Chapter 9
Efficient Instruction

Cognitive Load

We noted in Chapter 6 that instructional practices developed by cognitive load theorists are fully compatible with the principles of the ULM. Rather than review the details of the extensive instructional literature developed within cognitive load theory (or its equivalent), we refer you to two excellent references. The first is a recent book by Clark, Nguyen, and Sweller, which explicates essentially all of the work published by Sweller and his colleagues, and Mayer and his colleagues.[1] Earlier also, a book was written by Clark and Mayer on the same set of topics.[2]

The CORE Lesson Model

An instructional approach consistent with the ULM principles is the CORE lesson model developed by Calfee and colleagues, which guides teachers as they plan to integrate these fundamental principles into their teaching.[3] CORE is an acronym that stands for CONNECT – ORGANIZE – REFLECT – EXTEND. At the introduction of the lesson and throughout it as necessary, the teacher focuses students' thinking by connecting them to their prior knowledge or experiences either from previous lessons or from commonly held experiences. The teacher guides students in organizing their thinking to build connections with the lesson's information and/or procedures. This is frequently accomplished by teaching with graphic organizers that can be used as discussion or reading comprehension tools. Throughout the lesson, the teacher provides for repetition and connection by asking questions that encourage the students to stop and reflect upon what they are learning in the lesson ("What examples of amphibians should go in this section of the matrix?") and how they are learning the new information or procedures ("Why should we write the common characteristics of the two pre-war periods in the middle portion of the Venn diagram?") that span Bloom's taxonomy. The teachers plan ways to extend students' use of the new learning to other contexts. This portion of the lesson gives students the opportunity to practice applying their new knowledge in varied ways. The teacher asks questions at the close of the lesson that recap the learning

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and explicitly require the students to think about when they could use their new declarative and procedural knowledge in the future.

Explicit Knowledge Is Teachable; Implicit Knowledge Isn't

Learning is about connections. Explicit mental searching is rather straightforward. You set your mind to a target and then go looking for that target. You almost certainly know whether or not you have ever been in Nome, Alaska. You don't really know how this works. That is, you are not aware of any kind of spreading activation as it takes place. One of us lived in Alaska – but Nome is not connected to the rest of Alaska by roads. So, even when you've lived in Alaska, your mental search for yes/no on having been to Nome usually is a quick search. Since most of us know whether or not we've been in Alaska, the search usually is a quick and accurate one.

Implicit mental searching is quite different; you're not too sure what it is that you are looking for. There is no doubt that much of the real-world problem solving involves implicit rather than explicit searching. An argument in favor of implicit searching as an instructional tool is that it gives us real world practice. Many examples in science and business involve finding information that has similar characteristics to the problem at hand, but is not the same and sometimes very different in appearance.

The instructional question is whether implicit searching is preferable to direct explicit instruction. Learning is about building searchable connections. A teacher or curriculum designer certainly knows more about the relevant knowledge and how it should be organized and connected than a student. Direct instruction based on a good design will certainly build a students' knowledge base faster and build more explicit retrieval cues. As a result, students have more knowledge to search and can explicitly search faster and more accurately. But, even the best planned direct instruction cannot cover all of the possible ways the material could be interconnected or anticipate all of the possible situations in which knowledge might be usefully retrieved through implicit searching for ill-defined problems. Therefore, providing opportunities for students to engage in activities requiring implicit searching can help them build a richer knowledge base with more potential pattern matches.

One can learn without deliberately having a learning goal or consciously paying attention. Episodic memory is effortless memory; it happens. Episodic memory captures space in working memory without conscious effort. Learning by multiple exposures does happen; after a while, we get the sense of things. We also construct novel knowledge in working memory as we are problem solving or thinking. As we discussed in Chapter 4, learning from experience is implicit or sometimes called tacit learning.[4] Knowledge is more difficult to acquire tacitly. As we discussed in Chapter 4, implicit learning from problem solving or critical thinking is uncertain. From an instructional standpoint, tacit learning is more difficult to direct. The teacher or instructional designer can structure the environment in ways that hopefully promote the desired experience, but he/she cannot control whether students are directing their working memory allocation to the knowledge they are supposed to be learning. Mentoring or lengthy apprenticeships are instructional approaches often used. However often we may choose to use the term medical science, much medical practice is learned through residency and fellowship programs in which, what is learned has never successfully been written down. In fact, one of the most often studied areas of learning involves reading x-ray images on the way to becoming a radiologist.[5] Surprisingly, much of a radiologist's learning is tacit learning. Those in training, see a film, and then have an expert interpret that film.

