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Cognitive Load and Classroom Teaching: The Double-Edged Sword of Automaticity

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Research in the development of teacher cognition and teaching performance in K–12 classrooms has identified consistent challenges and patterns of behavior that are congruent with the predictions of dual-process models of cognition. However, cognitive models of information processing are not often used to synthesize these results. This article reviews findings from the research on teaching and teacher education through the lens of a dual-process model and emphasizes the role that cognitive load plays in driving teaching performance. Data reflecting the salience of automaticity and its relationship with cognitive overload are highlighted, and implications for teacher preparation and inservice training strategies are discussed. Specific suggestions for teacher training draw on empirical findings from cognitive approaches to training that emphasize the development of automaticity in teaching skills to minimize extraneous cognitive load and maximize effective performance.

Feeling overwhelmed by the amount of simultaneous activity in a classroom is a common experience for novice teachers (e.g., Carre, 1993; Corcoran, 1981; Kagan, 1992; Olson & Osborne, 1991; Veenman, 1984; Wideen, Mayer-Smith, & Moon, 1998). The attempt to attend to the needs and behaviors of an entire classroom while also trying to remember and implement a lesson plan inundates their available cognitive resources. Therefore, this cognitive overload limits the abilities of novice teachers to adapt effectively to complex classroom dynamics (Doyle, 1986).

Cognitive overload occurs when the total processing demands of external stimuli and internal cognitions exceed available attentional resources (Sweller, 1989). When conscious mental operations occur, they occupy some portion of limited working memory and constrain the attention available for other cognitive activities. Thus, levels of cognitive load significantly affect both learning and performance in authentic contexts (e.g., Goldinger, Kleider, Azuma, & Beike, 2003; Sweller, 1988; Sweller, van Merriënboer, & Paas, 1998).

This article analyzes a broad cross-section of empirical findings from studies of teaching through the lens of the dual-process model of cognition to demonstrate the utility of a cognitive theoretical framework for understanding teacher training and performance. A primary aspect of this model is cognitive load's modulation of the functional dynamic between deliberate (i.e., conscious) and automatic (i.e., nonconscious) processing. Following a discussion of the effects of cognitive load on general cognition and behavior, this perspective frames empirical findings from research on teaching and teacher education as manifestations of the same effects. Drawing on the compatibility of the findings in these distinct bodies of literature to advocate this hypothesis, the article concludes by discussing implications for preparing preservice teachers and interpreting the classroom behavior of teachers by applying training principles that address the development of automaticity for complex skills (Rogers, Maurer, Salas, & Fisk, 1997; van Merriënboer, Kirschner, & Kester, 2003; van Merriënboer, Kester, & Paas, 2006).

THE DUAL-PROCESS MODEL OF COGNITION

During the last century, both behaviorists and cognitive scientists have provided evidence that many mental and behavioral processes take place without conscious deliberation (Wegner, 2002). The dual-process model of cognition indicates that controlled and automatic processes operate independently but intersect at certain points to produce human performance (Bargh & Chartrand, 1999; Barrett, Tugade, & Engle, 2004; Devine & Monteith, 1999; Schneider & Chein, 2003; Sun, Slusarz, & Terry, 2005). The mental events available for conscious manipulation and control occur in working memory, function more slowly, and require more effort than

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other processes. Because the processing capacity of working memory is severely limited (Cowan, 2000; Miller, 1956), excessive cognitive load can prevent fully conscious, deliberate reasoning by forcing some goals to be either neglected or pursued predominantly through nonconscious mechanisms (Bargh, 2000).

In short, dual-process theories of cognition assert that information processing occurs simultaneously on parallel pathways. The controlled pathway generates conscious, slow, and effortful processing of perceptual and semantic information that tends to represent accurately instance-specific information. In contrast, the automatic pathway generates fast, effortless, nonconscious processing through pattern recognition-based processes that rely on heuristics and generalized and stereotypic schematic representations (Schneider & Shiffrin, 1977; Sloman, 2002). When the two pathways generate conflicting outcomes (e.g., the Stroop effect; Stroop, 1935), performance slows while the conflict is consciously mediated in working memory (Botvinick, Cohen, & Carter, 2004). However, if the demands on conscious processing exceed working memory capacity, cognition generated by the nonconscious pathway will manifest without the full benefit of conscious monitoring or modification (Beilock & Carr, 2001; Beilock, Wierenga, & Carr, 2002; Brown & Bennett, 2002; J. W. Payne, Bettman, & Johnson, 1993; Rieskamp & Hoffrage, 1999). To mitigate the limitations of working memory span on controlled reasoning, people frequently rely on "fast and frugal" reasoning strategies that reduce the quantity of simultaneous information necessary to be attended to through interactions with automatic processes (Gigerenzer, Czerlinski, & Martignon, 2002, p. 559). Such adaptations may either help or hinder performance. They may help because they permit other, task-relevant cognitive processing to occur. However, they may also hinder performance by limiting conscious monitoring that might otherwise detect and correct performance errors.

Historical Assumptions of Bounded Rationality in Teaching and the Dual-Process Model

Research on teaching and teacher education has predominantly grappled with the implications of humans' limited capacity for consciously mediated cognition by restricting its focus to the *bounded rationality* (Simon, 1957) of teachers' beliefs, intentions, and reflections (O. Lee & Porter, 1990; Rhine, 1998). The logic underlying this approach emerged from the early research on teachers' cognition (e.g., C. M. Clark, 1978–79; National Institute of Education, 1975; Shavelson, 1973, 1976; Shulman & Elstein, 1975) and shaped the course of future research in the area (House, 1996; Rhine, 1998). The perspective was best articulated by Shavelson and Stern (1981) in their seminal review of this literature:

> This assumption of rationality actually refers to teachers' intentions for their judgments and decisions rather than to their behavior for at least two reasons. . . . The first, most obvious reason is that some teaching situations call for immediate rather than reflective responses that probably preclude rational processing of information in making an informed judgment or decision. The second reason is that the capacity of the human mind for formulating and solving complex problems such as those presented in teaching is very small compared to the enormity of some "ideal" model of rationality (i.e., some *normative* model). In order to handle this complexity, a person constructs a simplified model of the real situation. The teacher, then, behaves rationally with respect to the simplified model of reality constructed. This conception of teachers with "bounded rationality," that is, rational within the constraints of their information processing capabilities, leads to a modification of the first assumption: Teachers behave *reasonably* in making judgments and decisions in an uncertain, complex environment. . . .
>
> The second assumption is that a teacher's behavior is guided by his thoughts, judgments, and decisions. If this is not true, "then teachers are automata of some kind" (Fenstermacher, 1980, p. 36). Hence the question of the relationship between thought and action in teaching becomes crucial yet problematic. . . . Fortunately or unfortunately, researchers studying teachers' thoughts, judgments, decisions and behavior do not have . . . an easy out because in order to understand teaching, we must understand how thoughts get carried into actions. (pp. 456–457)

This discussion embodies several common assumptions about research in this field that have shaped relevant studies to date. First, it acknowledges bounded rationality in human thought, but it asserts that teachers behave reasonably in relation to the beliefs they hold and the models of classroom situations they construct. In other words, their *intended* actions are rational in relation to their *consciously available* representations of teaching situations. However, their resulting behaviors may not appear rational if their beliefs and mental models are not accurate in their current situation. Second, Shavelson and Stern's (1981) commentary implies that theories which posit nonconscious decision making by teachers as an explanatory mechanism are unacceptable, because they position teachers as "automata" (Fenstermacher, 1980, p. 36). Further, they asserted that it is necessary to account for how (consciously-held) thoughts "get carried into actions" (Shavelson & Stern, 1981, p. 457).

Over the past 25 years, these two assumptions have functioned to restrict cognitively oriented inquiry in research on teaching to methods that rely on the verbal self-reports of teachers' decision-making processes. Shavelson and Stern (1981) identified six major, nonexperimental empirical methods for investigating teachers' classroom decision making that were prevalent at the time of their article: policy capturing, lens modeling, process tracing, stimulated recall, case study, and ethnography. These techniques continue to represent the dominant methods currently in use (e.g., Schoenfeld, 1998; Udvari-Solner, 1996; Winther, Volk, & Shrock, 2002). However, each of these techniques restricts the consideration of data to verbally reportable thoughts that represent the prospective, hypothetical, or post hoc reasoning of teachers about their (observed or unobserved) decision-making practices (Kagan, 1990). Thus, researchers have examined only a subset of teachers' cognitive activities utilizing data that often suffer from validity problems (Ericsson & Simon, 1993; Feldon, 2007; Nisbett & Wilson, 1977).

Evaluating data drawn exclusively from knowledge and beliefs that are consciously held precludes examinations of the full cognitive mechanism. Therefore, it is unsurprising that this research has failed to find robust outcomes linking teacher cognition to teaching performance (e.g., Mellado, 1998; Simmons et al., 1999).

The identification and experimental validation of actual cognitive mechanisms that drive teaching performance (e.g., the successful implementation of particular practices) has not been an active area of research (Spillane, Reiser, & Reimer, 2002; Zeichner & Conklin, 2005).[1] Simon's (1957) initial discussion of bounded rationality treats human reasoning's limited conscious information-processing capacity as fixed and independent of nonconscious or nonrational cognition. However, current perspectives suggest that the locations of the boundaries between conscious and nonconscious cognition are neither rigidly defined nor independent of environmental influences (e.g., Ericsson & Kintsch, 1995; Ericsson, Krampe, & Tesch-Römer, 1993; Fischer, Bullock, Rotenberg, & Raya, 1993; Fisk & Rogers, 1988; J. W. Payne et al., 1993; Rieskamp & Hoffrage, 1999; also see O. Lee & Porter, 1990). Therefore, the extent of conscious decision making is dynamically determined through interactions with other aspects of cognitive information processing. Sidestepping the theoretical and empirical challenges of examining the interactions between conscious and nonconscious processes in teaching has precluded the application of recent advances in psychological science to studies of teacher cognition and the continued improvement of effectiveness in teacher preparation.

Recent investigations into the interplay between these processes—particularly as a function of the demands placed on working memory—in domains other than teaching identify both specific mechanisms of cognition (Smith & DeCoster, 2000) and direct implications for training people to work effectively under high levels of complexity, stress, and uncertainty (van Merriënboer, 1997; van Merriënboer & Kirschner, 2007). Given the pervasive nature of uncertainty in teaching (Helsing, in press) and the tremendous interactional complexity of the classroom (Doyle, 1977; Jackson, 1968), it is valuable to revisit the relationship between cognitive conceptual frameworks and studies of teaching.[2]

COGNITIVE LOAD

Cognitive load is an index of mental effort that represents "the number of non-automatic elaborations [in working memory] necessary to solve a problem" (Salomon, 1984, p. 648). As skills become less effortful with practice, they move toward automaticity and impose less cognitive load (J. R. Anderson, 1995). Similarly, as schemas become more elaborate and integrate more declarative knowledge into a single representation (i.e., chunk), they occupy less capacity in working memory (Sweller, 1988). Consequently, novices attempting to solve a problem typically endure high cognitive load because they lack the experience and conceptual framework that make cognitive processing more efficient. In contrast, those with more experience typically need to invest less effort when performing the same activity and achieving an equivalent outcome (Camp, Paas, Rikers, & van Merriënboer, 2001).

Experts in various domains have demonstrated the reduced cognitive load necessary for their skilled performances relative to novices in the domain by maintaining high levels of performance despite additional load imposed by simultaneous secondary memory and concentration tasks (e.g., R. Allen, McGeorge, Pearson, & Milne, 2004; Beilock et al., 2002; Rowe & McKenna, 2001). Typical studies of this phenomenon require participants to perform a distraction task like evaluating or remembering sequences of random numbers while performing a typical task within their domain of expertise. Although the performance of nonexperts deteriorates (e.g., slower task performance, increased error rates, etc.), expert performance remains unaffected (e.g., R. Allen et al., 2004). The automated knowledge of experts occupies very little space in working memory, which allows for allocation of more resources to other cognitive activities (Brown & Bennett, 2002; Bruenken, Plass, & Leutner, 2003).

