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Cognitive load of critical thinking strategies

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ABSTRACT

Argument–counterargument integration (Nussbaum, 2008) refers to the process of evaluating, refuting, and synthesizing arguments on two sides of an issue when creating justification for an overall conclusion. This study compared the cognitive load of two critical thinking strategies related to argument–counterargument integration: (a) constructing design claims that minimize disadvantages of an alternative, and (b) weighing refutations (which weaken an argument by arguing that there are more important values at stake). College students ($N = 285$) first completed the Need for Cognition (NFC) scale and were then presented with materials summarizing arguments and counterarguments on the topic of grading class participation. Participants completed a small, integrative essay justifying a stand on the issue, and completed the Mental Effort Rating Scale (Paas, 1992). Participants who generated complex weighing refutations reported more mental effort than those constructing complex design claims (and the control group), with a stronger relationship with those high in NFC. The need to coordinate disparate elements in working memory may explain the higher load associated with constructing weighing refutations. Students may need more (and different types of) scaffolding in using this strategy than when constructing a design claim, which is a more sequential process.

1. Introduction

Critical thinking is important in contemporary life, where individuals face large amounts of information, complex problems, and rapid technological changes (Angeli & Valanides, 2009). Halpern (1998) proposed a taxonomy of critical thinking skills which contained *argumentation* as one major component (see also Beyer, 1995). Effective argumentation involves the generation and evaluation of arguments and counterarguments (Kuhn & Udell, 2007).

Constructing and evaluating arguments entails varying amounts of *cognitive load*, which refers to the demands on cognitive resources and "the manner in which cognitive resources are focused and used during learning and problem solving" (Chandler & Sweller, 1991, p. 294). There is little research, however, that examines the cognitive load involved in argumentation. Cognitive load theory holds that there are limited working memory resources available when information is being processed. Some research studies have documented the high cognitive demands of dialogic or written elaborated argumentation (e.g., De Bernardi & Antolini, 1996; Coirier, Andriessen, & Chanquoy, 1999; Kuhn, 2005), using cognitive overload in part to explain students' difficulties in engaging in effective argumentation. Yet to our knowledge no studies have actually measured the cognitive load associated with any argumentation processes. The intent of the present study is to measure the cognitive load involved in two specific strategies that were applied in writing argumentative text.

1.1. What is argumentation?

Although the term "argument" can refer to a raging discussion or debate (Andriessen, Baker, & Suthers, 2003), this is not how the term is used in research on critical thinking. In critical thinking, an argument is "a proposition with its supporting evidence and reasoning" (Beyer, 1995, p. 15). *Argumentation* represents a process of thinking and social interaction in which individuals construct and evaluate arguments (Beyer, 1995). Based on the central role that it plays in critical thinking, there has been growing interest among educational and developmental psychologists in argumentation (Nussbaum & Schraw, 2007).

Argumentation may take place within an individual (Voss, Wiley, & Sandak, 1999). This study focuses on argumentation in its interior, individual form, which occurs "when one argues with oneself or formulates a line of reasoning to support a claim" (Kuhn, 2005, p. 113). Students argued about an analysis question

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individually, considering the merits of both sides of an argument. Argumentation can occur in various types of media (Andriessen et al., 2003); specifically in this study it was through writing and completing diagrams.

1.2. Argument–counterargument integration

In the psychology of reasoning, an important goal is to create balanced reasoning (Baron, 1988). Nussbaum and Schraw (2007) emphasized that effective argumentation includes not only considering counterarguments but also evaluating, weighing, and combining the arguments and counterarguments into support for a final conclusion, a process he terms *argument–counterargument integration.*

Argument–counterargument integration is similar to some other constructs in the literature, for example active open-mindedness (Baron, 1988) and integrative complexity (Tetlock, 1984), which is the ability to differentiate and integrate multiple perspectives (Suedfeld, Tetlock, & Streufert, 1992). Differentiation refers to the perception of different dimensions of an issue and integration refers to development of conceptual connections among differentiated dimensions.

Argument–counterargument integration involves accepting or refuting components of opposing arguments. Nussbaum and Edwards (2011) identified three refutational strategies that could be used to construct an integrative argument in the context of oral discussion or writing reflective essays: weighing, constructing a design claim, and "other refutations." For example, consider an argument (from Nussbaum & Schraw, 2007) about whether candy should be forbidden at school as it makes children hyperactive and reduces concentration. The counterargument is that children should have candy in school because it pleases and energizes them.

