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Student Perceptions of Cognitive Efficiency: Implications for Instruction

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Abstract

This study used a phenomenological approach with content analysis to create a model of how students perceive cognitive efficiency (CE), which is generally described as increases in the rate, amount, or conceptual clarity of knowledge, versus cognitive costs needed to attain knowledge. Graduate education students completed a five-item open-ended survey to measure perceptions of CE and what factors they believed enhanced or inhibited CE. Analysis of results revealed that student perceptions of CE predominantly focused on malleable aspects of self-regulated and reflective cognition, aligning with many descriptions of expert teaching. Students described a diminished emphasis on knowledge acquisition and information processing, in contrast to views typically associated with CE in instructional and psychological research (Hoffman & Schraw, 2010; van Gog & Paas, 2008). Practical teaching and learning implications, including suggestions for instructional practice and future research are presented.

Keywords: cognitive efficiency, student perceptions, instruction.

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Percepciones de las y los Estudiantes sobre la Eficiencia Cognitiva: Implicaciones para la Instrucción

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Resumen

Este estudio utilizó un enfoque fenomenológico con análisis de contenido para crear un modelo de cómo las y los estudiantes perciben la eficiencia cognitiva (EC), que se describe de forma general como el incremento en la tasa, cantidad o la claridad conceptual de conocimiento versus los costes cognitivos necesarios para conseguir el conocimiento. Estudiantes graduados completaron una encuesta semi-abierta de cinco ítems para medir percepciones de EC y qué factores creían que aumentaban o inhibían la EC. El análisis de los resultados reveló que la percepción de las y los estudiantes sobre la EC se focalizó predominantemente en aspectos maleables de la cognición auto-regulada y reflexiva, acorde con muchas descripciones de enseñanza experta. Las y los estudiantes describieron un énfasis reducido en la adquisición del conocimiento y el procesamiento de la información, en contraste con visiones típicamente asociadas con EC en la investigación instruccional y psicológica (Hoffman & Schraw, 2010; van Gog & Paas, 2008). También se presentan implicaciones para la práctica de la enseñanza y el aprendizaje, incluyendo sugerencias para la instrucción y para la futura investigación.

Palabras clave: eficiencia cognitiva, percepciones de las y los estudiantes, instrucción.

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Cognitive efficiency (CE), also known interchangeably as mental efficiency (Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Stilley, Bender, Dunbar-Jacob, Sereika, & Ryan, 2010; Verplanken, 2006), is a growing topic of research in the domains of neuroscience (Ansari & Derakshan, 2011; Bassett, Bullmore, Meyer-Lindenberg, Apud, Weinberger, & Coppola, 2009; Doppelmayr, Klimesch, Hödlmoser, Sauseng, & Gruber, 2005; Neubauer & Fink, 2009; Rypma et al., 2008), psychology (Cates, Burns, & Joesph, 2010; Pyc & Rowson, 2007; Stilley et al., 2010), and instruction (Ayres & van Gog, 2009; Kalyuga, 2006; Kirschner, Paas, & Kirschner, 2009; Scharfenberg & Bogner, 2010). Although most conventional definitions of CE are domain specific, CE is generally described as increases in the rate, amount, or conceptual clarity of knowledge, versus cognitive costs such as mental effort needed to attain knowledge. Currently, there is little consensus regarding a conceptual model of efficient cognition or agreement how to measure and evaluate efficiency outcomes (Hoffman, 2012; Hoffman & Schraw, 2010; van Gog & Paas, 2008; Whelan, 2007).

Research in CE differs from most research on teaching and learning in that it focuses on optimal performance under restricted conditions, rather than on simple performance, while accounting for constraints such as time, effort, working memory, neurological processing, motivation, or variation in strategy use. Research in CE is important for both theoretical and practical reasons. From a theoretical perspective, cognitive and neurological views of learning emphasize that the constraints in human information-processing architecture must be considered to determine what constitutes optimal problem solving, learning, and associated pedagogy (Kirschner, Sweller, & Clark, 2006; Rypma et al., 2008; Stanovich, 2009). From a practical perspective, understanding student beliefs and perceptions has been closely linked to learning, motivation, and achievement (Pianta, Hamre, & Stuhlman, 2003), and more specifically CE is one of the primary considerations to inform instructional design (Beckmann, 2010). The development of a theoretical model that effectively articulates student perceptions of CE will assist educators in designing learning materials, pedagogy, and educational contexts that recognize student perceptions and meet the evolving teaching challenges encountered in the classroom (Corno, 2008; López, 2007; Valli & Buese, 2007).

Student perceptions of what constitutes efficient cognition have not yet been empirically considered. In order for instruction to be relevant and engaging it should align with students' needs and understanding about thinking and learning (McCaslin & Good, 1996; Perry, Turner, & Meyer, 2008). In addition, the appraisal of student thinking is highly relevant to foster abandonment of notions that may be misguided or inaccurate (Linn & Eylon, 2008). Assessment of student thinking is linked to promoting student conceptual knowledge (Fraivillig, Murphy, & Fuson, 1999), is instrumental in advancing constructivist pedagogy (Bereiter & Scardamlia, 1989), and ultimately creates opportunities for learning (Flutter, 2006; Flutter & Rudduck, 2004; Gillen, Wright, & Spink, 2011). Specific knowledge of student perceptions about CE will provide valuable insight to support instruction that matches student needs (Corno, 2008; Pianta et al., 2003).

