Running Head: UNIFIED LEARNING MODEL

The Unified Learning Model: Implications for Learning and Teaching

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Abstract

The Unified Learning Model (ULM) is proposed as an integrative framework for understanding current theory and research in learning and applying this theory and research to issues in teaching and instruction. The ULM integrates three aspects of cognition: (a) crystallized intelligence (expertise) as represented by accumulated knowledge stored in long-term memory, (b) fluid intelligence as represented by working memory capacity, and (c) motivation as represented by working memory allocation. How students direct their available working memory capacity will determine what is learned. Working memory capacity is expanded through chunking and automaticity that are determined by the students' level of expertise. Allocation of capacity is determined by the student's motivation. The ULM unifies several heretofore disparate themes in the learning literature.

The Unified Learning Model: Implications for Learning and Teaching

Introduction

Our purpose in this paper is to propose the Unified Learning Model (ULM) as an integrative framework for understanding current theory and research in learning. The ULM is not a scientific theory of learning itself. Rather, the ULM provides a practical way to conceptualize and organize three important factors that influence learning and are well known to teachers and education professionals:

- what the learner already knows,
- how able the learner is, and
- how motivated the learner is.

The ULM focuses on three cognitive components that underlie these factors:

- crystallized intelligence as represented by accumulated knowledge stored in long-term memory,
- fluid intelligence as represented by working memory capacity, and
- motivation as represented by working memory allocation.

The ULM integrates these components in a way that can inform decision making about teaching and instruction and can provide a guide for research and theorizing about influences on learning.

Development of the Unified Learning Model

The Unified Learning Model's Roots are in the ICML (Interactive Compensatory Model for Learning)

The initial formulation leading to the ULM was the development of the interactive compensatory model for learning (ICML, Figure 1, Schraw et al., 2005). The ICML depicted learning as influenced by three primary factors: prior accumulated knowledge, ability, and motivation, with prior knowledge considered the most important (e.g., see Shapiro, 2004). In the ICML, these three factors were seen as cognitively distinct from one another, as well as cognitively distinct from learning. Evolution of the ULM has involved the integration of these three factors within a single model of cognition.

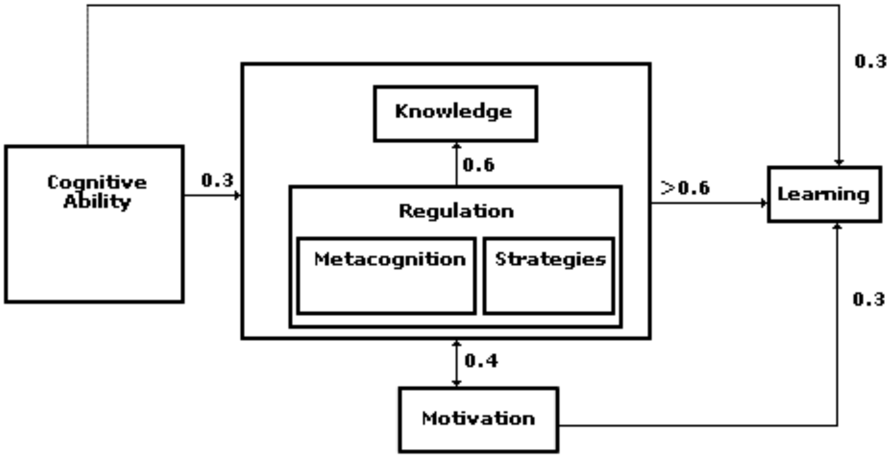

Figure 1. The ICML implies that its three components (prior knowledge, ability, and motivation) are distinct and separate from one another. The ICML regards prior knowledge as the best predictor of success with new learning, a notion that is well-supported in the literature.

Learning as Knowledge

The first modification was to place the ICML 'box' for learning within the 'box' for knowledge. Learning involves additions to knowledge or changes in knowledge. For a given moment and as the result of a learning experience, one might choose to isolate new learning since that is what usually is measured or assessed. Because the ICML considered factors impacting learning, it was reasonable and appropriate to split that learning apart from knowledge as in Figure 1. However, once learned, the newly learned materials become another part of the extant knowledge. That new knowledge is incorporated with extant knowledge was explicitly acknowledged through Figure 2 of the first ICML report (Schraw et al., 2005).

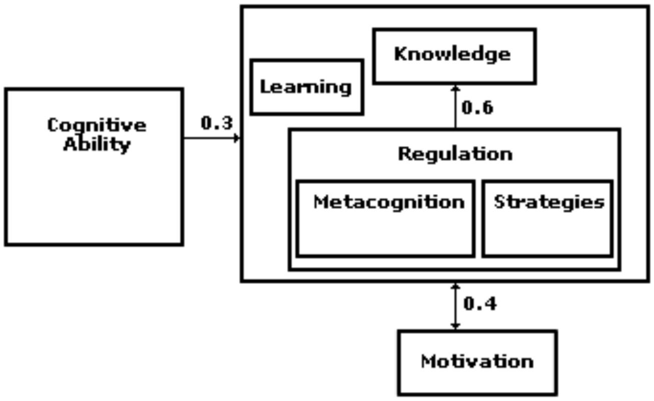

Figure 2. This schematic integrates new learning into the box that represents knowledge.

Ability

The ICML represented ability as distinct from knowledge. Ability has primarily been studied within the field of intelligence (Colom et al., 2004; Engle et al., 1999; Horn & Cattell, 1966). Contemporary views of ability/intelligence generally agree that there are two components:

- fluid intelligence, a rather fixed entity that deals with general cognitive capacity, and
- crystallized intelligence, a malleable entity that reflects accumulated knowledge that can grow through learning and experience.

Very recent work supports the crystallized/fluid model (Nietfeld et al., 2007). Crystallized intelligence, as conceptualized in current formulations of intelligence, is synonymous with knowledge as depicted in the ICML; therefore, overall cognitive ability could no longer be justified as an entity entirely distinct from knowledge.

Fluid Intelligence and Working Memory

If crystallized intelligence is the knowledge component in the ICML, what about fluid intelligence? Early work on intelligence (Spearman, 1904, 1927) developed the notion that an entity (called *g*) may be used as an overall indicator of intelligence. For some time, there has been a strong suspicion that Spearman's g is related to working memory capacity (Kyllonen, 1996). Recent work (Colom et al., 2004; Engle et al., 1999; Heitz et al., 2005) suggests that *g* is essentially the same as fluid intelligence and that fluid intelligence is basically working memory capacity. Engle et al. (1999) note "...but individual differences in capacity for controlled processing are general and possibly the mechanism for general fluid intelligence." Recognizing that the ability component in the ICML was fluid intelligence and that fluid intelligence was working memory capacity led to the revision of the ICML by Brooks and Shell (2006). They redefined the ability component of the ICML as working memory capacity as shown in Figure 3.