Types of Cognitive Load

Many surface-level features of learning environments and problem-solving activities can redirect cognitive resources from the primary objectives of tasks to other, less relevant goals (Sweller, 1988, 1989, 1999; Sweller et al., 1998). This reallocation of mental resources imposes "extraneous" cognitive load on the individual, inherently leaving less space in working memory available for manipulating information to achieve intended outcomes (Chandler & Sweller, 1991; Sweller, Chandler, Tierney, & Cooper, 1990).

Sweller (1999; Chandler & Sweller, 1991) distinguished three categories of cognitive load based on the properties of the tasks performed: *intrinsic* load, *extraneous* load, and *germane* load. Intrinsic cognitive load represents the burden to working memory inherent in the semantic content required

[1]For a discussion of political and philosophical conflicts surrounding this issue, see Kagan (1990).

[2]Although other reviews of research on teaching identify categorical distinctions between specific types of teacher cognition (e.g., comprehension, transformation, adaptation, instruction, evaluation, reflection, and new comprehensions; Shulman, 1987a), this article makes a broader argument about the role of the cognitive dual-process model in teaching. Therefore, it does not delineate subcategories of cognition.

for a particular task. In a teaching context, this includes the content knowledge to be taught in a lesson and the pedagogy itself, because the lesson cannot occur without these elements. In contrast, extraneous load represents unnecessary structural or semantic content that occupies space in working memory (i.e., an external or internal distraction). For example, a teacher may allocate attention during a lesson to irrelevant events, such as the arrival of a visitor or noise heard through the wall from a neighboring classroom. Germane load is the minimum level of cognitive load necessary for effective instruction (intrinsic load plus unavoidable extraneous load imposed by pertinent situational constraints). Examples of germane load in an interactive teaching situation may include (but are not limited to) the intrinsic load of the content and pedagogy, plus awareness of students' prior knowledge of the topic, assessment of verbal and nonverbal cues indicating their level of comprehension, and monitoring students' level of attention to the lesson. Any cognitive load processed that is not germane to the target task inherently deprives the individual of cognitive resources that could benefit target performance. In other words, attention given to irrelevant information (i.e., extraneous load) curtails the amount of working memory space that otherwise could be allocated to processing germane elements.

Because teaching is inherently a dynamic activity that requires the adaptive use of different information as circumstances change, intrinsic load in one situation may become extraneous in another. For example, investing effort in preparing for a parent–teacher conference represents germane load during time that is reserved for that purpose. However, the same thoughts impose extraneous load when other, more immediate teaching tasks require attention. Thus, situation-specific details contextually determine the extent to which particular cognitive activities are germane. In addition, as teachers acquire increased expertise in the classroom, they develop more elaborate schemas to process information efficiently and their actions require less mental effort to formulate and execute (Bereiter & Scardamalia, 1993; Berliner, 1986, 1988; Ericsson & Kintsch, 1995; Gobet, 1998; Sternberg & Horvath, 1995; Sweller, 1999). Therefore, teachers may demonstrate differential abilities to process information relevant to pedagogical tasks and may be able to process different amounts of extraneous load without experiencing a detriment to their performance.

Automaticity

Mental operations that process information with little or no conscious awareness (i.e., impose little or no cognitive load) represent automaticity. The characteristics of automaticity are that it (a) occurs without intention (or continues to completion without effort); (b) is not subject to conscious monitoring; (c) utilizes few, if any, attentional resources; and (d) happens rapidly (Moors & De Houwer, 2006; Wheatley & Wegner, 2001). Routines for specific tasks within a domain of expertise become highly reliable and require less concentration to perform as individuals practice their skills (J. R. Anderson, 1995).[3] Therefore, they impose little or no cognitive load in working memory. Leinhardt and Greeno (1986) described such routines in their comparative classroom study of expert and novice mathematics teachers. They found that experienced teachers more consistently executed effective instructional and classroom management routines with "little or no monitoring of execution" (p. 94). Further, the automated routines and effectively structured teaching schemas of experienced teachers imposed low levels of cognitive load, which "provide[d] them with the intellectual and temporal room necessary to handle the dynamic portions of the lesson" (p. 94). In contrast, novices performed in a slower and more effortful way that limited the dynamic allocation of mental resources. Vasquez-Levy (1998) similarly found that experienced teachers implement pedagogical scripts requiring "little explicit deliberation or forethought" (p. 537).

The consistent, repeated mapping of stimuli to responses leads to the acquisition of automaticity (Schneider & Shiffrin, 1977). Extensive practice results in the gradual elimination of conscious intermediate decision points during skill performance (Blessing & Anderson, 1996)[4] However, automated inferential processes such as situational assessment and attribution can develop implicitly without the focused effort typically required of advanced skill acquisition (Bargh & Chartrand, 1999; Cary & Reder, 2002).

Recent evidence indicates that many processes traditionally considered to be under full conscious control may also occur automatically under certain circumstances (e.g., Bargh, 2000; Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001; Wegner, 2002). As automaticity accompanies expertise, highly principled representations of domain knowledge generate fast, effortless performance. However, the procedures themselves become more ingrained and extremely difficult to change. They can automate to the extent that both goals and processes will sometimes activate without awareness or intent (Aarts & Dijksterhuis, 2000, 2003; Bargh & Ferguson, 2000). Once a skill automates, it no longer operates in a way that is available to conscious monitoring. Further, it runs to completion without interruption, which limits the ability to modify performance (Wheatley & Wegner, 2001).

For example, Doyle and Redwine (1974) found that regardless of the intent of experienced teachers to change their teaching behaviors from one lesson to another, they were unable to do so. In that study, 36 junior high school

[3]In the current article, highly experienced teachers are assumed to be experts to include the greatest proportion of relevant empirical literature. However, see Palmer, Stough, Burdenski, and Gonzales (2005) for an extensive discussion of alternative conceptions of teacher expertise.