The current study sought to answer three specific research questions using qualitative methods: how do learners describe cognitive efficiency; how do learners believe that cognitive efficiency can be enhanced; and what obstacles are described as inhibiting learners from being cognitively efficient? A phenomenological approach was used as existing literature has not documented student perceptions, or compared these perceptions to existing exemplars of CE found in expert teaching descriptions (Bereiter & Scardamalia, 1993; Berliner, 2001; Corno, 2008; Feldon, 2007; Hammerness, Darling-Hammond, Bransford, Berliner, Cochran-Smith, McDonald, & Zeichner, 2005; Sternberg & Horvath, 1995). The concordant views of students, teachers, and researchers may be invaluable in proposing instructional strategies that might promote efficient cognition in the classroom.

The Diverse Perspectives of CE

Researchers in education, psychology, and neuroscience interpret CE as either a physiological phenomenon contingent upon optimal neurological functioning, or as competency in knowledge acquisition when accounting for constraints on learning such as limited time or accelerated effort. CE research is typically situated within the framework of cognitive load theory, which assumes a limited capacity working memory, and in absence of automatic information processing, the need to dedicate more cognitive resources and effort when learning intrinsically complex material (Kalyuga, 2007). During knowledge acquisition, the relative effectiveness of instruction materials, the modality of delivery or pedagogical style can influence how learners regulate mental effort, and subsequently achieve CE.

Quantitative changes in the rate, amount, or frequency of knowledge acquisition can also determine CE (Hoffman & Schraw, 2009). Greater CE is associated with quicker learning, or the acquisition of more complex knowledge with a minimal investment of time or effort (Cates, Burns, & Joseph, 2010). Learners needing more time or exerting greater effort to achieve similar results in comparison to their own performance, or to the performance of others, are described as cognitively less efficient (van Gog & Paas, 2008).

All views of CE emphasize the importance of working memory capacity (WMC), which refers to "the limited-supply cognitive resources that can be allocated flexibly depending on the demands of the task" (Hambrick & Engle, 2003, p. 181). When learners automate cognitive processing the limits of working memory are moderated and CE improves. Distinct efficiency advantages are created as automation requires fewer cognitive resources, reduces the need for attentional focus, and allows for faster processing of information (Unsworth & Engle, 2007). For example, in mathematics, learners that bypass time consuming computational strategies can allocate capacity towards activities such as rehearsing new material, engaging in analogical mapping, or algorithmic approaches to problem solving. These activities eventually strengthen networks for math knowledge and improve overall competency in performance (Royer, Tronsky, Chan, Jackson, & Marchant, 1999). Automaticity frees up cognitive capacity to think about the problems to be solved, and to assist in learning additional content.

Most models of CE emphasize the mediating role of strategy use in reaching learning goals. Even when WMC is taxed, or when automaticity fails, learners can use strategies to enhance CE (Calvo, Eysenck, Ramos, & Jimenez, 1994; Hoffman & Spatariu, 2008; Swanson, Kehler, & Jerman, 2010; Walczyk & Griffith-Ross, 2006). Strategy choice influences CE since strategies vary in the amount of cognitive resources needed to execute the strategy, and some strategies, such as direct fact retrieval, are less time-consuming and less effortful. Conversely, some strategies are counterproductive to CE. When learners evoke self-regulatory approaches to monitor and reflect upon their progress towards learning goals additional task demands are created, and thus capacity must be appropriated between primary and secondary tasks (Feldon, 2007; van Gog, Kester, & Paas, 2011). Overreliance on automaticity can also lead to deficits in CE due to "arrested skill development" (Feldon, 2007, p. 131), resulting from a decrease in conscious monitoring, or a premature automation of skills prior to achieving expertise.

The research cited reveals that CE is a contextualized and task dependent cognitive process that is reliant on fast, controlled, yet automatic processing of information combined with the judicious use of strategies. Dual process models of cognition, using clear empirical distinctions from neuroscience and cognitive psychology (Feldon, 2007; Hoffman, 2012; Stanovich, 2004; 2009) mirror a similar multiplicative view to explain optimal cognition. Two complimentary, yet different modes of cognition are proposed, generally labeled as autonomous and controlled (see Stanovich (2004; 2009) and Evans (2008) for analysis and comparison). Autonomous processing, largely domain specific, is implicit, reflexive, heuristic, and relatively non-demanding of cognitive resources. Controlled processing is methodical, resource demanding, conscious, and analytical. The two symbiotic components work in tandem balancing physiological capability, learner motivations, and environmental constraints, with the goal of completing task demands. CE results when the two systems coordinate to reaching learning objectives with minimal time, low effort, and consistent accuracy.

How CE Applies to Teaching and Learning

Understanding the variation between the research findings described above and student perceptions of CE is highly relevant for at least three applied reasons related to teaching and learning. First, pre-instructional beliefs and lack of congruence between instructional objectives and learner understanding can perpetuate construct misconceptions (Chinn & Brewer, 1993) and impede construction of knowledge (Greene, Muis, & Pieschl, 2010; Hammer, 1996). Misalignment of student and teacher perceptions has been linked to inferior learning climates (Gillen et al, 2011; Pianta et al., 2003) and academic risk factors such as impaired student-teacher relationships (Fan et al., 2011). Potential consequences of cognitive inefficiency due to learner/teacher misalignment include ignoring critical content, misperceiving meanings and application of new knowledge, and inferior construct representations in memory, leading to poor recall (Vogel-Walcutt, Marino Carper, Bowers, & Nicholson, 2010).