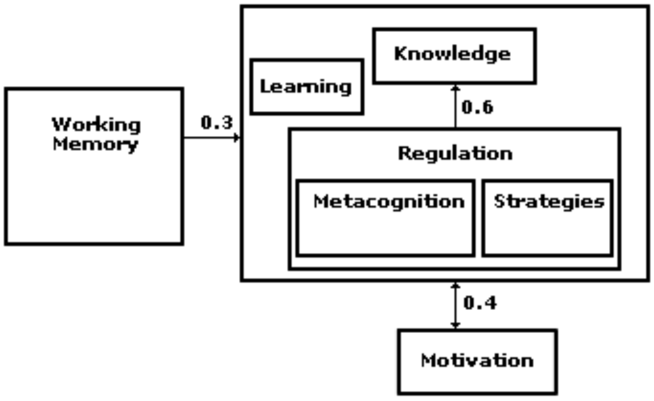

Figure 3. In this revision of the original schematic, the 'box' labeled ability is replaced with one labeled 'working memory.' The work of Colom et al. (2004) justifies this replacement.

Working Memory Capacity

Baddeley and Hitch popularized the term working memory in 1974, and provided a model for working memory (Baddeley, 1992; Baddeley & Hitch, 1974). Since that time, numerous models of working memory have emerged (Miyake & Shah, 1999). All of these models view working memory as that part of the cognitive system that deals with the temporary storage and manipulation of information and thoughts during cognitive processes. Working memory is not necessarily a distinct cognitive or neurological component. For example, Cowan (1999, 2005) describes working memory functionally as the currently activated subset of long-term memory.

Miller's classic paper (1956) was the first to report on a key aspect of working memory: that the ability to process and hold information is limited. Since then, working memory has been viewed as having a limited capacity (Baddeley, 1992). Working memory has an absolute capacity defined by the amount of sensory input and long-term memory that a person can activate at a given moment (Andrade, 2001). This implies that, when one speaks about a student having limited cognitive ability or limited fluid *g*, this is really the same as saying that the student has limited working memory capacity. Absolute working memory capacity exhibits large individual variance across the population (see Jarrold & Towse, 2006; Unsworth & Engle, 2007). Limited absolute working memory capacity has been implicated as a key factor in reading and other learning difficulties (e.g., Jarrold & Towse, 2006; McLean & Hitch, 1999; Unsworth & Engle, 2007).

Although absolute working memory capacity is important, the vast majority of the population possesses sufficient absolute capacity to learn effectively and perform most cognitive tasks that are encountered in school and work settings. But, if almost everyone possesses enough absolute working memory capacity (and, hence, enough fluid intelligence or "ability" to succeed), what accounts for the observed differences in learning and achievement that we typically ascribe to differences in ability?

Research in working memory points to a distinction between the absolute working memory capacity that a person has available and the amount of that capacity that is actually being used at any given time (Cowan, 1999; Engle et al., 1999). Ellis and Ashbrook (1988) put forth the resource allocation hypothesis which holds that performance on any task is dependent not on how much working memory capacity a person may have, but rather on how much of that working memory capacity is being allocated to the task. Similar arguments have been made in cognitive load theory (e.g., Kalyuga et al., 2003). If effective working memory capacity is dependent on how much of the available working memory capacity a person is allocating, then the question of interest becomes "what determines if and how much working memory capacity a person allocates?" This led to a reassessment of the relationship between working memory and motivation in the ICML.

Motivation and Functional Working Memory Capacity

Although every teacher has a definition for motivation, precise definitions appear elusive. A common definition from Pintrich and Schunk (1996) is "Motivation is the process whereby goal directed behavior is instigated and sustained." Motivation is the term often used to describe why we do what we do. We might speak of "what motivates someone to become a surgeon or to commit a crime?" We might ask "what motivates a learner to pursue an advanced degree in a difficult area?"

Brooks and Shell (2006) put forth a definition of motivation as the conscious or subconscious allocation of working memory to a task (see also Hertel & Rude, 1991). This conceptualization of motivation integrated with working memory is depicted in Figure 4. Absolute working memory capacity may set an upper limit to what one can learn or do, but functional capacity is determined by the amount of working memory being allocated at any given time and this allocation is primarily determined by motivation.

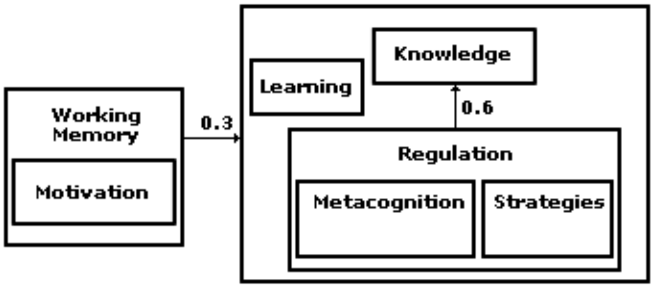

Figure 4. Defining motivation as done here allows motivation to become contained completely within the box formerly labeled as 'ability' but now labeled as 'working memory.' Motivation is the allocation of working memory

A growing body of work has shown that allocation of attention and cognitive resources to learning tasks is influenced by motivation and emotion (Ellis et al., 1997; Pekrun et al., 2002; Reed et al., 1996; Reed et al., 2002; Unsworth et al., 2005). Ellis and his colleagues (Ellis & Ashbrook, 1988; Ellis et al., 1997) have shown that emotion directly competes for working memory resources as well as influencing motivation. By integrating motivation with working memory, the ULM recognizes this dual role of motivation and emotion. Although motivation and emotion can increase the allocation of working memory resources, the need to regulate or attend to motivational concerns or emotions either negative or positive can direct attentional resources away from the learning or cognitive task at hand.

This integration of motivation with working memory has important consequences for thinking about both motivation and ability. As conceptualized, fluid intelligence or ability cannot be separated from the motivation to apply that ability. We cannot ask if a learner has the capability to do a task without also asking whether they have the motivation to do the task.

Working Memory and Crystallized Intelligence

Research in memory and cognitive science suggests that working memory capacity can be increased by the organization of related information into coherent groups for storage and processing often referred to as chunking (Gobet, 1998; Gobet et al., 2001; Miller, 1956). The absolute capacity of working memory appears to be about four to eight units. These units could be single entities like letters or larger units or chunks like words or "sound bytes." Chunking results from learning. Experts can hold larger amounts of information, including sensory data, and process more information than beginners or untrained people. For example, expert chess players can recall the positions of many chess pieces on a chessboard after viewing the board for only a few seconds; persons who don't know chess can recall only the general four to eight pieces associated with the general working memory capacity (Gobet, 1998; Simon & Gilmartin, 1973). Interestingly, experts can only recall a greater number of pieces if the pieces are in a game position; if the pieces are randomly placed, experts can recall no more than the four to eight pieces that non-players can recall.

As the storage component of working memory can be increased by chunking, the processing component of working memory can be increased by automaticity (Jefferies et al., 2004; Schneider & Shiffrin, 1977; Unsworth & Engle, 2007). Automaticity is the process of transferring a cognitive process from controlled to self-generating processing. Cognitive operations are controlled when they need to be actively monitored and directed. These control operations require working memory capacity. Through practice, cognitive operations can proceed without the need for monitoring and control of the low level details required to accomplish the operation. This reduces the need for working memory capacity; automatized processes do not require active attention and direction.

