Chapter 14
Improving as a Teacher

Learning is about managing working memory. You can no more get into the heads of your students than you can get into your own head. Helping students manage their working memories as they learn, therefore, is a tricky task. Worse yet, if you have twenty students in your class, then you have twenty different working memories to help manage – each with its own prior knowledge, goals, chunks, and so forth.

Data on effective teachers is hard to come by.[1] While some teachers are standouts – both good and bad – it is hard to measure. In spite of this, it often is said that having one excellent teacher during the elementary years is enough to keep a student on a successful track for the rest of their careers. Highly successful students are those with learning goals who work to achieve those goals. The most successful teachers are those who get students to buy into learning goals such that, in the absence of teacher input, they continue striving to achieve the learning goal.[2] Conversely, having two really bad teachers in a row is an experience from which few recover. A friend once told this story about a flight back to California from a speaking engagement in New York City. To pass the time midway into the flight, she started chatting with the young man sitting next to her and found out that he was from a rough area in the Bronx. She noticed that he had been reading the Jewish bible. Because she thought this was an unlikely choice, she asked him what he was reading and why he chose to read it on this flight. He stated that he was going to start his freshman year at Stanford, and the book was required summer reading for the entire incoming freshman class. As they continued the conversation she found out that he was the first one in his family to even consider going to college. One question led to another and he said that, when he was in elementary school, he had a teacher who turned him on to reading. He'd become an avid reader since then. Such is the influence of one good teacher!

While important data regarding this issue is hard to come by, there is one consensus among researchers and the general public: *teachers matter*.

Despite the enigmatic nature of trying to determine what is "good teaching", the ULM is very clear about what good teaching is. To restate what we said in Chapter 7, all good teaching is anchored in the three principles of the ULM. Effective teaching facilitates and attempts to optimize students' ability to allocate their working memory capacity to the things we want them to learn. Effective teaching meets students

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at their current level of prior knowledge and engages students' knowledge productively for learning. Effective teaching supports and enhances students' motivation for learning and facilitates patterns of productive student motivated self-regulation.

The five rules of learning provide further guidance on what effect teaching entails. Effective teaching must do the following:

1. Teachers must help students focus attention on relevant materials and avoid distractions using the learning environment, instructional materials, and connection to students' prior knowledge. This includes the types of classroom learning goals, how instruction and materials are designed and presented, how classrooms are managed, and how teachers facilitate students' own self-regulation.
2. Teachers must provide opportunities for repetition of new information or learning processes. This includes providing multiple exposures to information through different instructional activities and discussion, providing for effective assessment, and giving appropriate feedback. For skills this includes opportunities for practice.
3. Teachers must provide ways for students to connect what they are learning to what they have previously learned in the class, what they have learned in other classes, and their other prior knowledge. Teachers need to help students construct meaningful connections between what they know and what they are learning. This includes providing opportunities for problem solving and thinking in the classroom.
4. Teachers need to provide support for maintaining students' motivation through the way information is designed and presented, use of engaging activities, opportunities for use of knowledge, and how feedback is delivered. Perhaps the single most important thing teachers can do to motivate students is to be themselves motivated by their subject matter and model that excitement and motivation to their students.
5. Teachers need to remember that learning is learning. Directing attention, providing repetition, facilitating connections, and providing motivation are what good teaching is about. Good teaching doesn't follow fads or take short cuts.

From the perspective of the ULM, teachers who do these things will be "good teachers" and their students will learn effectively.

Teachers' Prior Knowledge

Many, if not most, things that we learn involve help from teachers. Even with respect to such things as electronic games, experienced gamers often teach or give hints to novice players, sometimes through elaborate Websites. Coaches and mentors usually play vital roles for experts; the importance of teachers becomes evident through study of those at the very top of their fields, essentially all of who can identify their mentors and/or coaches.[3]

In teacher and school talk, *pedagogical content knowledge* is a description used often. Early work in establishing this label is attributed to Schulman.[4] It is sometimes said, "So-and-so really knows her stuff but, she just can't teach." What teachers need to get across a body of content is not just the content but also some know-how about teaching that content. The pedagogical content knowledge very much depends upon the setting: the pedagogical content knowledge required for teaching reading in pre-school is different from fifth grade mathematics or high school chemistry or graduate instructional design. Knowing how to teach reading in chemistry is even different from knowing how to teach reading in social studies! Consuming and producing texts well in one discipline is quite different from doing the same thing in another one. A P-12 pre-service teacher presumably can learn about appropriate ways to do this in methods courses.