Second, some learning contexts, typical to many higher education classrooms, exacerbate the need for CE. Learners completing standardized or classroom testing under time limits, or students needing to rapidly learn material, are especially vulnerable to inefficient cognition (Walczyk, & Griffith-Ross, 2006). Unlike simple learning without time considerations, restricted conditions place additional demands upon learners to achieve fast performance, and time restrictions negate the value of using compensatory strategies that typically mitigate CE during unrestricted tasks (Hoffman & Spatariu, 2008; Walczyk, Wei, Griffith-Ross, Goubert, Cooper, & Zha, 2007). In a study of cognitive disruptions, similar to the type found in many classrooms, Bailey and Konstan (2006) found up to 27% longer task completion times and more errors on interrupted computational and reading tasks then when compared to an uninterrupted control group. The elimination of interference allowed for more focused attention and superior performance suggesting that counterproductive contextual variables can impede CE.

From a traditional information processing perspective (Ericsson & Kintsch, 2007), CE is a prerequisite for the use and refinement of higher-order thinking skills. Many instructional situations require that learners decipher relevant and key knowledge constructs from an abundance of facts by actively filtering out extraneous and irrelevant information. Ineffective filtering, or the dedication of time and effort to ancillary aspects of a task, may result in cognitive overload, or a focus only on non-salient task aspects (Kalyuga & Sweller, 2005). Learners addressing irrelevant task aspects have been associated with non-productive haphazard memory searches for solutions (Vogel-Walcutt et al., 2010), or failure to eliminate non-essential steps in the learning process (Kalyuga, 2006). The cognitively inefficient learner is disadvantaged, with impoverished resources dedicated toward shallow learning and unavailable to be used for reasoning, evaluative, and metacognitive strategies often found related to deeper learning, improved performance, and knowledge transfer (Corbalan, Kester, & van Merriënboer, 2009).

Third, several descriptions of expert teaching mention the need for efficient cognitive processing as a necessary component to be considered a teaching expert (Bereiter & Scardamalia, 1993; Berliner, 2001; Feldon, 2007; Hammerness et al., 2005; Hattie; 2003; Sternberg & Horvath, 1995). Expert teaching denotes the culturally determined qualities and practices that describe teachers deemed superior in comparison to normative or defined standards of performance, knowledge, or productivity (National Board of Professional Teacher Standards, 2012). Teaching expertise is not an automatic function of experience (Berliner, 2001), but instead involves the application of broad domain knowledge and a repertoire of teaching strategies (Fenstermacher & Richardson, 2000) that results in superior student achievement.

Models of teaching expertise vary broadly (see Hattie, 2003; Tsui, 2009 for reviews), but in regards to CE several themes transcend theoretical models. "Adaptive experts" (Bransford, Derry, Berliner, Hammerness, & Beckett, 2005, p. 48) rapidly retrieve information with minimal attentional resources, practice higher-order thinking skills routinely, judiciously and quickly direct cognitive resources and attentional control (Sternberg, 1998), while concurrently monitoring, evaluating, and adapting teaching strategies in response to classroom activity (Artzt & Armour-Thomas, 1998). Other expert teaching approaches suggest that superior working memory capacity, coupled with automatized schemas and routines (Feldon, 2007; Hammerness et al., 2005), and regulation and economization of mental resources, coordinated with a strong emphasis on metacognitive awareness are essential for teaching expertise (Bereiter & Scardamalia, 1997). Expert teachers devote greater cognitive resources to activities that promote learning, successfully manage the elimination of extraneous cognitive load and are far less likely to be consumed by prescriptive routines (Feldon, 2007). Table 1 summarizes empirically supported CE exemplars represented in a variety of expert teaching descriptions.

Table 1
CE exemplars included in expert teaching descriptions

	Regulation of mental effort	**Automaticity/ Working Memory**	**Filtering of extraneous cognitive load**	**Reflective cognition/**	**Speed/depth of knowledge acquisition**	**Speed of processing**	**Adaptive Strategy Use**
Bereiter & Scardamalia, 1993	X	X					X
Berliner, 2001	X	X		X			X
Feldon, 2007		X	X	X			X
Hammerness, Darling-Hammond et al., 2005	X	X		X	X		X
Hattie, 2003	X	X		X	X		X
Sternberg & Horvath, 1995	X	X		X		X	X
Schulman, 1987				X	X		X

The Present Study

The present study sought to aggregate perceptions of students understanding of CE. Although domain-specific descriptions of CE are well-articulated in education, psychology, and neurological research, no study to date has investigated student perceptions of what is considered optimal cognition. Graduate education students completed a five-item opened-ended survey developed by the author to measure perceptions of CE and what factors they believed enhanced or inhibited CE.

Phenomenological qualitative methods using content and comparative analysis were employed (Miles & Huberman, 1994). This method ideally fit the purpose of the study due to the intent to determine if student's perceptions of CE differed from research descriptions and in absence of any previous qualitative analysis of the CE construct. Since research-based findings describe CE as a multidimensional construct, qualitative approaches were ideal to disentangle the perceptions of students, as qualitative designs can reveal how constituent parts interact to define the construct. Findings should provide new evidence that will enable instructors to better align instructional materials and methods with student expectations, and provide a further understanding of the nature of how learner beliefs may be linked to instruction promoting CE.

