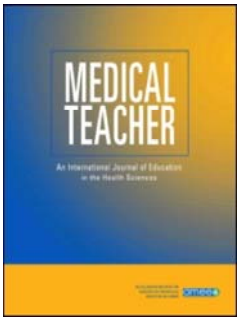

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TWELVE TIPS

Twelve tips for applying the science of learning to health professions education

H. C. Gooding[a], K. Mann[b] and E. Armstrong[a]

[a]Harvard Macy Institute, Boston, MA, USA; [b]Dalhousie University, Halifax, Nova Scotia, Canada

ABSTRACT

Findings from the science of learning have clear implications for those responsible for teaching and curricular design. However, this data has been historically siloed from educators in practice, including those in health professions education. In this article, we aim to bring practical tips from the science of learning to health professions educators. We have chosen to organize the tips into six themes, highlighting strategies for 1) improving the processing of information, 2) promoting effortful learning for greater retention of knowledge over time, 3) applying learned information to new and varied contexts, 4) promoting the development of expertise, 5) harnessing the power of emotion for learning, and 6) teaching and learning in social contexts. We conclude with the importance of attending to metacognition in our learners and ourselves. Health professions education can be strengthened by incorporating these evidence-based techniques.

Introduction

A wealth of data exists regarding how humans learn. Empiric investigations of the science of learning come from such disparate fields as cognitive psychology, neuroscience, sociology, anthropology, and behavioral economics. This evidence has important implications for those responsible for teaching, curricular design, and improving the effectiveness of learning. However, these findings have been historically siloed from each other and educators in practice. Notable efforts to translate this science to K-12 and Higher Education arenas have emerged in recent years (Pashler et al. 2007; Benassi et al. 2014). There is growing application of the science of learning to the health professions as well (Mayer 2010; McGaghie & Fisichella 2014; Young et al. 2014). In this article, we aim to bring practical tips from the science of learning to health professions educators to complement the 12 tips for Utilizing Principles of Learning to Support Medical Education (Cutting & Saks 2012). Specifically, we aim to highlight the complex relationships between six themes: 1) improving the processing of information, 2) promoting effortful learning, 3) applying learned information to new and varied contexts, 4) developing expertise, 5) harnessing the power of emotion for learning, and 6) teaching and learning in social context. We chose these six themes due to their extensive research base and broad applicability to all fields of health professions education. We conclude with a tip about the role of metacognition in learning.

In preparing these 12 tips, we have attempted to bring together findings from multiple fields and from differing theoretical constructs of learning. Much of the work on learning from cognitive psychology and neuroscience focuses on individual knowledge, whereas research from sociology and social psychology focuses on participatory learning in a community (Sfard 1998). We attempt to highlight the value in both perspectives and to provide practical tips for teachers and learners alike. Our descriptions of various theories and constructs are necessarily brief; we have cited the primary literature when possible and encourage interested readers to delve deeper into areas particularly relevant to their context.

Theme 1

Processing information

Cognitive Load Theory (CLT) suggests the human brain can only process a certain amount of information at one time (Sweller et al. 1998). Individuals constantly take in information through their senses and hold this temporarily in working memory. As the capacity of working memory is finite, information must be processed and stored in long-term memory for later use. Information in long-term memory is organized into schemas of increasing complexity, allowing individuals to retrieve a schema for use in working memory as a single construct. CLT divides learning further into the *intrinsic load* of the information to be learned and the *extrinsic load* required to process it. *Intrinsic load* reflects the complexity of the information itself. *Extrinsic load* is further subdivided into *germane* load, which refers to the cognitive work of organizing new information into schemas, and *extraneous load*, which refers to the effort required to process new information due to the way in which it is presented. CLT has implications for the design of instructional strategies and has been applied to health professions education in a number of useful reviews, including a recent 12 tips by Leppink and Duvivier devoted to this topic (Van Merrienboer & Sweller 2010; Young et al. 2014; Leppink & Duvivier 2016).

