Policy Implications for Preparing Expert Teachers: Applications of Cognitive Load Theory

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Abstract: Cognitive load theory is an instructional theory that describes learning structures in terms of an information processing system composed of a long-term memory that stores knowledge and skills in a relatively permanent fashion, a working memory that consciously processes the information that will be stored in long-term memory, and metacognitive monitoring that regulates this processing. Working memory is very limited in both capacity and duration, however, and these limitations can impede learning.
Cognitive load is defined as the total amount of mental activity imposed on working memory at a certain instance in time. Since effective instruction involves keeping instructional goals in mind, presenting high quality representations of content, guiding student interaction, monitoring students for evidence of inattention or misbehavior, and other instructional tasks, it imposes a cognitive load on teachers that frequently exceeds their working memory capacities. They often adapt by reverting to primitive teaching strategies that decrease cognitive load, but simultaneously reduce the likelihood of maximizing student learning. Expert teachers accommodate the limitations of working memory with metacognitive strategies that, in effect, reduce cognitive load. Developing expertise requires that teachers acquire these strategies, and effective teacher preparation programs must incorporate policies that ensure learning experiences which facilitate the development of the strategies. Only then will teachers have the capabilities needed to use the sophisticated teaching techniques that theory and research suggest will maximize student learning.
Key Words: Cognitive load theory, Expertise, Educational policy

Cognitive Load Theory

In recent years cognitive science has provided an expanding body of literature that has important implications for instructional design and the preparation of teachers. Cognitive load theory is an instructional theory generated by this body of literature. It describes learning structures in terms of an information processing system composed of a long-term memory that stores knowledge and skills in a relatively permanent fashion, a working memory that consciously processes the information that will be stored in long-term memory, and metacognitive monitoring that regulates this processing. Working memory is very limited in both capacity and duration, however, and these limitations can impede learning (Chandler & Sweller, 1990; Mayer & Chandler, 2001; Paas, Renkl, & Sweller, 2004; Sweller, 1999; Sweller, van Merrienboer, & Paas, 1998)

Cognitive load is defined as the total amount of mental activity imposed on working memory at a certain instance in time, and it suggests that there are two essential constraints on the efficiency of learning. The first includes characteristics of the learner, most particularly the extent to which the learner has task-relevant conceptual knowledge (i.e., schemata) in long-term memory and has automated procedural knowledge. The second is the complexity of the task or the information to be learned (Bruning, Schraw, Norby & Ronning, 2004; Mayer & Moreno, 2003).

The Complexity of Classroom Instruction

Cognitive overload occurs when an individual is required to process too many sources of information simultaneously. Teachers often face this problem. During teaching episodes, large numbers of events occur at the same time, these events occur rapidly and unpredictably, and they are visible to all and constantly scrutinized (Doyle, 1986; Bransford, Darling-Hammond, & LePage 2005). For example, to teach effectively, teachers must simultaneously keep instructional goals in mind, present high quality representations of content, guide student interaction, monitor students for evidence of inattention or misbehavior, informally assess learner understanding, and make adaptations when evidence indicates that students are not learning as much as possible (Darling-Hammond & Baratz-Snowdon, 2005; Emmer, Evertson, & Worsham, 2003; Evertson, Emmer, & Worsham, 2003). The simultaneity and complexity of these tasks imposes a very heavy cognitive load on teachers, so heavy that is often exceeds their working memory capacities.

Teachers then adapt by reducing cognitive load, most commonly by reverting to simpler approaches to instruction, such as lecture or excessive amounts of seatwork, which decreases both the complexity of instruction and the simultaneity of the events that occur within instructional activities. This helps us understand the prevalence of lecture, the most criticized of all teaching methods, yet the most commonly used (Cuban, 1993) and particularly in urban environments (Eggen, 1998). As a result, student learning, and particularly for learners with the greatest needs, is often reduced.