Several issues emerge immediately. Teacher content knowledge is one. It is generally conceded that knowledge of fractions is a stumbling block for many students. Newton studied pre-service teachers' knowledge of fractions in five areas including computational skill, basic concepts, word problems, flexibility, and transfer. She concluded that teacher knowledge at the end of a pre-service course, especially with respect to flexibility and transfer, was "low."[5] Teacher mathematics content knowledge based upon degrees in mathematics and certification are positively associated with student learning in high school mathematics.[6] Primary grade teachers' mathematics knowledge is correlated with student learning outcomes.[7] Evidence for depth of content knowledge in areas other than mathematics is less strong. One possible explanation for the larger effects in mathematics is that this subject tends to be largely learned in school and usually has only small outside-of-school inputs.[8]

Methods Courses Versus Professional Meetings

The methods course context almost never exactly fits the ultimate learner. There's fifth grade mathematics and then there's fifth grade mathematics for an inner-city parochial school whose students are mostly Hmong immigrants. Even then, the students are individuals, each of whom will bring unique prior knowledge to the classroom. So, tips about one student's prior knowledge are unlikely to apply to all students.

Still another issue about methods course approaches is that they rarely take into account prior knowledge and motivation in a systematic way. So, fifth grade math teachers may have some activities that seem to work for their students, and chemistry teachers know of classroom chemical demonstrations that seem to create situational interest (i.e., are motivating).

Applying the lens of the ULM to much of what is considered to be pedagogical content knowledge taught in methods courses will lead to revisions of that content.[9]

An effective place for teachers to acquire pedagogical content knowledge seems to be at professional meetings attended by experienced teachers with very similar teaching assignments. The specificity shared at these meetings seems to lead

to pedagogical content knowledge transfer. Successful teachers become more successful by learning from one another.

Video Clubs

Because all teachers do not have ready access to professional meetings, other modes of professional development should be sought out to increase the levels of pedagogical content knowledge across content areas. Attendance at professional meeting can present particular problems for teachers in rural schools where funds and substitute teachers are not plentiful. One practical option for almost any size school is to form "video clubs" within a school or district.[10] Teachers within these groups use videos of their teaching to stimulate discussions about teaching and learning in the content areas. These discussions can be further enriched and informed through common readings from journals published by content area professional organizations and books based on current research in teaching.

Attention: New Learning Requires Working Memory

You do not always have to work on new learning; it *can* just happen. That's what episodic memory (autobiographical memory) is all about. While incidental learning *does* happen, it's really inefficient. Moreover, in the absence of some remarkably dramatic event, episodic memory is both fragile and susceptible to modification.

If you want something to "stick," it needs to be in semantic memory, and the transition from episodic to semantic memory requires effort. You must allocate working memory to it. We attend to the top slot in working memory. To learn something you need to pay attention to it; it's got to make its way into working memory and become the focus of attention while there. For example, the role of attentional control in reading comprehension recently has been addressed.[11]

What kinds of things focus attention? For those students seeking grades, just saying "This will be on the test," usually is enough to garner attention. The drawback to this is in terms of focusing on performance (test scores matter) rather than learning. One of us recalls an event from 50 years ago when a roommate who was pre-med returned from a biology class during which the teacher had spent an entire period discussing his research.[12] After making several unflattering comments about the lecture, he scrawled a single word in large letters over each of eight carefully written single line pages of handwritten lecture notes: *Forget*. While this talk probably worked in terms of providing situational interest for a few students in the large lecture class, it certainly did not work for all, and not for that roommate.

An attention-getter may need to do two things: capture attention by relating new material to prior knowledge, and do it in a way that encourages later recall. The best way to find attention getters is to talk about prior experience. Sometimes a local happening or event in someone's life provides a source of attention. Generally speaking, the best way to find attention getters is to discover from other successful teachers what works. We've already mentioned unusual zoo animals as examples.