CONTACT H. C. Gooding Holly.Gooding@childrens.harvard.edu Harvard Macy Institute, 333 Longwood Ave, 6th Floor LO 64, Boston, MA 02115, USA

Tip 1

Reduce extraneous load whenever possible

Of the three types of cognitive load, extraneous load is most easily controlled by the teacher and should be reduced whenever possible to free up space for processing complex information. The Cognitive Theory of Multimedia Learning proposes evidence-based strategies to reduce extraneous load when presenting new material (Mayer 2008). In the classroom setting, these include reducing extraneous material, highlighting essential material, and presenting corresponding words and graphics together. In the workplace setting, extraneous load can be particularly high due to the complexity of auditory and visual stimuli in a hospital ward or clinic. Teachers should minimize these distractions (i.e. silencing unnecessary alarms, discouraging disruptions to rounds) whenever possible and teach learners how to recognize the impact of these distractions on their thought process.

Tip 2

Help learners manage intrinsic load and assist learners with germane load

Intrinsic load is highest for complex tasks with interacting elements (e.g. managing a patient on mechanical ventilation). It is also highest for novice learners, who have not yet created schemas for these complex processes. Teachers can help by starting with simpler examples with fewer elements or by chunking many elements into more manageable parts. Learners can be provided partially worked examples so they only have to supply a few missing parts (Van Merrienboer & Sweller 2010; Leppink & Duvivier 2016). Teaching sequences should be structured to assist learners with the creation of schemas of increasing complexity. To continue the example above, a student could first be taught initial ventilator settings for obstructive lung disease before moving to cases of ventilator settings required for patients with co-existing cardiovascular disease. Further examples for use at the undergraduate, graduate, and continuing medical education levels can be found in the excellent AMEE Guide or recent 12 tips on this topic (Young et al. 2014; Leppink & Duvivier 2016).

Theme 2

Promote effortful learning

Once learners have processed and stored information in their long-term memory, they need to be able to retrieve it at the appropriate moment. However, most of what is initially "learned" is forgotten if not routinely used (Murre & Dros 2015). Common study strategies such as rereading material, highlighting sections of text, and creating mnemonics do little to reverse the natural decay of memory (Dunlosky et al. 2013). Cognitive scientists Elizabeth and Robert Bjork coined the term "desirable difficulties" to describe the finding that more difficult study procedures lead to more durable learning (Bjork & Bjork 2009). As these study techniques are not intuitive and are by definition difficult, teachers must work to incorporate them and to convince learners of their value while being careful to not increase cognitive load.

Tip 3

Create opportunities for retrieval practice appropriate for the content to be learned

Retrieval practice, also known as test-enhanced learning, is one of the cognitive strategies with the strongest evidence base (Dunlosky et al. 2013). By allowing some information to be forgotten and then having to retrieve it from long-term memory, it is thought that we strengthen the neural connections necessary to retrieve that information again in the future when we need it. However, not all retrieval practice is created equal. Generative retrieval, where learners must generate their own answers to a test scenario, leads to more durable learning than choosing answers from a menu of options (Rowland 2014). The type of retrieval practice should match the complexity of the information or task to be remembered (Larsen et al. 2013). If we want learners to remember facts, simple factual recall should suffice. However, if we want learners to remember how to perform a complex psychomotor task, we should have them practice that whole task at regular intervals, such as in a simulation laboratory (Barsuk et al. 2010). Providing feedback on the retrieval or test exercise will enhance learning further (Butler et al. 2008). Learners should be taught the value of retrieval practice and encouraged to study with practice questions, flashcards, or through repeated psychomotor practice. A number of technological programs exist to facilitate retrieval practice for health professional students (Galgani & Haynes [date unknown]; Hausmann et al. 2015).