[4]It should be noted that complex skills typically do not become fully automated. Frequently, individual subprocesses of the overall skill set will evidence automaticity, but the products of those subprocesses will be integrated under conscious control (for a more extensive discussion, see Feldon, 2007).

teachers with professional experience averaging 7.25 years taught two consecutive lessons to small groups of randomly selected students in a microteaching-style laboratory classroom. The day prior to the lessons, they were asked to write down their planned time allocation for intended teaching behaviors during the lesson. After the teachers taught their first lessons, they received (manipulated) feedback on their behaviors indicating either a high or low level of discrepancy with their predictions of the previous day. They were also told that their students' performance on posttests of the material in the lesson was very high or very low. Prior to teaching a second lesson with a new set of students, participants again wrote down their intended time allotments and teaching behaviors for the next teaching opportunity. Observations of their teaching indicated that, regardless of their level of intent to teach differently in the second lesson, the teachers' pedagogical behaviors did not differ significantly between the lessons. Thus, the pedagogical practices they had acquired over their years of professional experience evidenced qualities of automaticity. Their behaviors were highly consistent and resisted effective self-monitoring, despite consciously held goals to act differently between one lesson and the next.

The Role of Cognitive Load in the Dual-Process Model

When individuals process high levels of cognitive load, they are less able to dedicate working memory resources to mental processes that usually entail both conscious and nonconscious processing. Consequently, dual-process cognitions like situation assessment and attribution may rely almost entirely on their nonconscious components in such situations and operate without conscious monitoring (Bargh & Chartrand, 1999; Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Thompson et al., 2004). When these automated schemas yield optimal performance without conscious monitoring, the quality of performance improves when working memory is occupied by other tasks (e.g., Beilock & Carr, 2001; Beilock, Kulp, Holt, & Carr, 2004; Gray, 2004). However, these representations may also be stereotypic schemas that incorporate irrelevant or insufficient information. When working memory is not occupied with other tasks, conscious monitoring either prevents the inappropriate application of these schemas or adapts them to align with individual circumstances.

For example, study participants assigned levels of blame to two individuals involved in a hypothetical automobile accident. Only one of the people involved in the accident was at fault (he did not stop at a stop sign). However, additional details suggested that the victim had negative personality traits. These traits were unrelated to the cause of the accident. When the participants considered the scenario without distraction, they assigned blame to the perpetrator of the accident and disregarded the victim's negative character traits. However, when presented with these facts while performing working memory tasks, participants were significantly more likely to assign blame to the victim (Goldinger et al., 2003).

Similarly, Blair and Banaji (1996) found that extraneous cognitive load led to a higher frequency of biased responses during sentence completion tasks. Participants who responded to ethnically identified stimuli were significantly more likely to supply racially biased and stereotypical information unintentionally when completing sentence stems. Further, Park and Jang (2003) found that when events occur while an observer is under high cognitive load, later recall attempts generate a significantly higher rate of false recollections than occur for participants who observe the same stimuli without the extraneous load. In other words, individuals processing extraneous cognitive load while interpreting events tend to form more stereotypical evaluations than they would with the benefit of additional conscious monitoring (Chapman & Johnson, 2002; Devine & Monteith, 1999).

In classroom settings, teachers continually assess the responses of their students in a variety of ways. In addition to evaluating the extent to which students have acquired specific knowledge through observation and questioning, teachers also respond to nonverbal cues that communicate students' motivation, emotional states, and other pertinent social information (Webb, Diana, Luft, Brooks, & Brennan, 1997). However, dual-processing mechanisms of interpretation lead to biased inferences when teachers do not allocate sufficient conscious resources to the process (Greenwald & Banaji, 1995; Macrae, Hewstone, & Griffiths, 1993). Studies of racial bias consistently find that elevated levels of extraneous cognitive load and speeded time constraints increase the level of bias in participant responses, regardless of the articulated beliefs or intentions of their participants (e.g., Blair & Banaji, 1996; Devine, 1989; Devine, Plant, Amodio, Harmon-Jones, & Vance, 2002; Fazio, Jackson, Dunton, & Williams, 1995; B. K. Payne, Lambert, & Jacoby, 2002; Wegner, 1994).

A number of studies on the biases of teachers in the classroom have indicated that stereotyping occurs with some frequency (Ritts, Patterson, & Tubbs, 1992). For example, studies of the Pygmalion effect or self-confirming bias indicate that teachers' preconceptions of student traits and abilities are better predictors of subsequent evaluations than actual classroom performance (Good & Nichols, 2001; Rosenthal, 2002). Other biases, including those related to physical attractiveness, have the same effects (Bessenoff & Sherman, 2000). In a meta-analysis of studies examining the biases of teachers regarding attractive students, Ritts and colleagues (1992) concluded that, overall, attractiveness had a moderate effect ($d = .41$) on teachers' assessments of students. Measures specific to academic outcomes (e.g., intelligence, future academic performance, etc.) generated an effect size of .36.

Babad (1985) found that teachers' years of experience reduced the magnitude of expectancy bias. Teachers with 9 or more years of experience did not demonstrate an expectancy bias at a statistically significant level when grading work by students who were arbitrarily labeled as high or low achieving. However, teachers with 8 or fewer years of experience did demonstrate a significant level of expectancy bias. Within the dual-process framework, teachers with greater amounts of practice in grading assignments (i.e., the senior group) were more likely to have evaluation procedures that were resistant to interference, because their procedures had become more automated and therefore imposed less cognitive load. Their higher levels of automaticity would also have limited the number of consciously mediated decision points during which expectancy could play a role. In contrast, novice teachers probably used less automated evaluation mechanisms. Consequently, they would have required greater mental effort to assess the student work and increased the likelihood of interference by nonconscious expectancy biases.

Unintended Actions through Cognitive Default

Cognitive defaults represent instances when cognitive load not only prevents the modification of generalized schemas but also causes active substitutions of intended actions with those that are less effortful (R. E. Clark, 2001; Ohlsson, 1996; Sweller, 1989). According to R. E. Clark (2001), "when working memory is exceeded, the more recently learned (and presumably more effective and less destructive) strategies will be inhibited in favor of the older (childish?) and more automatic and destructive alternatives" (p. 274).