Repetition

Repetition is required for long-term memory. If something is going to go into semantic memory, repetition is required. Repetition must also include retrieval and an attention to the spacing of repetition.[13] Research in vocabulary instruction has shown that learners need about seven encounters with a word to place it firmly in their memory and be able to retrieve it. Recall that Nuthall and Alton-Lee determined that students needed at least four repetitions of information in varied contexts for it to be learned.[14] Clearly, repeated exposure to the word seven times in one lesson is not as effective as exposures over a few days and weeks. A somewhat contemptuous description that has emerged in writing about school is "drill and kill." The drill part refers to repetition. The kill part usually implies "kill interest." Even today some societies consider learned persons to be those who have memorized enormous amounts of content. When no connections are important – as usually happens with rote memorization – the accepted strategy is rehearse, rehearse, rehearse, repeat, repeat, repeat, drill, drill, drill. It works! Heaven knows, it's not a lot of fun – at least until after you have accomplished a difficult goal such as being able to recite *the Gettysburg Address* from memory and can show that off.

Unless the particular learning goal *is* rote memorization (as with *The Pledge of Allegiance*, *The Lord's Prayer*, etc.), a successful teacher tries to find ways for students to repeat the same information that go beyond rote memorization. Earlier we cited the work of Beck and McKeown from their *Text Talk* project that begins with contextualizing a word by talking about its use in the story. ("In the story you will hear about how the farmer trudged home after a long day of work.")[15] In that example, the word used (trudge) was repeated in several different contexts, and each repetition also afforded new opportunities for making connections.

Sometimes you really do need drill. Whenever some knowledge must be automated, then it will need to be practiced over and over. Think about Tiger Woods practicing his putting – over and over and over. When an engineer is performing some calculation, he really can't afford to allocate resources to decide what five times seven is. Much expert knowledge *must* be automated. Also, recall the dramatic result from retesting all Swahili words, not just those that the learner was unsure of.[16]

Again, by talking with other teachers you'll find ways in which repetition has been included in games and other activities. It's never a one-size-fits-all proposition except when rote memorization is involved.

Connections

Learning is about connections. That's something we consider crucial in the ULM. Sometimes making connections is rather easy. For example, it is easy to see how you would connect the notion of angles with the notion of triangles. Even the names speak to the connections. And, of course, students know about connections. For example, Fred knows that if he throws a spitball at Sally's hair, John will break up

laughing and the class soon will be in an uproar. We all learn about connections, big and small.

Sometimes we just fail to encourage making connections. For example, in college chemistry laboratory experiments where students are expected to discover, say, the "molar mass of oxygen," the students often gather data and then often leave to write up a report. They never discuss the experiment or the results; they never are asked overtly to connect the things they have just done in lab to other things they have learned or are learning.

Sometimes we fail to connect the knowledge we have learned to those who discovered that knowledge. Most people have heard about Newton and Einstein. Few people have heard about Eric Kandel, the physician-scientist whose work provided much of the basis of our understanding of how neurons work and without which this book could not have been written.[17]

Connections to content often come in textbooks. We mention Kandel; to learn about his work, check the reference and read his book. Imagine what it must be like to sit in a Kandel seminar and hear about the ins and outs of his discoveries. Today, Web searching has made the task of making connections quite a bit easier. Students can be assigned the task of searching out connections.

Content connections are usually varied but often included in complete curricula. They can be fun.

Effortless Versus Requiring Effort

The ULM asks that you think about your teaching in new ways. Of those new ways, *perhaps none is more important than the notion of effortless versus requiring effort*. Effortless knowledge, knowledge that comes from our autobiographical memory system, is fragile and susceptible to alteration. It usually is not the goal of classroom instruction. Although semantic memory requires effort, it usually is the kind of knowledge we seek to impart in school. Not only does the content have to be brought into working memory and attended to, but this has to happen more than once. It's harder still if that knowledge needs to be automated.