Tip 4

Space retrieval practice over time and interleave content

The spacing effect, also known as distributed practice, refers to the fact that learning is more durable if repeated exposure to the material occurs over time (Dunlosky et al. 2013). The optimal spacing interval depends on how long the information needs to be retained. If too much time has elapsed before an individual is tested on previously learned information, effortful retrieval may simply be too difficult. Empiric studies in this area are few, but some data suggest the spacing interval should be 5–10% of the duration the information is to be retained (i.e. monthly if the goal is to remember the information at one year) (Cepeda et al. 2008). Interleaving different content in between the spacing intervals (i.e. learning cardiology for one week followed by pulmonary for one week, in an alternating fashion) appears to further strengthen the spacing effect by requiring learners to compare and contrast what they are learning (Dunlosky et al. 2013). In addition to employing spacing and interleaving in curricular design, teachers should encourage learners to distribute their study over time and avoid cramming.

Theme 3

Application of learning to new and varied contexts

Information is frequently learned in one setting (i.e. the classroom) and applied in another (i.e. the hospital). The ability to apply learning to a new and different context is known as *transfer* and is quite difficult to develop. In a classic series of experiments on transfer known as Duncker's radiation problem, only 10% of novice learners were able to solve a case regarding the use of gamma rays to treat an inoperable tumor (Gick & Holyoak 1980). However, when first given an example that required analogous reasoning, 29% were able to solve the case (Gick & Holyoak 1983). This increased to 79% when subjects were given the hint to use the analogous example to help them solve the radiation case. The best performance was seen in subjects who were given two dissimilar analogs before solving the case, with 52% solving the case before the hint and 83% after. The designers of these series of experiments found many subjects created their own schema for relating the two dissimilar analogs, and that the quality of their schema predicted their ability to solve the radiation case. This suggests that teaching with multiple varied examples allows learners to perform a critical task of germane load, the creation of schemas.

Tip 5

Explicitly prepare learners to transfer knowledge to new settings

Schema creation and transfer are at the heart of clinical reasoning. It is relatively simple to solve clinical problems that present exactly as they did in the classroom, as long as the learner has invested enough time committing them to memory through the effortful retrieval described in Tip Three. In order to solve clinical problems they have not encountered before (i.e. *transfer*), learners need to employ more advanced reasoning, examining the deeper principles underlying the problem. Teachers can help learners develop complex schemas which get at the deeper structure of problems by presenting them with multiple varied examples to compare and contrast (a technique promoted by interleaving, as noted in the Tip Four). Teaching students to engage in structured reflection as they compare and contrast cases with similar presentations has been shown to improve both retention and transfer (Mamede et al. 2012).

Cognitive load is related to the problem of transfer. Once in the clinical setting, learners are presented not only with novel presentations of cases but also with a host of new environmental factors, from the equipment available to the presence of the patient to the other professionals on the team. Teachers can help reduce the extraneous load of the clinical setting by having learners practice whole-tasks in increasingly realistic settings (e.g. first having learners accurately describe the steps for cannulating a vein in the classroom and then mastering the actual cannulation in a simulation center before attempting the procedure on a patient) (Young et al. 2014).

Theme 4

Promote the development of expertise

Much has been written about what distinguishes a novice from an expert. Experts solve problems more quickly and efficiently than novices and are more accurate, especially for more complex problems (Chi 2006). Experts notice patterns more readily and are more flexible in their approach to problems (Bransford et al. 2000). They are thought to have quantitatively more and qualitatively superior schemas in their area of expertise. This allows them to have rapid, automated approaches to common problems (often referred to as System 1 thinking) as well as the ability to recognize when to apply slower, analytic reasoning (often referred to as System 2 thinking) (Moulton et al. 2007; Kahneman 2013).

Tip 6

Engage learners in deliberate practice

Ericsson coined the term "deliberate practice" to describe his observations of how experts in a variety of fields reach their level of expertise through effortful practice, not innate talent (Mamede et al. 2012). Deliberate practice has three key components: (1) the setting of clear learning goals, (2) individualized training activities designed and supervised by a coach or teacher to achieve those goals, and (3) repeated practice activities which are refined by feedback from the coach or teacher. Current trends toward competency-based mastery learning in health professions education are consistent with the deliberate practice approach (McGaghie 2015). Ericsson himself proposes medical education adopt deliberate practice by creating libraries of cases for learners to engage with in repeated practice, supported by a teacher or mentor (Ericsson 2015). Engaging in repeated practice of simulated procedures such as intubation or laparoscopic surgical techniques are other common forms of deliberate practice (Cordero et al. 2013; Hashimoto et al. 2015).