The refutational strategy of *constructing a design claim* involves designing a solution that maximizes advantages while minimizing disadvantages of an alternative. For example, instead of candy, perhaps students should be allowed to eat snacks involving complex carbohydrates; this may provide them with energy without making them hyperactive. The refutational strategy of *weighing* involves contending that the value underlying one argument is not as important as an opposing one; for example, "pleasing students" is not as important as learning. Finally, *other refutations* are those that are not design claims or weighing refutation; other refutations typically attack the truth or relevance of a premise. For example, one could argue that banning candy will not have the desired effect because students will eat it clandestinely. We recognize that "other refutations" is a catch-all category that may encompass a number of different strategies; however, these are not the focus of the present investigation.

1.3. Cognitive load theory

Cognitive load theory (CLT) (Sweller & Chandler, 1994; Sweller, Van Merriënboer, & Paas, 1998) assumes that working memory has limited capacity and duration and that these constraints should be considered in designing efficient instruction. According to CLT, the cognitive load imposed on a student during learning is due to a combination of the complexity of the material to be learned (considered to yield intrinsic cognitive load) and the design of the instructional materials (considered to yield extraneous and germane load) (Sweller et al., 1998).

1.3.1. Intrinsic cognitive load

Intrinsic load is inherent to the nature of the material being taught. It is related to the "intellectual complexity of information" (Pollock, Chandler, & Sweller, 2002, p. 62), or what Sweller and Chandler (1994) call *element interactivity*: the extent to which elements of the task or concept interact with one another and therefore must be considered simultaneously in working memory. For example learning vocabulary words is low in element interactivity because each word is an element that can be learned individually. However, learning the "syntax" of a language imposes greater cognitive load because individuals must master the "syntactic and semantic relations of each word to every other word" (Sweller & Chandler, 1994, p. 188).

Intrinsic load is also a function of a learner's expertise because numerous elements for a low-expertise learner may be chunked into one element for a high-expertise learner in the form of a schema (Van Merriënboer, Kester, & Paas, 2006). Sweller and Chandler (1994) emphasize that schema acquisition and transfer from controlled to automatic processing are the major learning mechanisms that decrease the processing burden on working memory. However, before information can be organized into schemas in long term memory, it must be processed and connected to other information in working memory. Therefore, CLT has focused on the design of instructional methods that effectively manage limited working memory capacity (Paas, Tuovinen, Tabbers, & Van Gerven, 2003).

1.3.2. Extraneous and germane load

Extraneous and germane load result from the manner or design of instructional materials. Extraneous load is unnecessary load and reducing it should be a main focus when designing instruction. The other type of load associated with instructional design is "germane cognitive load," which contributes to better learning outcomes by facilitating schema formation and automation (Sweller et al., 1998).

1.3.3. Assessing cognitive load

DeLeeuw and Mayer (2008) argued that no one measure reflects total cognitive load, as each is sensitive to different types of load. Research has shown that self-reports, such as the "mental effort rating scale," are reliable measures of cognitive load (Ayres, 2006; Paas, 1992). Mental effort "is the aspect of cognitive load that refers to the cognitive capacity that is actually allocated to accommodate the demands imposed by the task" (Paas et al., 2003, p. 64). DeLeeuw and Mayer (2008) found that effort ratings are most sensitive to assessing intrinsic cognitive load (see also Ayres, 2006).

In addition, Barrouillet, Bernardin, Portrat, Vergauwe, and Camos (2007) suggested that time is a main factor reflecting cognitive load. In a study involving searching for products in online book stores, Schmutz, Heinz, Métrailler, and Opwis (2009) found that high cognitive load was related to longer task completion time.

In the present study, we focus on intrinsic cognitive load. We assume that extraneous and germane load will stay mostly constant among our conditions, allowing us to focus on intrinsic load. In addition, we assume that participants are able to reflect on their mental effort, which is directly related to intrinsic cognitive load (Ayres, 2006).

1.4. Connections between argumentation and cognitive load

Nussbaum (2008) argued that the disparate elements in argumentation (multiple reasons, claims, counterarguments, etc.) imply that many argumentation tasks have high intrinsic load. However, there is little research linking argumentation to CLT. In this section, we review the extant research and examine the role of some related constructs.