Method

Participants

Study participants were from a large southeastern U.S. public university (N = 47, F = 33, M = 14) and were a convenience sample of 80% education majors taking a graduate level course in learning and instruction. The majority of the participants were in-service teachers or individuals completing education courses for alternative route teaching certification. The participant demographic data indicated 78.7% were Caucasian; 10.6% Hispanic; 4.2% African-American; 4.2% Asian; and 2.1% did not indicate an ethnicity. The average participant age was 31.4 and the mean grade point average of participants was 3.26. Participation was encouraged by offering students extra-class credit resulting in 100% student participation from two different class sections taught by the same teacher. The sample of graduate education students was selected based upon anticipated future work in teaching and instruction and because of the emphasis on efficiency in some models of expert teaching (Berliner, 2001; Bereiter & Scardamalia, 1993; Darling-Hammond & Bransford, 2005; Feldon, 2007; Sternberg & Horvath, 1995).

Procedures

Data was gathered by administering an in-class survey that consisted of five open-ended questions designed to determine the student's perceptions of CE, and factors perceived as influencing the facilitation or inhibition of CE (See Table 2).

Table 2
Survey questions

1. What is cognitive efficiency?
2. How do you know when you are cognitively efficient, how can you tell?
3. What factors decrease your ability to be cognitively efficient?
4. What factors increase your ability to be cognitively efficient?
5. Do you believe cognitive efficiency is a general trait, or a trait that changes according to the subject matter you study or the task you do?
   _______General _____ Changeable ______ Both

The survey was administered prior to any class discussion of cognition or motivation during the term of the course to avoid responses being biased by any specific cognitive theory. Any participant indicating advanced knowledge of cognitive or motivational processes was excluded from the study. Advanced knowledge was determined by self-selection by the participants or exclusion by the researcher, if the participants had taken any previous courses in cognitive, motivational, or educational psychology at the graduate level. No participants required removal from the study. The survey questions were developed by the author based upon emerging research themes in cognitive load (van Gog & Paas, 2008; Paas, Tuovinen, Tabbers, & Van Gerven, 2003) and cognitive efficiency theory (Hoffman, 2012, Hoffman & Schraw, 2010, Stilley et al., 2010; Verplanken, 2006) that attempt to measure and define constructs related to information processing. Participants were informed that the intent of the research was to learn about how students defined cognitive efficiency under the premise that the research results could provide instructors with additional knowledge to enhance the efficiency of instruction.

Method of Inquiry and Analysis

Design

The current inquiry used a phenomenological lens to examine student's perceptions of CE. A phenomenological approach was chosen to offer researchers and practitioners a descriptive, reflective, and interpretive analysis of individual perceptions (Richards & Morse, 2013) that were previously unknown. Phenomenological premises (Giorgi, 1997) emphasize the researcher's goal of discovering the psychological substance of a phenomenon, not a "universal or philosophical essence" (p. 100). Data using the phenomenological approach allows the researcher to construct knowledge and understand the nature of the individual inquiry, with the current intent to analyze and compare previously unreported student perceptions of CE with those found in published research.

Data analysis method

Content analysis in three phases (Creswell, 2008; Miles & Huberman, 1994) was employed by the author to generate one or more codes from each survey response in order to summarize the data and create general categories from the full data set. During the first phase of content analysis, data repetitions and linguistic connections were used to generate 383 individual in-vivo codes (labels phrased in the exact words of participants) or lean codes (labels phrased in the words of the researcher). A summary is provided in Table 3. Descriptive code generation was used to determine individualized accounts of CE and the factors related to the facilitation and inhibition of efficient cognition. For example, when answering the question "what does it mean to be cognitively efficient?" a participant indicated "to be able to think coherently and rapidly without missing significant information". This statement generated the in-vivo codes of "coherence" and "speed", and the lean code of "thoroughness".

In the second phase of analysis, cluster coding was used to consolidate the phase one data to create 14 condensed categories, positioning each category at the center of the participant thought process, and relating to similar codes from phase one (Creswell, 2007). The phase two coding was completed individually by two trained graduate assistants resulting in 92% coding agreement. The initial categories were developed as a result of shared discussions between the coders. Initial discrepancies and ambiguous codes were resolved through discussion with the author until 100% coding agreement was reached. For example, phase two analyses included the consolidation of terms "fewest steps", "precision", and "accomplish the task effectively" into the category "organization".