For example, a teacher might intend to respond to a classroom disciplinary problem using a democratic induction strategy advocated in a preservice or inservice training session (e.g., Kohn, 1996). However, under the high levels of cognitive load imposed by the classroom environment, a more practiced, authority-based response might be used instead (e.g., Canter & Canter, 1992).

Overall, there is a relative paucity of empirical analysis on performance errors in teaching (Leinwand, 1998; Schmidt & Knowles, 1995). Although recent work has begun to focus on "bumpy moments" (Romano, 2004, p. 663) and teachers' subsequent reflections upon them (Romano, 2004, 2006), the emphasis has remained primarily in retrospective sense making rather than in investigations of factors that influence the occurrence of such problems (Copeland, Birmingham, De La Cruz, & Lewin, 1993).

In the teaching and teacher education literature, some studies examining the performance errors of teachers describe novice teachers who revert to pretraining models of teaching once working independently in the classroom (e.g., Nettle, 1998; Rich, 1990). These reports are consistent with cognitive default phenomena. However, analysis of this data has not previously utilized a cognitive framework.

Lortie (1975) argues that the beliefs of beginning teachers are grounded in an "apprenticeship of observation" based on heavily reinforced ideas of teaching that they acquire during their own schooling experiences. As individuals' experiences with classroom environments and teaching behaviors reinforce certain schemas representing teaching and the classroom environment, those beliefs provide a framework for the interpretation of events and the formulation of responses (Calderhead & Robson, 1991; Kunda & Thagard, 1996; Nespor, 1987; Pajares, 1992). Consequently, it is difficult to change these ideas during preservice training, and new teachers tend to revert to more familiar patterns of behavior in the classroom.

The cognitive default hypothesis similarly suggests that teachers' older, more reinforced knowledge is more likely to be used under the cognitive load imposed by an actual classroom, because it is less effortful than newer knowledge. Therefore, the actions of new teachers are likely to default to the manner in which they were taught rather than the way they were trained. Torff's (1999) discussion of teachers' knowledge use indicates that this phenomenon is common: "Folk conceptions [of pedagogy] function as a largely tacit 'default mode' for teachers' reasoning about education. . . . Competition between folk and expert pedagogies emerges, and temporary or permanent shifts to the default mode seem difficult to resist" (p. 205).

Leinwand (1998) provided a generalized example of this phenomenon in the classroom: "We have learned that when a principal or supervisor is in the room, we significantly increase the likelihood of an additional mistake" (p. 331). In these instances, teachers' awareness of the supervisor's presence imposes extraneous cognitive load, diminishing the available working memory capacity available to handle cognitive processing germane to instruction.

Simmons and colleagues (1999) likewise documented extensive evidence of unintended teaching actions by novices in a longitudinal study of 116 science and mathematics teachers during their first 3 years in middle and secondary school classrooms. They found that the behavior of novices consistently reflected actions that directly conflicted with their beliefs about their own teaching styles. The participants commonly reported that their teaching actions were student centered in the first 2 years of the study. However, review of the observation videotapes indicated that most participants reverted to teacher-centered actions during lessons. Further, the participants neither discovered nor reconciled the discrepancy between their self-beliefs and their actions. Thus, the combined levels of extraneous and germane cognitive load imposed during teaching generated unintended cognitive defaults to less effortful practices.

In an unpublished account, a teacher educator provided an extreme example of a cognitive default by a credential candidate in her program:

> It was a frustrating day; everything had been going wrong for Bob [a pseudonym]. The children were hyper, his plans weren't going well, and one little boy in particular was giving him an especially difficult time, testing Bob's patience with

> his offhand, unnecessary comments and disobedience. At the very end of the day, Bob asked all of the students to turn off their computers, and little Johnny [a pseudonym] just had to turn his on once again. As he was walking by to go to his own classroom, Bob said to him, "You really need to listen better," and gave him a little swat on the behind.... Bob immediately realized the inappropriateness of what he had done, and sought to correct it... Bob was very penitent and acknowledged that he had committed a grave error. (Wertz, 2003, pp. 5–6)

"Bob" knew both before and after the event that corporal punishment was unacceptable. However, in the stress (i.e., high cognitive load) of the moment, he defaulted to a less effortful solution that reflected his prior experiences with discipline.

Ironic Mental Processes

Excessive attempts to control mental events can also cause cognitive defaults. In these instances, the effort invested in preventing a thought or action ironically increases the likelihood that the undesired event will occur (Wegner, 1994, 1997). Wegner's model specifies the role of both conscious and automatic processes in mental control efforts. The conscious component (i.e., the operating process) attends to and effortfully modifies undesired thoughts or actions when they are noticed. Therefore, high levels of extraneous cognitive load interfere with the operating process by depriving it of working memory capacity. In contrast, the automated component (i.e., the monitoring process) continuously scans for undesirable thoughts and initiates the conscious operating process when they are detected. Cognitive load does not affect the automated monitoring process, because there is no competition for conscious processing resources, so it will consistently invoke the operating process. However, when sufficient working memory resources are unavailable, the operating process fails to modify the thought successfully. As a result, the monitoring process continues to initiate the operating process, which imposes increasing levels of cognitive load. This "feedback loop" ironically occupies the working memory space that would allow the operating process to successfully prevent the undesired thought or action from occurring. Further, it maximizes the likelihood of a cognitive default due to the high levels of cognitive load it imposes. Such cycles occur during a variety of phenomena, including depression (Wenzlaff, 1993; Wenzlaff, Wegner, & Roper, 1988), failed attempts at relaxation (Heide & Borkovec, 1983; Wegner, Broome, & Blumberg, 1997), pain control (Cioffi & Holloway, 1993), and racial prejudice (Devine et al., 2002; Monteith, Sherman, & Devine, 1998).