There are many activities that students look forward to. The first draft of this section was written on Halloween. At that time, the chemistry education listserv was filled with discussions about a chemical demonstration.[18] One takes potassium chlorate, a somewhat dangerous chemical, and heats it in a test tube until it melts. Then one carefully drops a sugar candy – often a Gummi bear – into the melt. The reaction is explosive.[19] When you eat a Gummi bear, you also make carbon dioxide – but you do it in a far less dramatic way. We have the classic case for situational interest. It's Halloween; kids know about Halloween candy and trick-or-treat. We humans oxidize eaten candy, but just not in quite this spectacular way. There are big flashes, loud noises; both fumes and excitement fill the air. Assuming this is done safely (it is *very dangerous* when not done properly), a good time will be had by all. At the dinner table, the student might say to her parents "Ms. Jones blew

up a Gummi bear in chemistry today." If something goes wrong, it may become the talk of the school or even the local news.

Here's the issue. In the absence of any other instruction, a month later the best students will have only a vague recall of the details of what transpired. They may remember the day for the rest of their lives, but the details of what they recall are likely to be far removed from the reality of what was done. Is this a problem? Well, it depends. If the goal was just to have a good time, then it is not a problem. If the goal is to better understand oxidation reactions, then this activity needs much more follow through. The facts need to be repeated. The explanations need to be repeated. There might even be a student question or two that needs an appropriate answer. Perhaps the students need to write a report, or write a sentence or two about this on a test or in some homework.

School can be fun; it need not be burdensome. When you are a teacher, you need to keep in mind that there is a balance between episodic memory (after all, it's *all* episodic when it comes in) and semantic memory where we are trying to store information for later use. One goal you should have is to tie activities together so that they involve repetition and connections.

Connections Are Connections

Learning is learning. In the sense that we are speaking about them, connections are connections. We take the view that too much is made of innate ability. Further, the literature does not really support the notions of either multiple intelligences or learning styles. At the same time, it is clear that some people are (or at least think they are) visual learners while others learn better from hearing and so on. We assert that, if this is the case, it is because of what they have learned rather than what they were born with.

Our "take" on modalities is different. You *do* have different sensory inputs. Sight, sound, smell, and touch *are* different. Each has inputs; each has "buffers;" each can come into working memory using one slot. You can "think" about each.

In Chapter 5, we described an experiment where students study and were tested in the presence of odors (chocolate, camphor).[20] Camphor-taught students tested better in camphor, and chocolate-taught students tested better in chocolate. How could this happen when odor had nothing to do with the content studied? As before, the ULM explains this observation in terms of pattern matching that is available for recall at testing. Having the same odor present gives just one more thing for a pattern to match against, and so goes the explanation. If you don't share a neurobiological view of learning as espoused in the ULM, then it is very difficult, if not impossible, to understand the result of this and similar experiments. Pavio made a reputation developing the dual coding theory.[21] Our view is that we should think of an n-coding theory in which all senses may play a role. Information from all senses can be stored, "played back," and included in pattern matching.

The reason to teach using different sensory modalities and test using different modalities is not really rooted in intrinsic differences among us humans; learning is learning. What does matter, however, is that all of us benefit when the connections we make involve as many inputs as possible. Connections in multiple modalities make learning easier.

This also makes practical sense. Much of what we do in schools ends up being measured by pencil-filled spots on papers of scanable response sheets. Virtually no one makes a living filling out such sheets. Instead, we apply whatever we have learned by writing or painting or talking or wielding a scalpel or whatever. Connections in multiple modalities make learning more realistic and potentially more useful. Internists must be familiar with issues of male prostate disease. In addition, they need to be able to palpate a prostate as part of a screening to detect such disease.

Closing Thoughts

When you are seeking ways to enhance your pedagogical content knowledge, try to frame what you are learning according to the ULM. For example, how will this new content comport with making connections? Does it afford you a good way to offer repetition? Will it generate the kind of situational interest likely to bring it into focus in working memory? If a suggestion looks like a good one for episodic memory, how can you follow it up with something aimed at moving it into semantic memory?

Ultimately, human learning works the same way for all of us. Yes, there are differences in working memory capacity, prior knowledge, and motivation. But, whatever a learner's current knowledge state, the three principles and five rules apply to new learning.

Notes

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