Table 3
Frequency of condensed categories by theme

Condensed categories	**Physiological**	**Cognitive/Affective**	**Environmental**	**Total**
Time to complete task	0	0	40	40
Organization	0	10	44	54
Distraction	0	32	32	64
Resources	10	0	1	11
Timely completion of task	0	0	10	10
Concentration	0	17	0	17
Interest	0	15	0	15
Awareness	0	8	0	8
Ability	0	18	0	18
Health	44	0	0	44
Accomplish task	30	0	0	30
Decision Making	5	7	0	12
Performance	42	0	0	42
Stress	5	13	0	18
Total	136	120	127	383

The third coding phase led to the identification of three main categories. *Physiological influences* included individual differences, health, or measurable conscious actions related to one's physical condition, but unrelated to cognition, that a participant described as related to efficiency. *Cognitive or affective determinants* represented what the participant was thinking or feeling when completing a task and being cognitively efficient. Cognitive and affective exemplars of CE were combined due to the interdependence of the constructs as described in the neuropsychology (Ray & Zald, 2012) and education literature (D'Mello & Graesser, 2011; Efklides, 2011; Pekrun, Elliot, & Maier, 2009). *The environmental category* emerged from codes that described the influence of factors external to the person attempting to complete a task, but were not related to the internal physiological state of the respondent. These themes and condensed categories served as the basis for the analysis and subsequent development of a model indicating what strategies contributed to enhancing CE (see Figure 1).

Next, an adaptive prototype design framework (Sternberg & Horvath, 1995) was used to create a table comparing student perceptions of CE to research descriptions, including instructional implications for each CE exemplar (see Table 4). Prototype models, originally conceived by Rosch (1973) were designed to eliminate the "fuzziness" of discrepant categorical exemplars. The prototype view contrasts similarities and differences among exemplars to evaluate the confluence of evidence on a particular topic.

Analysis and Results

The process of analysis was initiated by using the expertise of the researcher as a foundation of domain knowledge to describe results, assess intention, and ascribe meaning (Richards & Morse, 2013), while accurately transforming the essence of participant perceptions of CE. *Intentionality* (van Manen, 1990) was a planned analysis strategy, whereby the researcher sought to reflect on experienced phenomena, which included comparisons to descriptions of CE in neurological, psychological, and educational literature. The analysis process was repeated individually for each question described below.

What is Cognitive Efficiency?

Responses to the main research question, “What is cognitive efficiency?” generated 84 unique codes. Participants most frequently associated CE with completing a task quickly by utilizing time effectively (33.3%), with minimal resources (14.2%), and in an organized (21.4%) and reflective manner (13.0%), while minimizing intrusive thoughts (10.7%) and limiting environmental distractions (5.9%). The confluence of responses led to the conclusion that students perceived CE as the conscious ability to monitor cognitive operations while completing a task as quickly and as accurately as possible.

Responses coded as attributing CE to physiological attributes (22.6%) focused on the deliberate and conscious regulation of mental resources, not specifically task related, or the physiological readiness to complete a task. Mental resources included “targeted attention”, “avoidance of day dreaming” and the “regulation of effort”, but excluded cognitive strategies such as planning, setting learning goals, or executing strategies used to complete a task. Physiological readiness included ample sleep, energy, and nutrition minimally necessary to attempt and complete a task.

Cognitive and affective determinants of CE (32.1%) were based on descriptions of what the person was thinking and feeling while completing a task under the perception of efficiency. Cognitive factors included concentration, interest, and ability, whereas affective factors targeted reducing anxiety, avoiding stress, and fostering adaptive task motivation. Substantial variability existed in the type of cognition described by participants. Some participants emphasized an information processing view of CE (Ericsson & Kintsch, 2007) for example, stating CE is “To do something with the least number of steps and in the shortest amount of time while still doing it effectively”. However, another participant indicated CE was “the ability to think logically and rationally” suggesting a reflective approach to evaluating efficient cognition. Others contended that CE was not possible without “decisiveness”, “higher-order thinking skills”, “creativity”, or “confidence”.

Codes related to environmental factors (45.2%) emphasized the importance of controlling one’s context and conditions of thinking to achieve and maintain CE. Participants clearly indicated that the greatest environmental threats to CE were a result of distractions (16.6%) due to self-imposed stress such as lack of sleep (15.4%) or food deprivation (11.4%), or factors such as “noise”, “movement”, or “chaos”. One participant indicated, when there are “too many things going on at a time, the environment is not conducive to the task.” Another stated “the need to be aware and monitor what works for me”. The comments suggested that participants felt willing and capable to self-regulate their learning and thinking environments to foster CE.

Comparative analysis (Miles & Huberman, 1994) revealed a number of distinct contrasts in the perceptions of CE. A majority of participants (34) focused on the process of thought, while others (13) indicated their CE was based upon the quality of task outcomes. There was little variability in individual answers concerning the antecedents of CE. Participants implied that either internal processes (e.g., attention, deep concentration) determined CE (55.3%), or that external attributes such as controlling distractions were wholly responsible for their CE (29.7%). Only nine participants (19.7%) indicated that CE involved the regulation of both internal and external factors. Finally, participants were asked to evaluate the domain specificity of CE. Only two participants (4.2%) believed CE was exclusively a domain general trait, whereas most participants (53.1%) indicated CE was domain specific, or contingent on a specific task (40.4%).

Surprisingly, few participants alluded to the importance of background knowledge, or effortful cognitive processing as contributory to CE in contrast to widely accepted views of information processing (Hoffman & Schraw, 2010; van Gog & Paas, 2008) and neurological perspectives of CE (Rypma et al., 2008). Frequently participants stressed the influential role of self-regulatory strategies such as planning, monitoring, and reflective thought in achieving CE, a view consistent with many social-cognitive (Zimmerman, 2001) and dual-process theories of cognition (Evans, 2008; Smith & DeCoster, 2000; Stanovich, 2004).