Differences in the Thinking Between Experts and Novices

Research indicates that experts in any field reduce cognitive load and therefore accommodate the limitations of working memory more effectively than do novices in two ways (Bransford, Brown, & Cocking, 2000; Bruning et al., 2004). They first have complex schemas of domain-specific knowledge that are efficiently organized (such as an expert math teacher who has a large amount of organized knowledge about both mathematics and the instructional processes that help students learn mathematics). This factor helps us understand research that confirms the importance of knowledge in the development of expert performance in a number of fields, including teaching (Bruning, Schraw, Norby, & Ronning, 2004; Borko & Putnam, 1996). “The accumulation of richly structured and accessible bodies of knowledge allows individuals to engage in expert thinking and action. In studies of teaching, this understanding of expertise has led researchers to devote increased attention to teachers' knowledge and its organization” (Borko & Putnam, 1996, p. 674). The function of these richly structured and accessible bodies of knowledge is to reduce cognitive load.

Research indicates that at least four different kinds of knowledge are essential for expert teaching: knowledge of content; pedagogical content knowledge; general pedagogical knowledge; and knowledge of learners and learning (Borko & Putnam, 1996). The need for knowledge of content is undisputed and is well documented by research examining the relationships between what teachers know and how they teach (Borko & Putnam, 1996; Shuell, 1996). Pedagogical content knowledge involves understanding ways of representing topics so that they’re comprehensible to others, as well as an understanding what makes learning topics easy or difficult to learn (Borko & Putnam, 1996; Shulman, 1986). General pedagogical knowledge involves a general understanding of instruction and classroom management that transcends individual topics or subject matter areas (Borko & Putnam, 1996; Emmer, Evertson, & Worsham, 2003; Evertson, Emmer, & Worsham, 2003). Expert teachers also possess knowledge of learners and learning–an understanding of the students they work with, how they learn, and how that learning can be assessed (Bransford, Brown, & Cocking, 2000; Borko & Putnam, 1996). Knowledge of learners and learning is “. . .

arguably the most important knowledge a teacher can have" (Borko & Putnam, 1996, p. 675), because it focuses on how to help students during the complex process of learning.

The second way experts reduce cognitive load and accommodate the limitations of working memory is to develop as much of their procedural knowledge as possible to the point of automaticity, which is defined as the ability to perform mental operations with little awareness or conscious effort (Bruning et al., 2004; Schneider & Shiffrin 1977).

Policy Implications for Preparing Expert Teachers

On the surface, it would appear that the development of expert teachers is a straightforward process—learning experiences should be designed that help teachers acquire the knowledge of content, pedagogical content knowledge, general pedagogical knowledge, and knowledge of learners and learning that leads to expertise. Research indicates, however, that acquiring expertise is a lengthy and demanding process (Bruning et al., 2004), and many teachers never reach the level of expert (Berliner, 1988). This helps us understand why so many students go through teacher preparation programs and then quickly revert back to simplified instructional processes once they are out in the field (Borko & Putnam, 1996; Shuell, 1996). As indicated earlier in this paper, lecture has historically been, and continues to be, the most common form of instruction that exists in schools in this country (Cuban, 1993). This tendency can best be explained with cognitive load theory; teacher preparation programs have not adequately taken the cognitive load associated with effective teaching into account in teacher preparation programs.

If the patterns of instruction that have endured for so long are going to be changed, teacher preparation programs must help preservice teachers acquire the knowledge and skills necessary to reduce cognitive load, and program policies must be put into place that ensure, to the extent possible, that these elements then exist in the preparation programs. Reduced cognitive load then leaves teachers with working memory space that can be used to respond to the unpredictable events that inevitably occur during instruction. The following includes some of the suggested policy implications elements that a program should include to reduce cognitive load. Each is grounded in research that supports its inclusion.