You cannot turn off your working memory. Let's say you are in an apprenticeship, a learning situation. You hear what your master says and see the choices she makes, but she never explains why that choice is made. She might even say something like "I sure hope that works." What you have to process includes the circumstances, what is said, and the seeming decision points that appeared to emerge. There is no apparent rule or decision tree to apply to the situation. It's a bit like learning to bluff when playing poker or making an occasional "psych" bid in playing bridge.[6] Think about it; there can't be a rule for bluffing. If there were, bluffing would never work. If you ever discovered a rule for bluffing at poker, you'd be a fool to tell anyone that rule.

That said, nearly anything that is tacit ultimately could be made explicit. Once it is explicit, it can be taught using more direct instructional approaches, which will allow students to learn more readily. The most efficient way to engage in explicit learning is to use our working memories to think about what we are learning. That is, we attend to what we are learning with the intent of learning it – how it works, what the variables are, and so forth. We repeat; repetition is needed for learning. When we have a chance to think about what we are learning, we can better integrate it with what we already know. That is, we make connections that make sense to us. Good teaching and instruction can explicitly direct students to attend and guide repetition and connection.

Teachers can make it more likely for their students to make these connections through the questions that they ask during and especially after a lesson. Think about this scenario. You are teaching a lesson on the three branches in the American government. After asking the students to brainstorm what they know already about how the government is organized and then giving them the choice of books or websites to read for additional details, you help your students sort out all of this information by developing a chart or grid with them. The chart has headings across the top with the names of the three branches. Down the left-hand column you've written some of the characteristics like: function, duties, people, building where the branch is housed, and one interesting fact. After modeling how to think about the chart and interactively completing a few of the spaces during whole class instruction, you have your students complete the chart in small groups. The next step has the class come together as a whole group to compare/contrast the three branches of government using the information they have recorded on their charts. You extend and apply their learning by asking them to analyze a short scenario about how each branch of government might contribute to the passage or blocking of a proposed law. To close the lesson, you ask two kinds of questions – the product and process questions. Your product question may be as simple as, "Okay, what were we learning about in this lesson? Now, tell your neighbor an interesting fact from the readings or our discussion that was new for you. Sarah, what new information did David learn today? Besides for the quiz tomorrow, why is it important for you to know about these branches of government?" This is followed by your process question, "What did we use to organize our thinking about the three branches of government? Yes! We used a grid. When do you think you could use a grid again to help you think about what you've read? Why would it be helpful then?" When you employ a graphic or visual organizer as a learning/discussion/writing tool, you are making it easier for students to see and make explicit connections between and among ideas. Asking them to make a value judgment pushes them to think about the information more deeply than just the basic knowledge level. The process question pushes your students to think explicitly about transferring a way of thinking about information to different contexts. As soon as we start to mention thinking, we are in the realm of working memory – its capacity and utilization. We've already discussed the notion of cognitive load, and indicated that efficient learning depends upon managing cognitive load. Remember, teachers are working memory managers/trainers/coaches.

This is very much in line with what we learned in the past two decades about teaching how to read. Some students will pick up decoding just by interacting with texts through the scaffolding of more experienced readers (sometimes called "the whole language approach"). This leaves a significant number of students with less than optimal opportunities to learn to decode words, especially if they have limited experiences. At the point of school entry, it is much more efficient and effective to teach the alphabetic system explicitly than to try and supply enough implicit experiences to foster such development. In many ways the implicit approach might actually increase the gap between the more able readers and their struggling peers. Stanovich called it the Matthew Effect in which the rich are getting richer by having more practice and the gap between students increases with time.[7]

Optimal "Difficulty" for New Content

Learning requires connections; we need appropriate prior knowledge to connect to new knowledge. Efficient learning requires a match between the learner's prior knowledge and whatever new content they are dealing with. We may say that the new material is too difficult for the learner based upon her or his current skills. It means that the prior knowledge is either not there, or not chunked in such a way that the new knowledge can be brought into working memory in a way that allows for suitable new connections. Working memory capacity can be used up on small but necessary chunks without leaving enough room for other chunks that are needed to make sense of the new content. This is especially clear when learning a new language.

The other side of this is that, if the new material is too easy, the learner may not pay enough attention – thinking that they already have command of that content.[8] New learning requires working memory allocation, and learners sometimes think they already know something, so they really don't attend to it.