This research suggests that the functional capacity of working memory is variable and can be increased over time through acquisition of knowledge leading to the formation of chunks and automatization of cognitive processes. The implication of this is that working memory capacity is interrelated with knowledge stored in long-term memory (Gobet, 1998; Jefferies et al., 2004; Unsworth & Engle, 2007). This leads to the final revision of the ICML to produce the ULM.

The Unified Learning Model

The Unified Learning Model is depicted in Figure 5. The formerly distinct ICML components of prior knowledge, ability, motivation, and learning have been integrated into a single whole. Prior knowledge or crystallized intelligence that is stored in long-term memory interacts with working memory or fluid intelligence to produce learning and behavior. Working memory limits how much prior knowledge and new sensory information can be activated at any one time with this working memory limit itself determined by motivation and by the extent of prior knowledge chunks and automatized processes available. The current working memory capacity limits new learning. However, as learning occurs, knowledge increases which increases the effective working memory capacity allowing acceleration of future learning processes.

The original ICML was based on the premise that the different components, ability, knowledge, and motivation could be compensatory. Limited ability could be compensated for by more knowledge or motivation. Limited knowledge could be compensated for by higher ability or motivation. The ULM emphasizes these compensatory interactions even more. It is not just that these components can compensate for each other; it is that these components are, in fact, inseparable from one another. They continuously work in consort to produce learning and behavior.

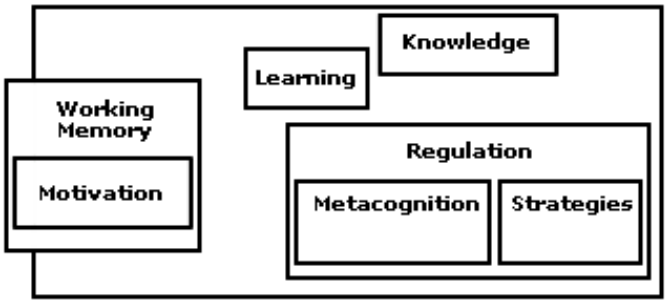

Figure 5. The Unified Learning Model treats learning as new knowledge co-located with prior knowledge. Working memory capacity limits the amount of knowledge that can be activated at once, and thus limits ability. A fully motivated learner is one using their entire working memory capacity in a learning task. Finally, as per the Cowan model, because working memory involves activation of prior knowledge it, too, is placed largely within the knowledge box.

Implications of the Unified Learning Model for Thinking about Learning, Motivation, and Intelligence.

Neurological Basis for Learning and Motivation

Although we do not intend the ULM to be a specific neurological model, the ULM is consistent with what is presently known about the neurobiology of the brain and its cognitive systems. As in most contemporary neurological models, long-term memory, the locus of crystallized intelligence or knowledge in the ULM, is seen as stored in the cerebral cortex (Kandel et al., 2000; Lømo, 2003; Unsworth & Engle, 2007). The ULM does not isolate working memory as physically separate from long-term memory. Rather, the ULM recognizes that working memory functions appear to involve a number of different brain areas, some associated with the cortex and others such as the hippocampus, which appear to serve more specific working memory functions (Kandel et al., 2000; Unsworth & Engle, 2007). The conceptualization of working memory being the activated subset of memory corresponds to much recent research that is focusing on how patterns of neural activation are associated with behavior. Considerable research has shown that neurological activity occurs both bottom up initiating in sensory input areas and proceeding through working memory to the cortex and top down initiating in the cortex and proceeding through working memory to influence sensory and motor areas (for example, see Kandel, 2005; Knight, 2007 and references therein; Lømo, 2003; Unsworth & Engle, 2007). This reflects the type of interaction between long-term and working memory proposed in the ULM. In the master schematic for the ULM shown in Figure 5, working memory is contained mostly within one large box, and it is implied that this organization is located in the cerebral cortex. This emphasizes the notion that the ULM envisions working memory in terms of activating portions of long-term memory. By placing some of the working memory box outside of the larger box, the ULM notes that at least some locus of human working memory resides in brain structures outside of the cortex, structures such as the hippocampus.

Neurological research also supports the portrayal of chunking and automatization in the ULM. Neural imaging studies show selected “robust expertise effects” for experts compared to non-experts (Ericsson, 2006; Hill & Schneider, 2006; Moore et al., 2006) reflecting “tuning” chunks of knowledge being activated together. With repeated practice, the brain areas associated with working memory that were activated during early stages of learning are bypassed reflecting developing automaticity (Dobbins et al., 2004). The conceptualization of motivation in the ULM also is consistent with a growing body of work in the neurology of emotion (LaBar & Cabeza, 2006). Considerable interconnection between higher brain areas such as the prefrontal cortex and lower brain areas associated with emotion (e.g., amygdala) as well as between the hippocampus (often thought of as a site of working memory) and these areas. This research is documenting considerable interaction between the cognitive and the emotion areas of the brain that corresponds to the interplay between working memory and motivation described by Brooks and Shell (2006) and incorporated into the ULM.

As a functional model of how cognition and emotion work, the ULM can provide a useful way to translate neurological research into educational practice. The ULM provides a functional description of these underlying neurological processes that deals with learning, cognitive, and behavioral processes at the level of the person as he or she is encountered in educational settings. At present, we cannot deal directly with the neurology of a student. We can, however, deal with student learning and cognition in ways that conform to our understanding of how these neurological mechanisms function.

Revisiting Intelligence, Knowledge, and Expertise

Spearman (1904; 1927) postulated that intelligence was a global entity (*g*). Although the idea of a single “intelligence” has appeal, contemporary views of intelligence have viewed it as a multi-component construct (Horn & Cattell, 1966). The ULM, however, represents an entity that seems very similar to Spearman’s *g*. Crystallized intelligence, fluid intelligence, and motivation are unified into a single integrated whole. None of these entities can be the locus of intelligence by itself. The overall performance or “intelligence” exhibited by a person at any given time will be determined by how these entities work together.

The ULM, however, equates crystallized intelligence with knowledge. Contemporary views of memory and knowledge, particularly those associated with the study of expertise, see these as continually developing (e.g., Chi et al., 1988; Ericsson, 2006; Ericsson et al., 2006). Classic psychometric IQ measures are not strongly associated with expertise (Ericsson & Lehmann, 1996; Taylor, 1975). Consistent with these views, the ULM sees crystallized intelligence as embodied in knowledge structures (schema or chunks) that are enlarged and enhanced by acquiring expertise (Ericsson, 1996, 2006; Ericsson et al., 2006; Hill & Schneider, 2006). Because of the dynamic nature of knowledge and the fact that knowledge can increase working memory capacity, intelligence as embodied in the ULM is a dynamic entity.