Although student perceptions were partially incongruent with information processing and neurological perspectives of CE, many parallels between student perceptions and expert teaching models were observed. Resemblance across perspectives centered on the need for rapid schematic organization of knowledge, the elimination of thought irrelevant to learning, and strategy adaption. Table 4 lists typical exemplars of CE aligned with a representative sample of student responses in conjunction with descriptions found in various teaching models.

Table 4
CE research exemplars, student perceptions, teaching descriptions, and instructional inferences

CE Exemplar	Sample Student Perceptions	Sample Teaching Description	Instructional inference
Regulation of mental effort	"To use time wisely and work smart." "In your mind you are able to get organized and focused all at once to accomplish a goal."	Executive control including planning, monitoring, and evaluating. The reinvestment of cognitive resources (Sternberg & Horvath, 1995).	View students as active participants in the construction of knowledge; sequence learning objectives logically; openly discuss potential difficulties learners may encounter during the learning process (Artzt & Armour Thomas, 1998).
Automaticity or enhanced working memory capacity	"Performing multiple tasks simultaneously, to find or create a path of least resistance." "When you don't have to reread instructions, coming to conclusions without a huge investment of effort."	"Operations that once took thought and planning come to be done with little or no effort" (Bereiter & Scardamalia, 1993, p. 119).	Present brief lessons that do not overload learners. Embed repetition into lessons that promote automaticity of procedures. Consider just in time lessons, activation of existing mental models, and supportive scaffolding for non-repetitive knowledge (van Merriënboer, Kirschner, & Kester ,2003).

Filtering of extraneous cognitive load	"Mentally efficient means that you have mental order. You don't waste time daydreaming." "To cut out a lot of white noise, other thoughts, other words."	"Unnecessary structural or semantic content that occupies space in working memory"….Teachers "develop more elaborate schemas to process information efficiently and their actions require less mental effort." (Feldon, 2007, p. 126)	Remove anxiety producing learning cues that might activate stress in high-anxious individuals, introduce preparatory periods that help learners adjust to restricted conditions. Provide learners with compensatory strategies to overcome anxiety (Ansari & Derasham, 2011).
Use of reflective cognition	"You do not know if you are mentally efficient because if you realize, metacognitively that your mind has wandered off task and you are no longer efficient." "To have a rational thought process when completing tasks."	Reflection and conscious deliberation (Tsui, 2009). "The teacher's skillfulness in monitoring…in-flight decision-making in dynamic environments (Berliner, 2001).	Given available resources, provide explicit instruction on how to monitor for efficient cognition with a focus on the evaluation of the thought process. (Helsdingen, van Gog, & van Merriënboer ,2011). Expert teachers monitor the learning process, learning outcomes and their own intrinsic interest, while seeking self-evaluation of teaching techniques (Kreber, Castleden, Erfani, & Wright, 2007).

Speed of or depth of knowledge acquisition	"Mental efficiency is achieved when the individual uses the minimal amount of time required to complete a thinking task." "A solid education teaches you how to think."	Expert teachers "can spontaneously relate what is happening….can quickly recognizes sequences of events occurring in the classroom which in some way affect the learning and teaching of a topic." (Hattie, 2003, p. 5) The depth of pedagogical content knowledge (Schulman, 1987).	Emphasize that efficient thinking and learning involves understanding of both the process and outcome of knowledge acquisition (Artzt & Armour Thomas ,1998). Create a classroom with structure and predictability including the use of scripted routines that promote learner preparation (Konrad, Helf, & Joseph, 2011).
Speed of information processing	"To be able to think coherently and rapidly" "Not missing significant and important information, but achieving a desired outcome quickly and thoroughly."	"People who are high on efficiency can rapidly retrieve and accurately apply appropriate knowledge and skills to solve a problem or understand an explanation" (Bransford et al., 1995, p. 49).	To promote quick individual understanding, during intrinsically complex learning, focus on practical application of knowledge, instead of theoretical mastery (Scharfenberg & Bogner, 2010).
Adaptive strategy use	"Using the fewest steps possible to reach a decision or understanding" "Know when to change gears and what does or doesn't work for you"	An adaptive teacher …has a propensity to check students' thinking and understanding on a continuous basis in a variety of ways and has a hesitant attitude about using any one approach with every student" (Corno, 2008, p. 171).	Employ contextualized thinking by demonstrating responsiveness to changing circumstances and student thinking through impromptu decision making during, not after instruction (Berliner, 2001).

How Do You Know When You Are Cognitively Efficient?

Students reported that they monitored CE by reflecting on their progress towards meeting learning goals. Completing the task at hand (22.6%), with the fewest possible distractions (20.8%), in the quickest amount of time (22.2%) were reported as the most common actualizations of CE. Focused attention of mental resources was frequently described as necessary to achieve CE (25.9%). Students remarked, being "focused in the clearest possible manner", having "thoughts flow without interruption", and being "able to think without getting distracted" as representative of being cognitively efficient.

Mental resources were described in cognitive, affective, and physiological terms included "working smart", "feeling confident", and having "a clear head". Specific cognitive determinants included having both interest and experience in the subject matter. Some participants claimed that they knew they were being cognitively efficient when they understood the information, "when you understand something, you can communicate". Another participant indicated a problem-solving focus stating "when I am able to see all sides of the situation and work toward a solution I am cognitively efficient". Others equated CE with physical well being and the regulation of stress. One student indicated "I can tell when I am cognitively efficient because I am not stressed out and worried that I am forgetting things, I feel calm when I am cognitively efficient".