Considering that social justice and equity are major priorities in current teacher education programs (Zeichner, 2003), the avoidance of acting on racially prejudicial stereotypes and biases is an important goal for novice teachers. However, the deliberate attempt to suppress prejudiced thoughts and actions increases the likelihood that they will occur (Monteith et al., 1998; Wegner, 1994). Macrae, Bodenhausen, Milne, and Wheeler (1996) asked participants to listen to autobiographical narratives by members of highly stereotyped groups and later recall the information presented. The narratives contained systematically varied quantities of stereotype-consistent and stereotype-inconsistent information. When the experimenters imposed extraneous cognitive load or instructed participants to suppress stereotyping thoughts intentionally, participants recalled significantly less stereotype-inconsistent information and significantly more stereotype-consistent information. By implication, teachers may fall victim to unintended biases in two ways. First, they may invest too much mental effort in suppressing biased thoughts while teaching, which could lead to ironic processes that actually increase the frequencies of teachers' biased thoughts. Second, they could fail to recall important evaluative information about a student if it diverges from a stereotypic view of the student's demographic or social group when they process too much extraneous cognitive load.

TEACHERS' EXPERTISE AS A MEDIATOR OF COGNITIVE LOAD DURING CLASSROOM PERFORMANCE

Given the vast quantity of sensory and semantic information simultaneously available in the classroom setting and the severe restrictions on the capacity of working memory, how do teachers succeed in meeting their students' learning needs? As teachers acquire expertise through experience, they exhibit attentional behaviors similar to those of experts in other domains (for a review, see Hogan, Rabinowitz, & Craven, 2003). The extensive knowledge bases of experienced teachers include both concrete information and abstract principles for teaching, so they differentiate between relevant and irrelevant cues in classroom settings more effectively than novice teachers (R. M. Allen & Casbergue, 1997; Kagan & Tippins, 1992). As a result, experts allocate a greater proportion of their attention to germane cognitive load than to extraneous load (Berliner, 1986, 1988; Sternberg & Horvath, 1995). Further, prior knowledge functionally expands the working memories of experts because their elaborate schemas organize information more efficiently within the limited working memory store (Ericsson & Kintsch, 1995; Gobet, 1998; Gobet & Simon, 1996, 1998; Masunaga & Horn, 2000). Similarly, the automated procedures of experts for interpreting, evaluating, and responding to classroom events impose little cognitive load (Blessing & Anderson, 1996). Thus, the functional span of their working memory is significantly larger than that of nonexperts, because they process less irrelevant information, represent information more efficiently within working memory, and require fewer attentional resources to make teaching decisions. This permits them to attend effectively to more complicated classroom interactions and the uniquenesses of individual students.

Sabers, Cushing, and Berliner (1991) demonstrated the advantage of expert working memory with teachers in a laboratory study. Novice and expert participants watched three television screens that simultaneously portrayed classroom activities during a teacher-directed lesson. The study participants commented on the actions of the students and the teacher and recalled the observed events after the tape stopped. As with experts in other domains, the most experienced teachers were better able to make sense of and integrate diverse cues from the classroom. They both noticed more pedagogically significant details during the video and conveyed more principled conceptual information about the events during their subsequent recall. In contrast, novices were often unable to attend successfully to the many simultaneous activities presented on the screens. Further, novices' recall emphasized discrete, behavioral events without the more sophisticated interpretations generated by their senior colleagues.

In the classroom, this advantage of expert working memory allows expert teachers to accommodate greater complexity and adapt more effectively to unusual situations than do novices. Basic pedagogical skills, classroom management issues, and curricular content impose nearly all of the cognitive load that novices can process successfully (Borko & Livingston, 1989; Sabers et al., 1991; Swanson, O'Connor, & Cooney, 1990). Experts' automaticity in aspects of these skills permits them to allocate greater attention to subtleties and uniquenesses. For example, compared to experts, novice teachers frequently fail to consider specific individual differences between students during pedagogical decision making in the classroom (Schempp, Tan, Manross, & Fincher, 1998). They also struggle to adapt effectively when circumstances demand unexpected deviations from prepared lesson plans (Borko & Livingston, 1989; Borko & Putnum, 1996). Further, novices are less successful in interpreting and responding to the nonverbal cues of students (Webb et al., 1997) and retaining their focus on long-term instructional goals (Housner & Griffey, 1985) than are experts.

In contrast, experts respond fluently and effectively to classroom challenges (Bloom, 1986; Carter, Sabers, Cushing, Pinnegar, & Berliner, 1987). They dedicate simultaneous attention to both instruction and classroom management, so they address disruptive behaviors of students more successfully than do their novice colleagues (Swanson, O'Connor, & Cooney, 1990). Novices, however, must occupy greater proportions of their working memory with effortful use of pedagogical "scripts" or with classroom management strategies. Thus, they are less likely than expert teachers to be able to address both instructional and management issues concurrently. Therefore, they frequently perceive and respond to small subsets of relevant events in a classroom relative to experienced colleagues observing the same interactions (R. M. Allen & Casbergue, 1997; Gonzalez & Carter, 1996; Needels, 1991).

IMPLICATIONS FOR TEACHER PREPARATION

Teacher education moved away from behavioral training approaches because researchers found that a narrow focus on prescriptive routines was not effective for the complex, dynamic nature of classroom teaching—particularly with increasingly diverse groups of students (C. M. Clark, 1988; C. M. Clark & Yinger, 1977; Darling-Hammond & Snyder, 2000). Instead, teacher education programs emphasized pedagogical theory and conceptual frameworks to provide teachers with flexible knowledge that could be adapted to unique classroom situations (Floden & Buchmann, 1993; Kessels & Korthagen, 1996; Korthagen & Kessels, 1999). However, student teachers typically report that they have great difficulty converting theory into practice in their classrooms, and many experienced teachers fail to see connections between them (L. M. Anderson et al., 1995; Levine, 2006; Merseth, 1999; Veenman, 1984).

From a cognitive perspective, these findings are unsurprising, because approaches that emphasize theory may not emphasize the rehearsal of teaching skills prior to working in the classroom. Kagan's (1992) review of teacher preparation concludes that a "common theme . . . is the inadequate procedural knowledge provided to novices in university courses" (p. 142). Accordingly, Levine (2006) reports that 76% of teachers in the United States practice for no longer than one semester before going into the field. Without sufficient practice, skill automaticity does not develop (Fisk, 1989).