In the ULM, the expression of intelligence by an individual is determined by the particular knowledge that is currently activated and the amount of working memory that is allocated which depends, in turn, upon the level of current motivation. Intelligence also is expressed at a particular time within a particular environment consistent with many current views that see skill and behavior as situated within particular contexts (Hatano & Greeno, 1999). So, although the ULM might reflect an integrated view of intelligence similar to *g*, this intelligence is quite different than classic conceptions of intelligence (Horn & Cattell, 1966) or even contemporary theories of intelligence and multiple intelligences that view intelligence as fixed or biological/genetic based ability.

The integration of knowledge, working memory, and motivation that produces intelligent behavior also is apparent in the development of intelligence itself. Expertise is primarily acquired from serious study of a discipline (Alexander, 1992, 2004; Chi et al., 1988; Ericsson, 2006) and expert skill is a result of deliberate practice (Ericsson, 1996, 2006; Ericsson et al., 1980; Ericsson et al., 1993). Deliberate practice refers to time spent focused on some aspect of a more complex performance. Consistent with the ULM, research shows that deliberate practice requires the complete or almost complete allocation of working memory resources to the practice. This level of practice must be supported by appropriate levels of motivation (Alexander, 2004; Alexander et al., 1995; Zimmerman, 2002, 2006). As expertise develops, the acquired knowledge and skill lead to more and larger chunks and more automaticity, which themselves increase working memory capacity allowing more resources to be allocated to practice, which produces greater learning. As expertise develops, motivation also increases (Ericsson & Lehmann, 1996; Zimmerman, 2002), which increases the working memory capacity allocation. This cycle of interrelated increases in knowledge which allow subsequently greater learning of new knowledge has been termed the “Matthew Effect” (Stanovich, 1986). The ULM provides an effective way to organize and understand why these cognitive, learning, and motivational processes work the way they do.

Cognitive Load Theory (CLT)

Cognitive load generally refers to the total amount of demand placed on working memory by mental activity (Cooper, 1998; J. Sweller, 1988). Contemporary theories of cognitive load recognize three types of load (van Merrienboer et al., 2006). *Intrinsic* load refers to the number of elements that need to be held in working memory. *Germane* load refers to cognitive activity in working memory that is directly related to the task or to-be-learned information for the purpose of processing and manipulating that information. *Extraneous* load refers to load imposed aspects of the task or learning environment such as need to deal with multiple materials or pay attention to multiple sources of information. Much work in instructional design over the last two decades has aimed at reducing extraneous load (for example, see R. C. Clark & Mayer, 2003). Extraneous load also can come from non-task related sources such as emotions or other aspects of the environment that are competing for attention. Extraneous load interferes with learning or performance because it uses up working memory space which is then not available to handle intrinsic or germane load.

The integration of working memory, knowledge, and motivation in the ULM provides a way to organize and understand load issues. Chunking would reduce intrinsic load by either reducing the amount of information that must be held or increasing the size of each unit being operated on in working memory. As van Merrienboer et al. (2006) note, experts have less intrinsic load because they can handle large chunks of information at a time. Automaticity would reduce germane load by shifting some cognitive activity out of working memory.

The ULM extends current thinking about cognitive load by highlighting the role of motivation in determining load. First, emotional and motivational concerns are seen as directly imposing load in some circumstances when emotion directly takes up working memory capacity (Ellis & Ashbrook, 1988; Ellis et al., 1997). Perhaps more importantly, the ULM emphasizes the role that motivation has in changing effective load. Persons who are unmotivated are unlikely to allocate all of their working memory capacity to a task. This decreases the capacity available to deal with the cognitive load from intrinsic, germane, and extraneous load components associated with the task. Increasing motivation can increase the effective working memory capacity available. Thus, in the ULM, cognitive load is related to the task and task environment, but also is related to the person's motivation. An example of this would be what have been termed "seductive details" (Garner et al., 1992). Seductive details are unrelated to the material to-be-learned, so from a cognitive load perspective, they are extraneous load because they compete for attention with relevant material (Harp & Mayer, 1998). However, if a seductive detail increased a student's motivation for the material, he or she might devote more working memory capacity to the rest of the learning task, thereby making more overall space available for intrinsic and germane load in the long term despite the immediate extraneous load cost of attending to the seductive detail (Schraw, 1998). The ULM highlights that we cannot talk about cognitive load without talking about that load in relation to both absolute and effective working memory capacity and how allocation of that capacity is being motivated.

Self-Regulation and Active Learning

Much of the prior discussion has implied an active management of working memory. What does it mean to say someone is "allocating" working memory resources or someone is motivated or cognition is "controlled"? These questions have been addressed within the field of self-regulation (Boekaerts et al., 2000; Zimmerman, 2002; Zimmerman et al., 2001). Broadly, self-regulation deals with how persons manage and direct their thoughts and behavior. Self-regulation theories hold that persons are capable of exerting conscious or volitional control over their thoughts and actions. Generally, self-regulation theories consider regulation to have three components: skill, will, and metacognition.

Skill concerns whether persons have the knowledge they need to effectively self-regulate. In educational contexts, this is usually expressed in terms of learning strategies (e.g., Pressley et al., 1987; Weinstein et al., 2000; Weinstein & Mayer, 1986). Learning strategies are techniques and skills students use in learning and classroom settings to help them understand and remember what they are trying to learn. These can be methods for enhancing memory such as paraphrasing and summarizing information or techniques such as taking notes during lecture or highlighting textual materials. A large body of research has shown these types of strategies to be associated with learning.

Metacognition deals with the monitoring and application of skills or task management. Regardless of what learning strategies a student possesses, they will not apply these strategies if they do not realize they should. Considerable research (Brown et al., 1983; Pressley et al., 1987) has shown that poor students do not necessarily lack knowledge of what to do when they are not understanding or learning but often are very deficient at recognizing when they do not understand. Deficits in monitoring and applying the right strategies effectively play as much of a role in self-regulation failures as lack of knowing what to do.

Will concerns whether students have the motivation to apply the self-regulatory skills they possess. Because volitional actions like applying learning strategies and doing metacognitive monitoring are seen as effortful, students need motivation to exert this effort. If students are not motivated in the classroom, they will likely not self-regulate effectively (Pintrich, 2003; Pintrich & Schunk, 2002; Zimmerman, 2002; Zimmerman & Schunk, 2004).

Self-regulation imposes cognitive load. Because learning and task strategies involve processing and manipulating information they constitute germane load in cognitive load theories. Metacognition imposes both an intrinsic load because working memory space is needed for monitoring and extraneous load because monitoring and task management themselves distract from resources that can be devoted to germane load. As noted by Winne (1995):

> Monitoring levies charges against a learner's limited attentional resources (or working memory capacity). In the midst of a task, overly frequent monitoring or monitoring against a vague or too long list of criteria, may put students in a deficit position. It can obstruct access to cognitive resources they should apply toward acquiring the subject they are studying by assembling new information with prior knowledge, translating information across representational forms, and rehearsing information ... .