What Factors Decrease Your Ability to Be Cognitively Efficient?

The reported impediments to achieve CE were largely based upon physiological factors, such as sleep and food deprivation (19.4%), stress (13.9%) or illness (12.9%). Environmental constraints including noise, and cognitively disruptive aspects of learning were cited as detrimental to CE by 13.9% of participants. A variety of changeable factors such as the ability to control distractions and lack of motivation were additional reasons that inhibited efficient cognition. Lack of task focus and maladaptive motivation were also cited as inhibitory to CE, as one individual stated, "use it or lose it" when referring to the need to dedicate resources to a task when trying to be efficient. Only 6.45% of respondents indicated lack of ability or intelligence as interfering with their ability to achieve CE, suggesting that most learners in the current sample held an incremental and controllable view of efficient cognition.

What Factors Increase Your Ability to Be Cognitively Efficient?

Four primary strategies evolved from the 84 codes developed to describe how CE may be improved: modeling optimal health (16.6%), limiting distractions (16.6%), gaining more experience through practice or increasing knowledge (15.4%), and organizing thoughts and resources (10.7%). Little emphasis was placed on motivational criteria typically associated with task success such as goals, task challenge, or effort (Csikszentmihalyi, 1997; Pintrich, Marx, & Boyle, 1993); however six students indicated interest was a necessary component to increase CE.

Students allocated the regulation of CE into two broad categories: behavioral (48.8%) and mental control (38.2%). Behavioral control means specific actions that individuals take related to the physical task environment or surroundings, such as "organizing the work setting", or removing "external interference". Whereas mental control means monitoring or orchestrating changes in cognitive processes including, "deep thinking", "centeredness", or "having a clear mind". Figure 1 provides a graphic representation by theme of what strategies students considered when attempting to improve CE.

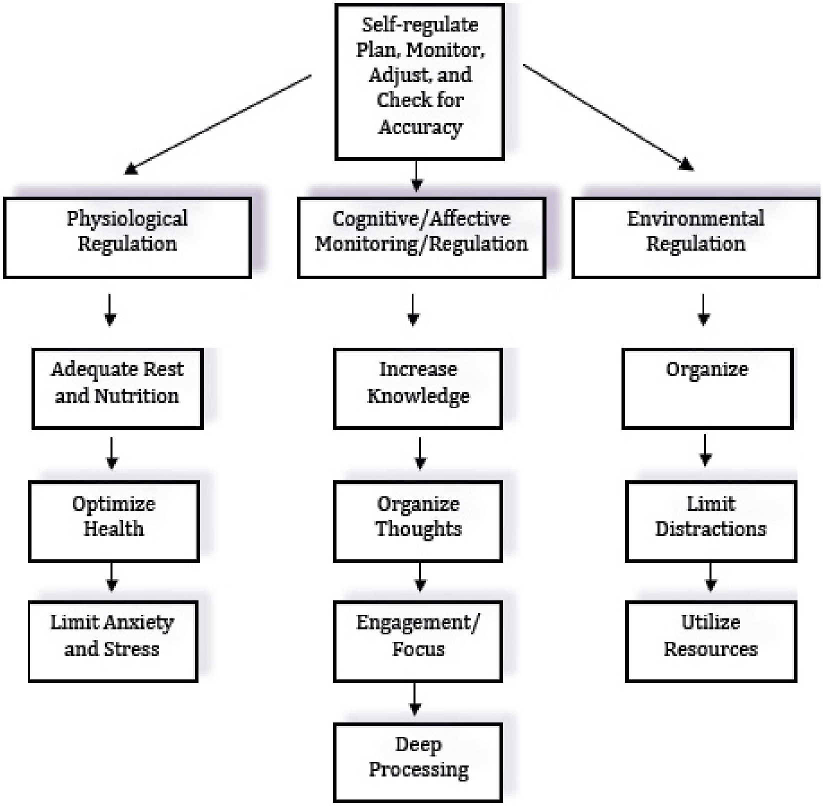

Figure 1. Model of strategies used to increase CE

Discussion

The current study sought to understand student perceptions of efficient cognition. Several of the views espoused by students differed in emphasis from research-based perspectives of efficient cognition (Hoffman & Schraw, 2010, van Gog & Paas, 2008) and efficiency in descriptions of expert teaching (Berliner, 2001; Bereiter & Scardamalia, 1993; Darling-Hammond & Bransford, 2005; Feldon, 2007; Sternberg & Horvath, 1995). First, beyond the need for attentional control, students significantly understated the role of working memory and processing resources as instrumental in CE. Second, students associated success in cognitive tasks as largely dependent upon physiological readiness and stamina. Last, students placed substantial importance on the role of experience, not qualitative changes in learning as a determinant of CE. Given the influence of learner conceptions on selective attention, deeper processing, and more accurate retrieval (Pintrich et al., 1993) the incongruence between research findings and student perceptions may have notable ramifications for learning and teaching.