Tip 7

Help learners to create learning-oriented goals

It is not enough to simply practice a skill or procedure; students must articulate clear goals to engage in deliberate practice. However, the nature of these goals may differ. According to psychologists Elliott and Dweck, *learning* goals focus on increasing competence whereas *performance* goals focus on confirming current competence (Elliott & Dweck 1988). Students with learning goals tend to believe that intelligence is malleable and personal growth is possible, to respond more positively to feedback, and to be less likely to disengage from challenging tasks, as compared to those with performance goals (Mangels et al. 2006). Unfortunately, health professional students are often performance-goal oriented, having had to achieve a certain level of performance to obtain admission to competitive programs (Perrot et al. 2001; Madjar et al. 2012). Teachers can help promote learning goals by framing assessments as opportunities to learn and improve on one's relative weaknesses as opposed to opportunities to prove one's abilities.

Offering frequent low-stakes assessment instead of infrequent high-stakes assessment can also help promote the development of learning goals.

Theme 5

Harness the power of emotions for learning

Human emotion is ever-present, whether we are bored or excited, happy, or sad. In their review of the role of emotion on learning in the health professions, LeBlanc et al. (2015) define emotions as both the physiologic response to our situation (e.g. the stress or arousal response) and the subjective experience of that response as a mood (e.g. excited, happy, sad). According to the Circumplex Model, emotions have both a valence (positive or negative) and a degree of arousal (strong or weak) that together give us important information about our surroundings (Posner et al. 2005). Emotions affect the likelihood of our attending to information as well as how memory is stored and later retrieved; teaching with emotional content enhances the likelihood that information is retained by learners (Kensinger 2004). As the healthcare environment is full of situations that evoke strong emotions, it is critical for educators to consider how the emotional state of their learners is impacting learning (LeBlanc et al. 2015).

Tip 8

Teach learners to recognize their emotional state and its role in their learning

A learner's emotional state impacts how they process new information. In general, people in positive moods focus on the bigger picture, incorporating more disparate pieces of information, while people in negative moods focus on details, restricting their focus (Gasper & Clore 2002). Either can be appropriate for a given situation. For example, during a resuscitation of an unconscious patient, the healthcare team's anxious state may help them focus on the specific algorithms necessary to resuscitate the patient. Positive emotional states have been associated with more "cognitive flexibility" and thus may be more beneficial when complex diagnostic reasoning is needed (McConnell & Eva 2012, p. 1318). Due to their more global focus, learners in positive moods may better see the global principles underlying a problem and therefore more easily transfer information learned to a new setting (Brand et al. 2007). Teachers can harness the power of emotions by having learners reflect on the emotional context of their work with patients, teaching them to recognize how cases make them feel as well as think. Narrative medicine can be particularly useful, as telling our stories and those of our patients bring emotional content to the forefront, enhancing our attention and affiliation with the work (Charon 2007).

Tip 9

Create learning spaces that are psychologically safe

Although high-arousal, negative-emotion states such as fear can enhance memory for events they can also impede problem-solving, as noted above (Buchanan 2007). While there is a long history in the hierarchical medical profession of purposefully using fear and intimidation to motivate learning, we know little about whether this teaching strategy actually leads to transfer of knowledge to new settings (Brancati 1989; Musselman et al. 2005). In contrast, there is evidence that feeling safe in a learning environment leads to more creative problem-solving and greater learning, particularly in team learning (Ashauer & Macan 2013). Teachers can help to create this sense of emotional and psychological safety in learners by promoting an emphasis on learning and improvement, as noted in Tip Seven, by recognizing and validating the range of emotions experienced by learners, as noted in Tip Eight, and by developing positive and supportive relationships with learners (Haidet & Stein 2006).