The ULM provides a cognitive model that captures the dynamism that is implied in self-regulatory theories. As such, the ULM can help us understand how and why students succeed or fail at effective self-regulation and what needs to be done to overcome self-regulatory difficulties. In the ULM, self-regulation is influenced by the interaction between knowledge in long-term memory, working memory capacity, and motivation. Self-regulation is a form of "intelligence" about a specific set of knowledge and behaviors. It is an important enough intelligence to be specifically noted in the ULM model (see Figures 1-5). As such, all the previous discussion about intelligence and its development applies here. Students become better at self-regulation the same way they become better at anything else; through learning appropriate self-regulatory knowledge and developing expertise at using specific strategies and metacognitive skills (Weinstein et al., 2000; Zimmerman, 2002). Also, like any other intelligent behavior, the execution of self-regulation in any setting is affected by the extent to which self-regulatory knowledge is chunked and the extent to which specific strategies have become automatized (Pressley et al., 1987). Automatization of metacognitive components is especially important because this frees up working memory resources to be devoted to task specific intrinsic and germane load (Winne, 1995).

The ULM defines what it means to say that a learner is motivated to self-regulate. A learner is motivated if they are willing to devote available working memory capacity to self-regulating their learning. Not all learners are willing to do this, and even good students may not be willing to do this all the time. Conversely, as with any expression of intelligent behavior, being motivated in and of itself will not be enough. Motivated self-regulation will only be effective if the student has sufficient strategy and metacognitive knowledge and skill to apply to the learning task.

Returning to the questions raised at the start of this section, we can answer them from the prospective of the ULM. Someone is an "active" learner or "allocating" their working memory, if they are engaged in self-regulation. This engagement implies that they are applying metacognitive task management skills and task-related learning or problem solving strategies to the task at hand, and are motivated to devote enough of their available working memory capacity to handle the intrinsic and germane load generated by this regulation. This active learning need not mean any visible behavior or even any overt cognitive processing. Highly expert self-regulators may have automatized many of the learning strategies and metacognitive monitoring and task management skills and execute these with little observable effort. They also may manage much larger chunks of information and not need many of the learning strategies devoted to overt linking and grouping of information. When students are successful at devoting almost all working memory resources to the germane load of actually engaging strategically with the information they are trying to learn, they may appear to be doing nothing at all. But in the ULM, "active" is a working memory phenomenon rather than an overt behavior. Conversely, a student might appear to be very behaviorally active but if this activity is directed at extraneous load task management issues, there may be little actual working memory allocation to the germane load of learning. Observing performance-based feedback has been taken as a means of determining that active learning is underway (Brooks et al., 2005). There are circumstances in which such feedback might be observed without the engagement of germane load and, therefore, little resulting learning. At the same time, the active questioning and debate that often follow a technical lecture at a professional conference make clear that any lack of observable behavior on the part of audience members prior to the questioning cannot be taken as evidence for lack of active learning.

Flow

Sometimes humans enter states in which they are utilizing fully all of their available motivated working memory capacity. This circumstance has been called flow (Csikszentmihalyi et al., 2005). Flow involves complete, focused attention and completely automatized behavior without any conscious metacognitive monitoring. It is a characteristic of experts including scientists, athletes, and musicians, but is also experienced in small increments by everyone who "loses themselves in the moment" of an activity. Feelings associated with flow include fulfillment, great freedom, skill, and enjoyment. In the ULM, flow would be achieved by having a complete focus of 100% of working memory capacity on a task with all germane load automatized.

Although flow is a desirable state for behavior, it is not a desirable state for learning. As discussed previously, learning requires deliberate practice (Ericsson, 1996, 2006; Ericsson et al., 1980; Ericsson et al., 1993). Deliberate practice requires active application of metacognitive monitoring and attention to performance and feedback. These preclude flow. Once a behavior is automatized, it can be executed in a flow state, but no further learning or skill development will occur simply from flow execution. To become more skillful requires relinquishing flow for active, deliberate practice.

Implications of the Unified Learning Model for Thinking about Teaching and Instruction

From the perspective of the ULM, the primary goal of education is the development of expertise (crystallized knowledge). Learning is accomplished through the allocation of working memory (fluid intelligence) to acquiring new knowledge and skill. The effectiveness of learning is determined by the interaction between existing expertise, motivation, and working memory capacity. Abstracting from these basic principles of the ULM, we can say that the goal of teaching and instruction is to maximize the effectiveness of student learning by optimizing their allocation of working memory in the educational setting.

Basic Principles of Teaching and Instruction Embodied in the ULM

We can extract certain general principles about teaching and instruction from the ULM. These are:

- The ultimate goal of all teaching and instruction is development of student expertise.
- The primary function of teaching and instruction is directing how working memory is being allocated.
- Teaching and instruction must be adapted to the current expertise of the student.
- Maintaining student motivation is critical.

From the perspective of the ULM, these four principles inform all teaching and instructional decision making. The ULM places the focus of teaching and instruction on the student. Teaching and instruction are about engaging students with educational materials in ways that promote the development of their expertise. Regardless of any specific instructional or teaching approach, the ULM says that teaching and instruction will be effective when they direct motivated working memory allocation to the to-be-learned information at an appropriate level relative to the student's existing knowledge. If any of these criteria are not met, the teaching or instruction will be ineffective. We examine each of these principles and then consider their application to current issues in teaching and instruction.

The Goal of Teaching for Expertise

The ULM embodies the dictum that "experts are made not born." As discussed previously, research shows that expertise is learned (Alexander, 1992, 2004; Chi et al., 1988; Ericsson, 1996, 2006; Ericsson et al., 1980; Ericsson et al., 1993). The ULM dictates that nearly any child can learn to become proficient in any academic area. The ULM stands in contrast to views that children's potential is limited or determined by talents or “intelligences” (see Waterhouse, 2006 and subsequent papers for recent critiques of these views). From the perspective of the ULM, all teaching and instructional activities should be directed at facilitating student learning and development. In the ULM, learning is a function of how much of ones working memory is devoted to the task of learning. How working memory is being allocated among learning and other possible competing tasks is a function of what goals students are pursuing. Thus, it is critical that classroom and instructional goals be focused on learning.

Although this dictum may seem obvious, maintaining a focus on learning is not always easy. Considerable research in Goal Theory (e.g., Meece et al., 2006; Pintrich, 2000a, 2000b) has documented that differences in how students perceive the goal structure in classrooms has a dramatic effect on students’ learning. Classrooms that emphasize learning as the goal of classroom activities foster higher self-regulation, motivation, and achievement than classrooms that emphasize performance or outcomes. The ULM suggests why this occurs. In the ULM, intrinsic and germane load are related to learning. Anything else is extraneous load. If a student is pursuing any goal other than learning, any working memory allocated to that goal would increase extraneous load and decrease the working memory capacity allocated to learning.