The descriptions of CE suggested that students have their own clear conceptions of what constitutes optimal cognition. As such, students described how they assessed and evaluated discrepancies between states of routine performance and visualized states of optimal cognition. The self-evaluation and contextual remedies described closely parallel representations of self-regulated learning strategies designed to promote academic achievement (Pintrich, 2000; Zimmerman, 2001). Models of self-regulation employ specific metacognitive strategies whereby learners consciously and actively regulate cognitive resources, motivation, and behavior in an effort to enhance progress towards reaching learning goals. In the context of CE these self-regulatory strategies involve maximizing resources to quickly and accurately attain error-free performance. The model depicted in Figure 1, developed from aggregation of responses, suggests that student perceptions of how to enhance CE and research-based descriptions of self-regulation may be closely aligned, if not indistinguishable.

The most frequently contemplated strategies to improve the efficiency of cognition were internal controllable factors such as focused attention on task goals, or blocking out aversive environmental stimuli. Students' advocacy of these types of control strategies suggests a minimized awareness that cognitive capacity, and thus CE, can be mediated by the use of information processing strategies. Students may not believe, or may not be aware, of their ability to modify the transactional aspects of cognition. Two plausible explanations may account for the diminished emphasis by students, unconscious automatization of resources, or lack of motivation to use certain strategies. Both social-cognitive and dual process theories suggest that some types of cognitive associations such as explicit rule-based processing associated with problem solving and complex learning takes longer and are more effortful and thus may be subject to learner motivation (Karoly, 1993; Smith & DeCoster, 2000; Stanovich, 2004). In addition, many laboratory accounts of self-regulatory behavior contend that some self-regulated learning strategies are a depletable, yet renewable resource, and learners may fail to activate strategies despite capability (Bannert & Mengelkamp, 2008), or personal agency (Pintrich & Zusho, 2002).

Only one-fifth of students stated that CE could be improved by both internal and external regulatory approaches, suggesting that student perceptions of CE may align with polarized views of motivational processes during learning, such as dichotomous entity or incremental views of intelligence, or related performance and mastery goal orientations (Dweck, 1986). Most students viewed CE as a contextually driven, domain-specific phenomenon and thus may believe task success is influenced by effort allocation, or ability, but not both. Partitioning intellectual efficiency into two classes may also account for the heavy reliance by some students upon physiological readiness as a CE prerequisite. In absence of the belief that CE is controllable by internal regulation, students may overly rely upon manipulation of their physical environment as the best method to enhance CE. Interpretations of this nature are critical to teaching effectiveness as learner beliefs have been empirically linked to receptivity of conceptual revision (Pintrich et al., 1993; Mason, 2007), strategy choice (Zimmerman, 1989), and student motivation (Dweck & Leggett, 1988). These findings are especially relevant for educational contexts with restricted conditions such as standardized testing. Students with misaligned perceptions of CE may needlessly forgo helpful strategic interventions and inadvertently hinder test performance.

Despite the apparent incongruity of student perceptions with information processing research several commonalities exist with expert teaching descriptions (see Table 4). The similarities focus on quickly regulating effort during knowledge acquisition, automating procedural knowledge, and eliminating extraneous cognitive load while using a variety of adaptive learning strategies. Although no models of expert teaching focus exclusively on CE, several models consider promoting learner efficiency as a necessary prerequisite to achieve developmental trajectories for teaching expertise (Bereiter & Scardamalia, 1993; Feldon, 2007; Sternberg & Horvath, 1995). The investigation of corollaries across teachers, students, and researchers serves as the basis for the prototype view (Sternberg & Horvath, 1995) used to create Table 4, which served as a foundation to suggest instructional inferences that inform CE.

Recommendations for Practice

Isolated knowledge of student's perceptions of CE may be considered inert in absence of instructional implications that foster the development of CE in the classroom. Table 4 displays the nexus of student perceptions and a cross section of evidence from expert teaching descriptions to suggest that several logical inferences may be proposed to cultivate efficient thinking, learning, and problem solving among students.

First, learners need to know that CE is a multidimensional construct that is influenced by knowledge acquisition, enhanced processing ability, judicious effort, and adaptive strategy use. Instructors providing greater awareness that CE can be simultaneously regulated by both internal and external strategies may assist students in making gains in both the amount and quality of knowledge they must master. Approaches that emphasize both the algorithmic nature of information processing and the analytic reflective aspects of learning closely mirror dual-processing descriptions of cognition (Evans, 2008; Smith & DeCoster, 2000; Stanovich, 2004) and may be well suited to deconstructing CE.

Second, adaption of strategies that foster CE are highly relevant in light of ongoing changes in teaching standards that emphasize the need for learners with better critical thinking and problem-solving ability as a means to address authentic learning challenges within and outside the classroom. Third, researchers and instructors should consider the importance placed on self-regulation by learners and investigate how reflective cognition and metacognitive awareness influence CE. Student perceptions suggested that CE and self-regulated learning were closely aligned implying that accurate and well-calibrated metacognitive activity may be a materially similar construct as CE. Although the sample used in the current study were graduate students who perhaps may have had knowledge of self-regulated learning (although not yet covered in their current course of study), and it is unknown if these views of CE are a basis for generalization to other populations.

Empirical studies controlling for multicollinearity of variables are needed to determine the extent of variance in CE explained by judicious strategy use of all kinds across different domains and populations. The coalescence of neurological evidence garnered from brain-based studies that identify locality of information processing and behavioral assessments such as think-aloud protocols should provide additional evidence as to how learners may manipulate and control their cognition as a means to enhance or attain CE.

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