Theme 6

Learning in relationship and context

Learning does not occur in an individual vacuum. Individuals learn in interaction with the environment in a reciprocal, dynamic way; they interact with people, processes, attitudes, and beliefs related to the social culture. Bandura's Social Cognitive Theory posits that individuals learn by observing others; the degree to which they incorporate observed behaviors into their own practice depends on both their self-efficacy for the behavior to be learned and the environmental response to their attempts at the new behavior (Bandura 1986). Social learning also draws on sociocultural theories from anthropology and sociology as an important part of health care education is socialization into the professional community of medicine. Finally, workplace learning draws on both cognitive and sociocultural approaches, with particular emphasis on situated learning (Yardley et al. 2012). The premise underlying situated learning is that learning is always situated or attached to the context in which it is learned.

Tip 10

Attend to the social nature of learning

Numerous studies have used frameworks drawn from sociocultural theory to understand the complexities of learning about the values, language and skill of those more established in the community (Haber & Lingard 2001; Dornan et al. 2007). Teachers can harness the power of social learning by being explicit about how they are thinking about a problem, inviting learners to the conversation as peers, being conscious of themselves as role models, and role modeling desired behaviors. Teachers should also attend to the hidden curriculum experienced by students, using reflective exercises to make the social learning transparent and being open to discussing what students are learning from the social environment (Hafferty 1998; Gaufberg et al. 2010). Students should be encouraged to reflect on how the social context of their learning may affect their personal identity formation and career choice. For example, Hill and Vaughn found that female students interested in surgery were unable to identify with other women in surgery, leading them to self-select out of a surgical career (Hill et al. 2015).

Tip 11

Create authentic experiences for workplace learning

Situated workplace learning helps with both the retention and retrieval of knowledge (Yardley et al. 2012). Knowledge and skills become situated in the context of how they are used to understand and solve relevant problems of practice. Teachers must be careful to guide learners through processes of solving problems and applying their knowledge to varied cases within the workplace in order to help learners transfer their situated learning to different workplace environments.

Tip 12

Promote metacognition in our learners and ourselves

Metacognition, or thinking about thinking, is critical for helping learners to understand how they learn and to develop techniques for managing ongoing learning (Quirk 2006). Active-learning techniques have been shown to increase metacognitive strategies such as organization of new learning and linking new learning to previous knowledge (van Vliet et al. 2015). Peer review of exams and writing assignments can also increase metacognition and learning, presumably by exposing learners to how people other than themselves think through problems (Mynlieff et al. 2014). Teaching faculty and students evidenced-based principles of learning from the tips above is another way to increase metacognition. One medical school has taken the approach of using an entire course in metacognition to help learners grasp concepts such as cognitive bias, the role of emotion in learning, and the need to tolerate the uncertainty inherent in medical practice (Eichbaum 2014). A simple technique for promoting metacognition, especially useful in the workplace, is to have everyone think aloud when solving problems. Critical reflection of one thoughts and reactions also promotes the integration of new knowledge (Mamede & Schmidt 2004).

Conclusions

We have presented six themes incorporating 12 tips drawn from the science of learning across a variety of fields. As this represents a large breadth of theoretical and empirical research, we encourage readers to try one theme or tip with which to experiment and evaluate the effects in their context. We believe these tips have value for learners, for teachers, and for those responsible for the design and delivery of curricula. For learners, the tips provide a means to understand their own learning and engage actively in learning effectively. Effective learning skills provide an important foundation for life-long habits of learning in and from practice (Schumacher et al. 2013). For teachers, the tips suggest specific strategies to use to improve their students' learning. For those developing and implementing curricula, the tips suggest considerations of curriculum design that support effective, evidence-based approaches to learning.

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

Notes on contributors

Holly C. Gooding, MD, MSc, is an Assistant Professor of Pediatrics and Medicine, Harvard Medical School, and Boston Children's Hospital, Boston, Massachusetts.

Karen Mann, MSc, PhD, is a Professor Emeritus in the Division of Medical Education, Dalhousie University, Nova Scotia, Canada.

Elizabeth Armstrong, PhD, is a Clinical Professor of Pediatrics, Harvard Medical School, Boston, Massachusetts.

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