Differences in goals may be subtle. Sweller (1999) has noted that solving a problem is not the same as learning to solve a problem. If the goal is to get the problem correct, students may invoke problem-solving strategies such as trial and error that may get the problem solved (performance goal), but result in no learning of the underlying principles embodied by the problem. Similarly, students can engage in a problem-based learning activity or hands-on science experiment and be focused on completing the activity rather than on learning the relevant problem solving or inquiry methods or conceptual understanding that the activity is supposed to be teaching. To keep students from having a disconnect between the learning goals of the instruction or activity and their own potential performance goals, teachers need to manage how they present activity goals to students and help students maintain focus on learning versus simply performing. Bereiter & Scardamalia (1993) have noted that many students see school as a series of tasks to be competed rather than as a place of learning or personal growth. Teachers need to be cognizant that how they frame the purpose and goals of classroom work can dramatically affect how students formulate their own learning or performance goals (Meece et al., 2006) and subsequently how students ultimately allocate their working memory to intrinsic or germane versus extraneous load.

A final issue is students who pursue neither performance nor learning goals. Ames (1992) has found that some students adopt work avoidance goals in school. Essentially these students simply want to get through the class with the least amount of time and effort. Many times these students are too unmotivated to allocate their working memory to any type of productive learning. Teachers need to identify these students and help them increase their motivation toward school and classroom activities. Even good students may adopt work avoidance goals for specific tasks. Clark (1982) noted that more able students who chose guided, highly structured approaches, even though they learned more from unguided, more self-directed approaches, did so because they thought they could achieve required learning outcomes with a minimum of effort.

Directing Working Memory Allocation

In the ULM, the role of teaching and instruction parallels that of self-regulation. If self-regulation means that a learner is managing their own allocation of working memory, then teaching means that the teacher is managing some or all of this allocation of working memory for the student. Students self-regulate by being motivated to apply metacognitive task management skills and task-related learning strategies to direct enough of their available working memory capacity to handle the intrinsic and germane load needed by the learning task. Similarly, we can conceptualize teaching and instruction as activities directed at supplying task management skills, facilitating learning strategies, and motivating students in ways that help students direct their working memory capacity to the intrinsic and germane load in the learning setting. In a similar way to that in which the components of the ULM can compensate for each other, teaching and instruction can compensate for deficiencies that a student might have in any of these components.

Highly self-regulated students need very little direct teaching or instructional support. These students possess the expertise in metacognitive management and learning strategies and motivation to effectively direct their own learning. If they are provided with a knowledge rich environment, they likely can do most learning on their own. All students, however, are not expert self-regulators. Like any other form of expertise or intelligence, self-regulation abilities develop over time. Younger children usually do not have high levels of self-regulatory expertise. Self-regulatory expertise also interacts with domain expertise. Even when a student is expert at self-regulatory knowledge, if they are new to a subject, they will have little prior knowledge of the content being learned and thus will have to manage new information without the benefits of prior knowledge chunks. Finally, students are not always highly motivated for all subject areas. Even expert self-regulators may operate sub-optimally if they are unmotivated in a subject area or particular classroom. In all of these situations, teachers and instructional designers need to provide support to compensate for diminished self-regulatory capacities by providing management, strategic, and motivational components within the instruction itself.

Much metacognitive management in self-regulation involves monitoring the effectiveness of the learning strategies being used in terms of understanding material, remembering what is being learned, and improving skill in practice. For teachers, the monitoring function is performed through feedback to students. One-to-one tutoring provides the greatest opportunity for effective feedback because student’s learning strategy use and performance can be continuously monitored by the tutor and immediate feedback can be given. Although this level of monitoring support is not possible in classrooms, teachers still need to incorporate methods such as questioning and observation of student work to monitor how students are progressing. These allow teachers to provide appropriate feedback and guidance to help students better allocate their working memory. As younger students are less expert in their own metacognitive monitoring, the need for teacher monitoring will be higher for younger students. But, it also will be higher for students of any level of self-regulatory expertise when they are starting work on a new subject area.

The second metacognitive management function is control of strategy use. Teachers can execute this control for students by explicitly directing them to engage in certain strategies. This can be as simple as directing students to attend to specific information or as complex as providing instructional methods that force students to engage with the information in ways that increase germane load. For example, giving students prompts to self-explain problem solving increases their learning of problem solving procedures and transfer of learning (King, 1992; Renkl & Atkinson, 2003; Rittle-Johnson, 2006; van Merrienboer et al., 2006).

Monitoring and control functions also can be performed through different types of instructional formats. Students in cooperative groups can share monitoring and control functions. This would be especially effective for younger students who lack personal self-regulation expertise. Students can compensate for each other's regulatory deficiencies because each student will have different strengths that can be combined in the group. Monitoring and control functions also can be embedded in media. Many computer-based instruction and tutoring programs contain monitoring components that track student responses and provide feedback to inform students of errors and to direct their use of strategies (Aleven et al., 2003).

Adapting Teaching and Instruction to Student Expertise

Consistent with a number of other models of learning (e.g., Alexander, 2004; Shuell, 1990; van Merrienboer et al., 2006; Zimmerman, 2002), the ULM emphasizes that teaching and instruction must be adapted to the existing expertise level of the student. Teaching and instructional strategies appropriate for a novice learner may not be appropriate for a more expert learner. A consistent finding is that learners with higher prior knowledge or self-regulation skills benefit more from instruction that is less guided or structured; whereas learners with lower prior knowledge or less self-regulation skill benefit more from instruction that is more guided and structured (R. E. Clark, 1989; Snow & Lohman, 1984). More recent work in cognitive load theory (e.g., van Merrienboer et al., 2006) shows that different levels of instructional and teacher support are appropriate for students with different levels of expertise.

The basic structure of the ULM holds that the ability to have working memory capacity available for learning is a function of how much prior knowledge the student has. The ULM postulates that novice learners will have less capacity available, thus will require more support from teaching and other aspects of instruction, such as worked examples (J. Sweller, 1988) or teacher scaffolding (Aulls, 2002). Because learning in the ULM also is a function of the students' self-regulation skill, the need for support also will interact with the student's existing self-regulation expertise. Clark (1982) noted that more expert self-regulators likely have better developed learning strategies for themselves than those that can be provided by teachers or embedded in instructional materials, so they likely will learn better with less support.

Providing worked examples has proven to be an effective instructional strategy (Chi et al., 1989; Paas & van Merrienboer, 1994; J. Sweller & Cooper, 1985). The ULM sees this as the result of the student being able to use the example as a chunk in working memory, and then allocate other working memory resources to the germane load which itself involves prior learning that must be modified to enable the student to deal with the material presented in the example. The addition of completion activities (van Merrienboer & Krammer, 1990) to this mix provides a motivational element to help the teacher ensure that the student is engaging with the worked example in a manner that does help bring about the context-specific self-regulatory learning that will be needed to deal with similar related problems encountered in the future (van Merrienboer et al., 2006).

In the ULM, expertise or intelligence is dynamic and variable. So we cannot talk about novice and expert capability as fixed. Students' self-regulatory skills and ability to access prior knowledge vary across time in learning settings. Just because a student acts expert in one subject or on one lesson does not mean that they will act expertly in all subjects and lessons. As a result, students may require different levels of teacher or instructional support across a lesson, class, or activity (e.g., Woltz, 2003).