Emphasis on clear and focused learning objectives (Bransford et al., 2000). Interestingly, teachers often conduct instructional activities without having clear learning objectives in mind (Good & Brophy, 2003; Zahorik, 1996). When teachers are clear about their learning objectives, cognitive load is reduced in at least two ways. First, the learning objectives guide teachers' thinking about the most effective ways to represent topics during the planning phase of instruction and how to sequence those representations, and second, having clear objectives in mind simplifies decisions about questioning and guiding students' developing understanding as they conduct the lesson. Making planning systematic and simplifying the conduct of the lesson reduces cognitive load. Further, clear learning objectives are completely consistent with constructivist approaches to instruction (Eggen & Kauchak, 2006; Ormrod, 2006), and they do not imply an authoritarian view of teaching and learning (Bransford et al., 2000; Shuell, 1996).

Emphasis on aligned instruction. Instructional alignment describes the match between learning objectives, learning activities, and assessments and it is essential for promoting learning (Anderson & Krathwohl, 2001). "Without this alignment it is difficult to know what is being learned. Students may be learning valuable information, but one cannot tell unless there is alignment between what they are learning and the assessment of that learning.

Similarly students may be learning things that others don't value unless curricula and assessments are aligned with . . . learning goals" (Bransford et al, 2000, pp. 151-152). When teachers have carefully thought about their learning objectives, the learning activities that are designed to help students reach the objectives, and assessments designed to determine the extent to which the objectives have been met, the thinking that occurs during learning activities is simplified and cognitive load is reduced.

Emphasis on high quality examples and other representations of content. Effective teachers develop instructional episodes around the representations of content they provide students, which reflects their pedagogical content knowledge (Cassady, 1999; Shuell, 1996; Eggen, 2006). Selecting representations of content that help learners reach learning objectives help ensure instructional alignment, which simplifies the instructional process and reduces cognitive load.

Focus on classroom organization with particular emphasis on automatized routines. Research indicates that experts in every field convert as many of their procedures as possible to automatic routines (Bransford et al., 2000; Bruning et al., 2004). Expert teachers, and particularly those in elementary schools, have their students literally practice procedures to the point of automaticity (Emmer et al., 2003; Evertson et al., 2003), which means the teachers need spend virtually no time or cognitive energy on monitoring students to ensure that they follow the procedures. This decreases cognitive load significantly.

Development of essential teaching skills, such as clear communication, skilled questioning, providing feedback and conducting effective reviews, to the point of automaticity. Questioning, for example, is arguably the most important tool teachers have for helping students build understanding (Olson & Clough, 2004). The process of generating and asking questions and responding to student answers can impose a heavy cognitive load on teachers, so heavy that they are likely to revert to "telling" instead of "asking" if questioning skills have not been developed, essentially to the point of automaticity. This is particularly important when teachers are now increasingly being asked to guide learning rather than simply deliver information (Leinhardt & Steele, 2005).

Importance of the Policy Implications

As learning processes become better understood, educational leaders now increasingly emphasize that learners at all levels should be provided with fewer topics that are developed in depth rather that a wider array of topics presented more superficially (Anderson, 2005; Schunk, 2004). This also applies to the learning experiences provided for preservice teachers. Historically, preservice teachers are provided with a wide array of topics, and the topics are covered somewhat superficially. Instead of the complex and well-integrated schemas and automatized procedural knowledge that experts possess, many teachers begin their careers with knowledge that is essentially inert, and skills that are yet rudimentary. Then, to reduce the cognitive load associated with instruction, they revert to simplified instructional strategies and learning activities that maximize classroom control (Duke, 2000).

As an alternative these learning experiences need to be narrowed, deepened, and designed with their impact on cognitive load in mind. If learning experiences can help preservice teachers acquire the knowledge and skills that can reduce the cognitive load that instructional complexity imposes, the likelihood of teachers using more sophisticated teaching strategies will be increased.

References

Anderson, J. R. (2005). *Cognitive psychology and its implications* (6th ed.). New York: Worth.

Anderson, L., & Krathwohl, D. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Addison Wesley Longman.