Because skill performance prior to proceduralization requires the compilation of individual steps from declarative knowledge in working memory, it is stilted and highly effortful (J. R. Anderson, 1987; Binder, 2003). Therefore, constructing new procedures on the fly in authentic teaching situations is problematic and precludes conscious processing of other relevant information. The elevated levels of cognitive load that result are likely to induce the cognitive defaults and biases that these programs seek to prevent. However, the graduates of programs that do offer extended and well-scaffolded practice opportunities tend to be more consistent and more effective in their teaching (Levine, 2006; Rose & Church, 1998).

The dual-process cognitive framework offers a new perspective from which to understand teaching performance. It also offers an opportunity to examine practices used to prepare new teachers. The current teacher education literature provides an extensive treatment of various methods in teacher education (e.g., Ballou & Podgursky, 2000; Cochran-Smith & Zeichner, 2005; Darling-Hammond, 2000; Feiman-Nemser, 2001; Korthagen, Loughran, & Russell, 2006; Rose & Church, 1998; Sikula, 1996; Wilson, Floden,

& Ferrini-Mundy, 2001). However, the designs and investigations of various approaches to teacher preparation typically do not consider cognitive load and automaticity. Incorporating these factors into the development of teaching skills suggests two broad goals for teacher preparation programs to accommodate the complexity of the teaching environment: maximize the working memory capacity of novices for classroom interactions to reduce cognitive defaults and stereotyping, and minimize the amount of cognitive load necessary to perform core skills effectively in the classroom, so that defaults—when they do occur—are more likely to be compatible with the training. These goals can be accomplished by facilitating the development of automaticity in effective teaching practices (R. E. Clark & Elen, 2006; Rogers et al., 1997).

Training for Automaticity

Complex tasks like teaching "have many different solutions, are ecologically valid, cannot be mastered in a single session and pose a very high load on the learner's cognitive system" (van Merriënboer et al., 2006, p. 343). Reducing levels of cognitive load through the development of automaticity would provide the benefits previously discussed. However, concerns about the ability to adapt to new or rapidly changing situations generate objections to the goal of acquiring automaticity for skills required by complex tasks. Some of the expertise literature suggests that automaticity leads to arrested skill development, because automated processes cannot be consciously monitored or easily changed (Ericsson, 1998, 2004). Consequently, if skills automate before reaching an optimal level of effectiveness for all situations, learners will be unable to perform adaptively. However, this hypothesis is not supported by empirical studies of automaticity and expertise (Feldon, 2007).

Automaticity and adaptivity. Complex skills consist of differentiable subskills (F. J. Lee & Anderson, 2001). Therefore, they do not automate as monolithic processes. Instead, components of the complex skill will automate to different extents based on the consistency of the triggering stimuli for each aspect of the overall process (J. R. Anderson, 1995; Shiffrin & Dumais, 1981). Thus, any procedure may entail either the sequential execution of automated and consciously controlled subskills or the concurrent execution of both automatic and conscious elements (Bargh & Chartrand, 1999; Cohen, Dunbar, & McClelland, 1990; Hermans, Crombez, & Eelen, 2000). Consciously mediated decision points within the overall process maintain the adaptability of the procedure, but subskills that do not require modification will continue to operate in an automated manner.

In addition, experimental evidence indicates that within limits, automated procedures do transfer adaptively across a range of stimuli (J. R. Anderson, 1987; Cooper & Sweller, 1987; Fisk, Lee, & Rogers, 1991; Fisk, Oransky, & Skedsvold, 1988; Kramer, Strayer, & Buckley, 1990; Schneider & Fisk, 1984). As long as the stimuli that induce the automated procedure maintain their structural relationships, individual features can vary without automated procedures interfering with performance.

Concerns about the rigidity of procedures that may not be effective in all situations also arise within the teacher education literature. Findings from research examining the generalizability of effective practices suggest that standardization of teaching behaviors could limit the effectiveness of teachers, because teaching routines that benefit students in one classroom may be detrimental in another (Nuthall, 1974, 2005; Shavelson & Dempsey-Atwood, 1976). For example, Nuthall (1974) found that patterns of classroom interaction that were positively associated with the achievement of students for one teacher were negatively associated with student outcomes for a teacher in a different classroom. Similarly, Heath and Nielson (1974) analyzed a series of studies that attempt to link patterns in the behaviors of teachers to student academic achievement and concluded that "the research on the relation between teacher behavior and student achievement does not offer an empirical basis for the prescription of teacher-training objectives" (p. 481). Specifically, they observe that the selection of specific target teaching behaviors disregard both *who* and *what* is being taught.

However, current conceptions of procedural knowledge differentiate between observable behaviors and the cognitive decisions that underlie them (Schraagen, Chipman, & Shute, 2000). When using cognitive task analyses to understand effective procedures, instructional designers elicit knowledge from experts to identify each point in the procedure that requires a decision to be made. Then an accurate and comprehensive set of appropriate cues to inform the decision are compiled and linked to the subskills employed on the basis of the decision made (R. E. Clark, Feldon, van Merriënboer, Yates, & Early, in press).[5] Integrating all of these components into instruction enables learners to most efficiently and effectively reach expert levels of performance (R. E. Clark & Estes, 1996; Feldon & Clark, 2006; van Merriënboer, Clark, & de Croock, 2002). If teachers are properly trained to attend to germane cues and disregard extraneous cues while teaching, they can respond appropriately on the structural basis of the classroom context (Fisk & Eggemeier, 1988; Fisk et al., 1988; Klein & Calderwood, 1991).

For example, practice lessons are frequently recorded using videotape and analyzed collaboratively by teacher candidates and their supervisors. A mentor who facilitates the reflective process effectively will draw the attention of learners to pertinent cues and explain how those cues might warrant

[5]The concept of cognitive task analysis is not new to understanding expert teachers' skills. Leinhardt (1990) offered guidelines for eliciting teachers' craft knowledge that were developed during the Carnegie Forum's Teacher Assessment Project (Shulman, 1987b). Similarly, Schoenfeld (1998) discussed the derivation of decision rules used by expert teachers.

different responses when circumstances change (Lampert & Ball, 1998; Sherin & Han, 2004; van Es & Sherin, 2002). Successful identification of these decision points coupled with a repertoire of viable alternative responses has proven to be effective basis for instruction in other complex domains requiring dynamic decision making (e.g., Crandall & Getchell-Reiter, 1993; Hoffman, Crandall, & Shadbolt, 1998; Velmahos et al., 2004).

