Tour, D. Abbey Road

Before I provide you with the correct answers, and discuss them, please go back to the quiz and now answer the questions you skipped in phase 1 (the ones you decided not to answer). Now in phase 2, answer them! You will get 1-point if your answer is correct, but you will not be penalised if you get it wrong (for incorrect answers you will get zero point). Thus, guess! Now in phase 2, mark your answer with a square or with a different coloured pen (a mark that is different to the one you previously used in phase 1). Good Luck!

Now that you are done answering all the questions, let's mark your answers and discuss them. Please mark your answers as follows: First, *only* mark your initial answers from phase 1. Give yourself 1-point for every correct answer and take away 2-points for every incorrect answer. Write down the total. Then, mark only the remaining questions (the ones you initially skipped and only answered in phase 2). Count how many such questions you initially skipped and how many of them you answered correctly in phase 2. Write down the number of correct answers as a function of how many questions you answered in this phase (e.g., 3 out of 6, or 50%). The correct answers are: 1-C, 2-D, 3-C, 4-B, 5-C, 6-A, 7-A, 8-C, 9-B, 10-D, 11-B.

What is the total of the points you got in phase 1? In this phase you were highly penalised for incorrect answers (minus 2-points). If your total is a negative number (which is highly likely and typical), then your meta-cognitive skills can do with some enhancement… A negative score would reflect that at least a third of your answers were wrong. That you incorrectly thought you knew them, when in fact you did not. You overestimated your own knowledge. If, however, you have a positive number, do not celebrate just yet. Your meta-cognitive skills may be poor nevertheless, you may have underestimated your own knowledge. To ascertain this, examine your score in phase 2. If you indeed guessed, then you should have gotten approximately 25% correct answers. If your correct answers were higher than that, then it was not a matter of chance, but a function of your knowledge. The 'Good Luck' in phase 2 was only relevant to those who had good meta-cognition and answered all what they knew in phase 1, and now were genuinely guessing. More than 25% of correct answers in phase 2 reflects that you were not actually guessing - that you should have answered more questions in phase 1. You did not do so because you did not know that you knew the answers…. Thus, your meta-cognitive skills were not too impressive or accurate. This entire exercise is, of course, only for illustration purposes; for example, you may have indeed been lucky when you guessed, and the small number of questions are not sufficient to really measure meta-cognition.

The message is clear, meta-cognition relates to one's ability to know what they know (and know what they do not know). Socrates was considered the smartest person because of his meta-cognitive abilities. Meta-cognition is a critical part of learning, especially when the learners are active and in control. If they are to guide and drive their own learning, then it is imperative that they know what they need to learn. Meta-cognition is also important if learners are less active, because even when they are relatively passive, if they do not think they need to learn something, then they will be paying less attention, be less motivated, etc. Thus, meta-cognition is relevant to all learning, but is especially critical to self-guided learning, to learning that puts the learners in their rightful place: the driving seat.

Most people have poor meta-cognitive skills. This is not surprising, especially since it is hard to train people in this area. Although it is difficult to provide and enhance general meta-cognitive abilities, it is quite simple and straightforward to give domain specific meta-cognitive insights. This type of tool consists mainly of a pre-learning self-assessment in which the learners are tested on their knowledge of the specific learning domain. The results, provided to the learners, can help them understand and know what they are good at, and what they are not so good at, i.e., give them knowledge about their knowledge in the domain in question. This will enable them to recognise their weaknesses and their training needs.

The learners' meta-cognition is important to engage them where they need to engage. However, it does not guide them how to engage. What is the best learning strategy? Unfortunately there is no recipe that fits every situation, every learner, etc. The best learning strategy not only depends on the learning domain, complexity and structure of material, specific content, and so on, but also depends on the specific learner. Their ability, past experience, pre-existing knowledge, cognitive style, etc.

Cognitive Strategy Instruction (CSI) is aimed at teaching the learners how to enhance their learning by adopting optimal learning strategies. This is accomplished by exposing the learners to a variety of learning strategies. These techniques are explained, analysed as to their strengths/weaknesses, and how they fit different learning materials/objectives. The learners are provided with hands on experience using these various techniques so they can get a true feeling and evaluate how well these techniques work for them. CSI enables and encourages the learners to tailor and develop their own learning strategies.

An investment in Cognitive Strategy Instruction is well worthwhile. It benefits the organisation because not only is the learning enhanced, but a whole range of other activities is affected. CSI provides the learners with tools that maximise learning and efficiency in many non-formal and non-structured learning environments that exist within the organisation.

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Cognitive Awareness

Dr Itiel Dror

If you need to get to a certain location, then you look at a map. However, a map by itself is useless without spatial awareness of where you are and where you need to get to. Only then can the map help you figure out how to close this gap, i.e., the gap of where you are relative to where you need to be. Similarly, cognitive awareness tells you where you are and where you need to get to in terms of skills and knowledge. Spatial awareness pertains to physical spaces, whereas cognitive awareness pertains to knowledge spaces.