Berliner, D. (1988, February). The development of expertise in pedagogy. Paper presented at the annual meeting of the American Association of Colleges for Teacher Education, New Orleans, Louisiana.

Bransford, J., Brown, A., & Cocking, R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academy Press.

Bransford, J., Darling-Hammond, L., & LePage, P. (2005). Introduction. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 1–39). San Francisco: Jossey-Bass/Wiley.

Bruning, R., Schraw, G., Norby, M., & Ronning, R. (2004). *Cognitive psychology and instruction* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

Calderhead, J. (1996). Teachers: Beliefs and knowledge. In D. Berliner & R. Calfee (Eds.), Handbook of educational psychology (pp. 709B725). New York: Macmillan.

Cassady, J. (1999, April). *The effects of examples as elaboration in text on memory and learning*. Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada.

Chandler, P., & Sweller, J. (1990). Cognitive loead theory and the format of instruction. *Cognition and Instruction, 8,* 293-332.

Darling-Hammond, L., & Baratz-Snowdon, J. (Eds.). (2005). *A good teacher in every classroom: Preparing the highly qualified teachers our children deserve*. San Francisco: Jossey-Bass/Wiley.

Duke, N. (2000). For the rich it's richer: Print experience and environments offered to children in very low- and very high-socioeconomic status first-grade classrooms. *American Educational Research Journal, 37*, 441–478.

Eggen, P. (1998, March). *A comparison of inner-city middle school teachers' classroom practices and their expressed beliefs about learning and effective instruction.* Paper presented at the annual meeting of the American Educational Research Association, San Diego.

Eggen, P. (2001, April). *Constructivism and the architecture of cognition: Implications for instruction.* Paper presented at the annual meeting of the American Educational Research Association, Seattle.

Eggen, P. (2006, April). *Interpretations of Constructivism: Clarifying Issues and Implications for Instruction.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Emmer, E., Evertson, C., & Worsham, M. (2003). *Classroom management for secondary teachers* (6th ed.). Boston: Allyn & Bacon.

Evertson, C., Emmer, E., & Worsham, M. (2003). *Classroom management for elementary teachers* (6th ed.). Boston: Allyn & Bacon.

Good, T., & Brophy, J. (2003). *Looking in classrooms* (9th ed.). Boston: Allyn and Bacon.

Leinhardt, G., & Steele, M. (2005). Seeing the complexity of standing to the side: Instructional dialogues. *Cognition and Instruction, 23*(1), 87–163.

Mayer, R., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages? *Journal of Educational Psychology, 93,* 390-397.

Mayer, R., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. In R. Bruning, C. Horn, & L Pytlikzillig (Eds.), *Web-based learning: What do we know? Where do we go?* (pp. 23-44). Greenwich, CN: Information Age.

Olson, J., & Clough, M. (2004). *What questions do you have? In defense of general questions: A response to Croom*. ID=11366. Retrieved August 20, 2004, from http://www.tcrecord.org/ content.asp?content

Ormrod, J. E. (2006). *Educational psychology: Developing learnings* (5th ed.). Upper Saddle River, NJ: Pearson.

Paas, F., Renkl, A., & Sweller, J. (2004). Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture. *Instructional Science, 32*(1), 1–8.

Schneider, W., & Shiffrin, R. (1977). Controlled and automatic human information processing: Detection, search, and attention. *Psychological Review, 84,* 1–66.

Schunk, D. (2004). *Learning theories: An educational perspective* (4th ed.). Upper Saddle River, NJ: Merrill/Prentice Hall.

Shuell, T. (1996). Teaching and learning in a classroom context. In D. Berliner & R. Calfee (Eds.), Handbook of educational psychology (pp. 726B764). New York: Macmillan.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14.

Sweller, J., van Merrienboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10,* 251–296.

Zahorik, J. (1996). Elementary and secondary teachers' reports of how they make learning interesting. *The Elementary School Journal, 96*(5), 551–564.