Maintaining Student Motivation

Motivation is linked biologically with emotions and physical reactions, and teachers do not have direct access to these processes. So for teachers, facilitating students' motivation primarily involves processes that influence students' beliefs. A full review of the considerable body of work done in motivation is beyond this paper (see Elliott & Dweck, 2005; Pintrich, 2003; Pintrich & Schunk, 2002). The ULM does suggest specific focus on two particular beliefs.

Self-efficacy beliefs (Bandura, 1997) concern a person's confidence in their capabilities for doing behaviors successfully. Self-efficacy beliefs are consistently the strongest predictors of academic achievement (Pajares, 1996) and are especially potent predictors of effective self-regulation. Bandura especially has noted that self-efficacy sustains motivation for the lengthy and demanding process of developing expertise. Sustained engagement in deliberate practice is effortful with at times little obvious payoff. Because the ULM sees development of expertise as the primary goal of education, self-efficacy is an especially important motivator. Teachers, therefore, should focus motivational efforts on development of positive self-efficacy.

A considerable body of research has documented teaching and instructional practices that facilitate enhanced self-efficacy (King, 1992; Palincsar & Brown, 1984; Pintrich & Schunk, 1996; Schmuck & Schmuck, 1992; Schunk, 1989, 1991; Zimmerman, 2002). An especially critical role is played by teacher feedback. Feedback that focuses on the process of learning and increasing competence through effort build efficacy much more than feedback focused only on the results of learning such as test scores or grades (Schunk, 1983). Self-efficacy also is built by experiencing mastery of a subject. Students need to see progress in order to feel confident that they can progress. Self-efficacy should not be confused with self-esteem, however. Self-efficacy is built by overcoming challenges, so failure on the way toward mastery is not bad as long as the totality of experiences are moving toward greater mastery.

The second key belief is the student's view about the nature of learning and intelligence, sometimes called epistemological belief. Just as teachers and other educators need to believe that "experts are made not born" and that children can learn to become proficient in any academic area, students need to believe this about themselves. Research by Dweck & Legget (1988) has shown that students who believe that intelligence is dynamic and developing, as the ULM portrays, are more motivated and self-regulated than students who believe that intelligence is fixed and unchangeable. If students do not believe they can get better, they have little reason to try. Recent research by Dweck (Blackwell et al., 2007) has shown that explicit instruction concerning the changeability of intelligence was more potent for improving self-regulation and achievement in children than was instruction in learning strategies. It seems critical that teachers themselves believe that students can develop expertise through sustained study and deliberate practice, and that they transmit this belief to their students.

Externally Expanding Working Memory Capacity

The ULM holds that learners have limited working memory capacity that sets a cap on how much can be learned at any given time. Although this capacity is affected by expertise and motivation, there is still an ultimate maximum. There is no way to exceed this maximum within an individual. This capacity, however, can be expanded by using external resources outside the student. Although the ULM is a model of "inside the head" cognition, all of the working memory functions that must be performed do not need to always happen inside the head of an individual student.

Intrinsic load can be off-loaded using memory devices such as notes, diagrams, and sketches. Rather than attempt to hold all information in working memory, some information can be retained in these formats for later access. Germane load can be off-loaded through teacher scaffolding. Teachers can prompt students to use appropriate strategies and can model how to do strategies (e.g., reciprocal teaching, Palincsar & Brown, 1984). Teachers also can reduce self-regulatory load by helping students monitor their learning and by modeling self-checking methods.

Memory also can be expanded through tools, especially computerized tools. Salomon, Perkins, and Globerson (1991) and Norman (1991, 1993) have argued that technology could extend human intelligence by virtue of joint mind-machine collaboration. The use of technology could not only enhance output or productivity but also enhance learning. Similar arguments with supporting research have been made for Computer Supported Collaborative Learning (Koschmann, 1996; Koschmann et al., 2001) and computer supported knowledge building (Scardamalia & Bereiter, 1994). The ULM posits that the effectiveness of any technology tool will be a function of how well it helps students direct working memory allocation, manage cognitive load, as well as how it impacts motivation.

Inquiry, Discovery, and High-Invention Methods

The ULM can help clarify issues raised in recent discussions of the effectiveness of discovery or inquiry methods versus direct instruction (see Kirschner et al., 2006). Nothing in the ULM explicitly endorses either direct instruction or more discovery-oriented methods. The ULM, however, does suggest conditions under which more direct and more discovery-oriented methods are likely to be successful.

The ULM posits that learning success is dependent on effective allocation of the students' working memory to the learning task. Thus any type of instruction, be it direct instruction or discovery, will be effective to the extent that the instruction engaged students to allocate their working memory to the information to be learned. Consistent with previous discussions of self-regulation and adapting instruction to students' prior knowledge, the extent to which students will need instructional support the help their engagement will depend on their own self-regulation skill and their prior knowledge of the subject domain.

Discovery and similar high-invention strategies usually demand high levels of engagement on the part of the learner. Students must invent their own understanding of the information generating high germane load. Before students have integrated information into chunks, there is high intrinsic load. Finally, students must monitor and direct the overall activity and learning creating additional load from the metacognitive self-regulation required. Because of the high levels of intrinsic, germane, and extraneous load that learners must manage, they must devote almost all of their working memory capacity to the task. Although this engagement may seem to indicate active, effective learning, van Merrienboer et al. (2006) have noted that discovery environments create a paradox due to element interactivity. In order to develop meaningful chunks, students need to hold more information in working memory creating high intrinsic load, but the high self-regulation load required by discovery approaches does not leave enough working memory capacity for this intrinsic load. Thus, students often end up with only learning isolated fragmentary information rather than conceptually integrated chunks (see also Kirschner et al., 2006). This trade off between engagement and the complexity of chunks students can manipulate themselves is depicted in Figure 6.

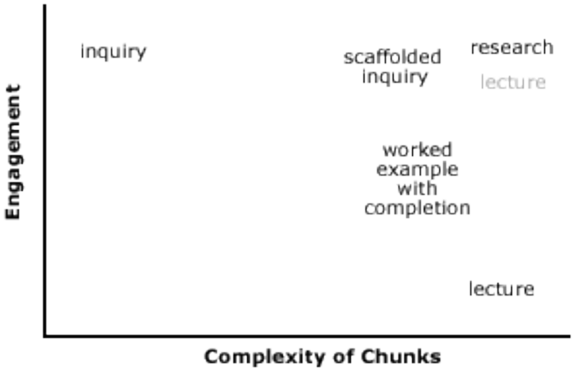

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Figure 6. Schematic of instructional strategies in terms of level of engagement and the complexity of chunks.