The ULM suggests that for efficient learning to occur, there is an optimal content difficulty for new material that is to be learned. Vygotsky called this the zone of proximal development.[9] What the ULM does is make the requirements more explicit for being in the zone of proximal development. That is, *the material to be learned must fill or nearly fill the learner's working memory without exceeding the learner's working memory capacity*.

In a classroom of twenty to thirty students, it is extremely unlikely that all students will be well described by one and the same zone. This may be true when the content is completely new (no one knows anything) or old (everyone knows the material) but, for most classrooms, learners have different zones – implying the value of small group instructional configurations.

Storage and Retrieval

Learning is a product of working memory allocation. Learning is about storage of new information. We are almost never satisfied with simply asking whether the new knowledge has been stored. It's like asking someone who is completely lost after having a vast rollout of information, "Did you follow that?" and having them respond with a smile and a nod. Teachers have no direct control of their own working memories, let alone those of their students. If a teacher said, "Now store this in your semantic memory" and expected her students to store it, there would be no effect. Teachers often do say things like, "This is important." That's a cue to pay special attention because you may need to use this or, more often, this will be tested.

We satisfy ourselves that students know something through assessment, and we discuss that separately. The ULM suggests that the best results will occur when we practice retrieving in those contexts that matter. Put another way, this suggests that we "teach to the test." Further, it implies that we "test often." If you don't like the context, change the test; that is, change the test that you are teaching to. Make your tests more like the contexts in which retrieval is likely to take place. The Class-Plus Writing Assessment is one such assessment that is designed to determine how well your students are able to compose an informational text under the most supportive conditions.[10] It offers teachers a template for creating a writing assessment that is developmentally appropriate for their class. That's why pilots and physicians train with simulators. Teachers training pilots and physicians strive to make the learning environment as realistic as possible. There are tradeoffs in costs of learning. More resources are allocated to their training of pilots and physicians because "lives are at stake" as the result of the work.

Formative assessment is a good idea. If the assessments reflect the contexts in which the knowledge is to be used, this is nothing more than practice. Frequent formative assessment really should be just practice. High stakes assessment may actually limit student performance because the emotions (anxiety for example) and possible consequences will occupy some of the working memory slots thus inhibiting effective processing.[11]

Notes

1. Clark, R. C., Nguyen, F., & Sweller, J. (2006). *Efficiency in learning: Evidence-based guidelines to manage cognitive load*. San Francisco: Pfeiffer.
2. Clark, R. C., & Mayer, R. E. (2003). *E-learning and the science of instruction*. San Francisco, CA: Jossey-Bass/Pfeiffer.
3. Chambliss, M. J., & Calfee, R. C. (1998). *Textbooks for learning: Nurturing children′s minds.* Malden, MA: Blackwell.
4. Sternberg, R. J., & Horvath, J. A. (Eds.). (1999). *Tacit knowledge in professional practice*. Mahwah, NJ: Lawrence Erlbaum Associates.
5. Lesgold, A., Rubinson, H., Glaser, R., Klopfer, D., Feltovich, P., & Wang, Y. (1988). Expertise in a complex skill: Diagnosing x-ray pictures. In M. T. H. Chi, M. J. Farr, & R. Glaser (Eds.), *The nature of expertise* (p. 436). Mahwah, NJ: Lawrence Erlbaum Associates.
6. http://en.wikipedia.org/wiki/Bluffing (Accessed March 23, 2009); http://en.wikipedia.org/wiki/Psychic_bid (Accessed March 23, 2009).
7. Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly, 21*, 340–406.
8. Kalyuga, S., Ayres, P., Chandler, P., & Sweller, J. (2003). The expertise reversal effect. *Educational Psychologist, 38*(1), 23–31.
9. Vygotsky's terminology includes the "zone of proximal development," or ZPD. (Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.)
10. Calfee, R. C., & Wilson, K. M. (2004). A classroom-based writing assessment framework. In C. A. Stone, E. R. Silliman, B. J. Ehren, & K. Apel (Eds.), *Handbook of language and literacy: Development and disorders*. New York: Guilford Press.
11. Gimmig, D., Huguet, P., Caverni, J., & Cury, F. (2006). Choking under pressure and working memory capacity: When performance pressure reduces fluid intelligence. *Psychonomic Bulletin & Review, 13*(6), 1005–1010.