A Model for Incorporating Automaticity Into Training

Van Merriënboer's (1997) four-component instructional design (4C/ID) system provides a concrete example of a well-developed and empirically validated approach to the training of complex skills that utilizes considerations of learners' cognitive load to structure learning tasks (R. E. Clark et al., in press; van Merriënboer & Kirschner, 2007). The premise of the system is that

> complex learning is always involved with achieving integrated sets of learning goals—multiple performance objectives. It has little to do with learning separate skills in isolation, but it is foremost dealing with learning to coordinate and integrate the separate skills that constitute real-life task performance. Thus, in complex learning the whole is clearly more than the sum of its parts because it also includes the ability to coordinate and integrate those parts. (van Merriënboer et al., 2002, p. 40)

4C/ID identifies two distinct types of subskills within a complex procedure. The first type consists of *nonrecurrent* skills that achieve a consistent goal but the decisions and actions of which may differ from one situation to the next. These skills rely on schema-based cognitive strategies and allow for performance flexibility based on conceptual understandings of the task, the context, and the domain. The second type consists of *recurrent* skills that are highly consistent between situations. These elements adhere to definable rules that link particular cues to specific decisions or actions.

In contrast to the part-task rehearsal approach of early instructional design systems (e.g., Reigeluth, 1983), nonrecurrent skills are not decomposed into separate components to be learned piecemeal for later reassembly by the learner. Although this approach restricts learners' levels of cognitive load while learning the subskills, compiling these parts into an integrated whole imposes very high intrinsic load, because all subskills must be held simultaneously in working memory to develop the connections between them (Atkinson, Derry, Renkl, & Wortham, 2000; Renkl & Atkinson, 2003; van Merriënboer, Kirschner, & Kester, 2003). Instead, authentic learning tasks are practiced in their entirety, but cognitive overload is prevented by manipulating the complexity of the situation. Thus, the first whole task learning activity is constructed to be as simple as possible without eliminating its authenticity. In addition, pertinent conceptual and heuristic scaffolding is presented to the learner as it is needed (i.e., just-in-time support; Romiszowski, 1997), beginning with fully worked-out examples and gradually fading out support as the learner's skill improves and intrinsic cognitive load decreases.

This approach is reminiscent of some implementations of microteaching, which have reported very high levels of success in preparing teachers (Metcalf, Ronen Hammer, & Kahlich, 1996). D. W. Allen and Eve (1968) described an approach in which teacher candidates present brief lessons to very small groups of students to develop an integrated knowledge base of theory and practice. Particular performance objectives are established for the candidate, and intensive feedback is provided immediately after performance. Current applications of the approach also involve extended candidate reflections on their experiences (Amobi, 2005). These formats bear close resemblance to the 4C/ID approach. However, they tend not to incorporate the mechanisms that foster automaticity in recurrent skills and maximize the ability to transfer skills to different and more complex situations. Specifically, teacher candidates typically do not have opportunities to engage in many repetitions on a regular basis, and levels of complexity (e.g., number of students, sophistication of content or pedagogical approach, etc.) are not always manipulated to increase with the skill of the individual learner (Cruickshank et al., 1996; Cruickshank & Metcalf, 1993).

In the 4C/ID system, the development of automaticity is particularly important for recurrent skills. Because these skills are highly consistent across situations, they can automate efficiently. In addition, developing these skills to automaticity increases the amount of working memory available to process the complexities inherent in nonrecurrent learning tasks (van Merriënboer et al., 2003). Practice opportunities are presented in a just-in-time format, where repetitions are embedded within learning tasks for nonrecurrent skills. As recurrent skills become relevant in the complex learning task, learners repeat the step as part-task practice until it can be performed quickly and correctly without additional scaffolding. In this way, recurrent skills reach automaticity without being severed from the cues in the authentic context that initiate their use (Carlson, Khoo, & Elliot, 1990).

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

The hypothesized role that automaticity plays in teaching represents a double-edged sword. In some ways, automaticity is beneficial and critical to the effective functioning of a teacher in the classroom. It reduces the overall level of cognitive load necessary to process multiple complex interactions, which allows the allocation of working memory to careful assessments of the needs of individual students. In other ways, however, automaticity may undermine the quality of classroom instruction by leading teachers to form biased assessments and default to unintended behaviors when levels of cognitive load are too high. Future studies of cognitive load's impact on teaching performance that directly test its magnitude in authentic classroom environments will allow for more specific accounts of these effects and their underlying mechanisms.

The dual-process model of cognition suggests the hypothesis that optimal teacher preparation would foster the development of automaticity for desired, adaptive behaviors and cognitions while reducing the role of maladaptive automated processes. Specifically, training for automaticity in teacher preparation should enhance classroom performance in three ways: (a) reduced likelihood of cognitive overload and consequent cognitive defaults, (b) increased likelihood of adaptive (i.e., desired) behaviors when cognitive defaults do occur, and (c) increased availability of working memory space for conscious monitoring of evaluation processes to avoid unintended biases. The maximization of available cognitive resources will enable less experienced teachers to manage their classrooms successfully and allocate sufficient attention to the individual students they teach.

Through the investigation of the dynamic relationship between cognitive load, teacher training, and teaching performance, research utilizing the dual-process model of cognition has the potential to shed light on teaching preparation and performance in new ways. When integrated with efforts to identify ecologically meaningful patterns in classroom interactions (e.g., Nuthall, 2005; Wideen et al., 1998), monitoring dynamic fluctuations in the cognitive load of teachers will provide a comprehensive, multitiered framework for understanding their performance. This will shed further light on effective techniques for preparing novice teachers to enter the classroom successfully.

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