In the ULM, the element interactivity paradox can be partially resolved by the student's expertise. Students with more prior knowledge can access already chunked knowledge to lower intrinsic load, and students with higher self-regulatory expertise can free up capacity for intrinsic and germane load by reducing the load from self-regulation in the activity. From the perspective of the ULM, discovery and related instructional methods will be appropriate only for relatively expert learners in advanced courses in a topic. This is consistent with a number of similar arguments concerning discovery approaches (Kirschner et al., 2006; Spiro et al., 1994, 1998; van Merrienboer et al., 2006). As noted in Figure 6, as chunk complexity increases in the instructional setting, the amount of support non-expert students will require also increases. It may be appropriate to provide this support in the form of a lecture when the complexity is too great for students and requires an expert organization (see Hmelo-Silver, 2004).

Discovery approaches often do produce higher student motivation and engagement with the instruction. Students, especially young students, like doing discovery and inquiry activities. Clark (1982) has documented, however, that liking an instructional method and learning from instruction are not the same. More novice and lower ability students typically express more motivation and preference for less directed instructional methods, even though they do not learn as much as they would from more direct instruction. Teaching and instruction in the ULM is based on the premises that effective instruction must help students direct working memory capacity effectively and adapt to the expertise level of the student. But, because student allocation of working memory also is affected by motivation, the ULM recognizes the benefits of incorporating motivating activities such as discovery and inquiry into the overall instructional mix. It may be worthwhile to have a suboptimal instructional activity from a pure learning standpoint to obtain more long-term motivation for continued study of a domain. We also note in Figure 6 that, although lecture is often thought to be the opposite from inquiry in terms of motivation and engagement, appropriately targeted lecture (especially in conjunction with other more inquiry-oriented strategies) can be engaging (Hmelo-Silver, 2004).

Social Construction

The ULM is compatible with social constructivist views of knowledge, learning, and instruction. Nothing in the ULM precludes the creation of knowledge in a social community. The ULM holds that this socially constructed knowledge is only meaningful for any individual student, however, if it becomes part of that student's prior knowledge in long-term memory. Knowledge that does not become part of the student's own long-term memory will cease to exist for that student once the social setting ends.

Thus, from the perspective of the ULM, socially constructed knowledge is like any other knowledge that resides in a location outside the student, such as the natural environment or in books or other media. For that knowledge to become part of the student, it must be taken in through the senses and processed through working memory into long-term memory storage. These processes are the same for socially constructed knowledge as any other knowledge.

Social learning settings impose unique self-regulatory and extraneous load demands, however. In addition to the regulatory and load requirements imposed by the to-be-learned information, there are social interaction demands. Students must monitor and regulate their social interactions as well as their learning. We can predict from the ULM that students' effectiveness in doing this social regulation will be a function of their expertise in social interaction. This expertise will be a function of students' knowledge of social environments, the interaction protocols for engaging with fellow members of the social environment, and their skill in engaging in patterns of social discourse and interpersonal interaction. The more expert students are in these social self-regulatory mechanisms, the more of their working memory resources can be devoted to the germane load associated with storing knowledge that is being socially constructed. Conversely, we can predict that students who lack social skills and knowledge of discourse conventions will have to devote considerably more working memory capacity to these and hence have reduced learning.

From the perspective of the ULM, teachers need to structure and facilitate social learning activities in ways that reduce the extraneous load associated with engaging in the social setting. This would be especially important for younger students who have not yet developed a full range of social skills, and for students from diverse cultural backgrounds who may be unfamiliar with the social conventions and discourse patterns of the dominant classroom culture. In these situations, teachers may have to facilitate discussions or specify roles for participants and rules of engagement (Brown, 1997; Johnson & Johnson, 1997). The need to reduce load associated with regulating the social setting may explain why many successful group learning methods, such as jigsaw (Aronson et al., 1978; Slavin, 1980) and fostering communities of learners (Brown, 1997; Brown & Campione, 1994) often contain very explicit interaction instructions.

Social learning settings also can affect goals and motivation. The social environment sets up the potential for competition between goals for learning and goals for social outcomes (making friends, influencing people, exerting power). As noted by Wentzel (2005; Wentzel & Wigfield, 1998), social goals compete with instructional and learning goals, and this competition can be magnified by a social learning environment. As with the previous discussion of competing goal contexts, this competition will reduce allocation of working memory capacity to the learning outcomes of the social construction. The ULM highlights the importance of paying attention to potential competing goals and what they are motivating students to pay attention to in the learning setting. From an instructional standpoint, this suggests that teachers structure social learning activities in ways that keep the focus on the learning task and monitor social learning interactions to insure that learning remains the focus of the discourse and activity.

The ULM Final Summary

In this paper we have proposed the Unified Learning Model as a framework for thinking about learning, teaching, and instruction. The ULM integrates three aspects of cognition:

- Long term memory
- Working memory capacity
- Motivation

In the ULM, learning is a function of working memory allocation. How a student applies his or her available working memory capacity to the learning situation will determine what is learned. The student's available working memory capacity can be expanded through chunking or automaticity which is determined by the level of the student's expertise in the subject area. Allocation of the available capacity is determined by the student's motivation. As more knowledge is learned, expertise increases which increases the future learning capability and future motivation.

From these principles of learning, the ULM suggests four general guidelines teaching and instruction.

- The ultimate goal of all teaching and instruction is development of student expertise.
- The primary function of teaching and instruction is directing how working memory is being allocated.
- Teaching and instruction must be adapted to the current expertise of the student.
- Maintaining student motivation is a critical element in any instruction.

At its most basic, the ULM says that teaching is supporting students in whatever ways are necessary for maximizing their allocation of working memory. This involves

- keeping students focused on learning as the goal of their educational activities.
- providing direct or indirect support to help students direct their working memory capacity to the appropriate learning material.
- providing instructional supports to help beginning students manage cognitive load in ways and help increase their intrinsic and germane load capacity.
- providing meaningful motivators that go beyond making instruction fun to developing students' positive beliefs about the nature of learning and their own emerging capabilities and self-efficacy.

These basic principles of learning, teaching, and instruction can help inform instructional design and teaching methods. Regardless of whether instruction follows a direct or indirect approach or whether instruction is done in individual, didactic, or collaborative settings we can predict that teaching and instruction that corresponds to the underlying principles of learning and instruction derived from the ULM will be effective and instruction that violates these principles will be ineffective. This way of thinking moves questions of teaching and instructional effectiveness away from a focus on specific methods or approaches to a focus on how the teaching or instruction facilitates student working memory allocation. As we have discussed, any instructional method can be effective or ineffective depending on how it interacts with students' expertise and motivation. The ULM provides a model for determining what methods and instructional supports will be most likely to be effective for a student given their existing prior knowledge of the subject, self-regulation expertise, and motivation.

The ULM also highlights areas where more research is necessary. Although we know much about the individual components, we currently have only a limited understanding of how the interactions between knowledge, working memory, and motivation hypothesized in the ULM operate at the biological, cognitive, and behavioral levels. Kandel (2005) has noted that understanding how persons allocate their attention remains a seminal problem in cognition and neuroscience. The ULM provides an integrative model for directing the focus of this inquiry. The ULM also provides a focus for research on teaching and instruction. Future educational research should be directed at identifying instructional supports that help direct students' effective working memory allocation in accordance with the instructional principles indicated by the ULM.

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