Learning, acquiring certain knowledge and skills (as well as being able to retain and use them…), is analogous to getting to a physical location in the sense of finding a way to move from your current state (where you are, or what you know) to your desired goal state (where you need to be, or what you need to know). In this sense the actual learning material is a necessary but not sufficient condition to learning, just as having a map is a necessary, but not sufficient condition, to finding your way in a novel environment.

As we well know, using the map is highly dependent on first of all knowing where we are (which includes finding ourselves on the map and orienting the map) and knowing where we need to get to. Then we can relatively easily work out the best route to get to where we need to be (which will also depend if we are driving or walking, want the shortest route or the scenic route, etc.). In many ways this stage is relatively easy, as the problem is already well defined. Thus, getting to where you need to get to depends primarily on your spatial awareness and less on having a good map.

Therefore, the quality of the map is important in how well it facilitates finding the route to get you where you want to be. However, the more critical, and often neglected value of a good map, is how easy it is to locate where you are and where you want to get to. These issues relate well to learning where much emphasis is too often only given to the efficiency of the learning to move you from your current knowledge state to the one you need, rather then fully appreciating and dealing first with the issues of properly identifying the knowledge gaps. Just as spatial awareness identifies your location in space relative to where you need to get to, cognitive awareness identifies your knowledge and skills in the knowledge space relative to where you need to be.

Cognitive awareness is critical for learning because it clearly lays out the knowledge deficits and how best to remedy them ('the gap and the possible routes to close it'). Once this gap is identified and understood, then one can assess the best ways to close this gap. These gap closing routes may consist of e-learning, traditional learning, or blend learning, or may lend themselves better to apprenticeship, learning on the job, or other modes of informal learning. The point is that choosing the most suitable and efficient way to learn is dependent on first identifying the knowledge gaps, i.e., on cognitive awareness.

Thus, learning should have three stages:

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1. Meta-cognitive knowledge about your own knowledge. Thus knowing what you know and knowing what you do not know (readers who are interested in more detail on this topic are referred to my article dedicated to "Meta-Cognition and Cognitive Strategy Instruction").
2. Understanding what you need to know. This can be trivial when there are clear corpuses of knowledge, such as in regulatory, health & safety, and IT skills. However, many times knowing what knowledge you need is not so straight forward. These skill and knowledge needs can be provided to the learner externally, or the learners' themselves need to identify them. Whether they are self generated or provided to the learners has important implications to their engagement, motivation, involvement, and commitment (readers who are interested in this topic can read more details in my article "The three C's of learning: Control, Challenge, and Commitment").
3. The final stage is figuring out how best to close the knowledge gaps defined by the cognitive awareness of stages 1 and 2. These first two stages will define and carve out the different ways learning can take place, and many times suggest which one would be the most efficient.

In spatial awareness we have the technological aid of satellite navigation. Such systems use a GPS (Global Positioning System) to tell you where you are. Then, after you input where you want to go to, it will tell you the best route how to get there. In learning we are far from achieving such sophisticated and convenient systems. But even with physical space and satellite navigation systems, there are some interesting issues that may help us shed light on the knowledge space and learning. For example, we may want to get to a certain and well defined location (an exact address), we may want to get to a less defined location (such as 'a good restaurant'), or we may just want to drive around for fun. And then there are issues on how to generate and communicate the directions; from whether to use sound (and which voice to use) to if and how the system can dynamically adapt to a new set of directions in response to drivers' error (e.g., missing a turn).

All of these clearly apply to learning. For example, can technological learning systems adapt in response to learners' errors or learning difficulties, can the learners control how the learning material is conveyed and communicated to them, etc. Technology enhanced learning offers great opportunities, however these technologies are far from being exploited to their fullest potential. Many times these technologies are just a transcription of learning material that was developed for use in another medium. It would be nice if learning programs will include a 'KPS' (Knowledge Positioning System) which assesses the learner's current state of knowledge, and then a 'learning navigation system' which will figure out, and efficiently communicate, the best learning program to achieve the acquisition, retention and use of the needed knowledge. Although such things are --at best-- in the realm of the future (or of science fiction), some elements can be implemented and achieved if we take the cognition underlying learning to guide the use of current technology.

Learning is not limited to designing learning material, the overall complexity is enormous. However, if learning (and technology enhanced learning in particular) continues to develop as if it were a blind person navigating in a field, it can be expected to continue to achieve only limited results. With new technologies new potentials and opportunities arise, but we are surely not going to properly exploit

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them to their fullest (if at all) if we continue along a blind path. Technologies by themselves offer little to no improvement; in fact they can 'damage' learning (I refer the readers who are interested in more detail to my article "Shall I Remember? How learning technologies should facilitate, but too often hinder, memory"). To take full advantage of the new opportunities and frontiers opened with new learning technologies one must take a holistic cognitive approach based on the scientific understanding of the human mind and brain. In the six articles I have written in this series of "The Science of Learning" I have tried to give the readers some appreciation and insight to this approach and what it entails. I hope the readers found it both interesting and useful.

Note: The journal series of Technology and Cognition is dedicating a whole special issue to Learning Technologies that will further examine and investigate this domain. For those interested in contributing an article to this special issue, or in receiving a copy, please see http://users.ecs.soton.ac.uk/~id/technologySI4.html

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