2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #53522

Work-in-Progress: Expanding Self-Report Measures of Cognitive Load: Development and Preliminary Validation of a Peripheral Load Subscale

Gabriel Van Dyke, Utah State University

Gabriel Van Dyke is a Graduate Student and Research Assistant in the Engineering Education Department at Utah State University. His current research interests are engineering culture and applying cognitive load theory in the engineering classroom. He is currently working on an NSF project attempting to improve dissemination of student narratives using innovative audio approaches. Gabe has a bachelor's degree in Mechanical Engineering from Utah State University (USU).

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Abstract

Cognitive Load Theory (CLT) has become a foundational framework for understanding how instructional design affects student learning, particularly in cognitively demanding fields such as engineering. Among the most widely used self-report measures for cognitive load is the instrument developed by Leppink and colleagues in 2013, which differentiates between intrinsic, extraneous, and germane load. However, subsequent research by the developers has called into question the validity of the germane load subscale, suggesting that it may not accurately represent a distinct construct within CLT.

This work-in-progress study builds on the evolving understanding of this instrument by refining and expanding Leppink et al.'s instrument by maintaining the validated intrinsic and extraneous load scales while developing new items to assess peripheral factors contributing to cognitive load. This addition warrants a reconceptualization of extraneous load into two categories. One category, didactic load, retains the current focus on instructional design, while the other, peripheral load reflects the cognitive burden imposed by factors unrelated to inherent difficulty of the subject or its instructional design, such as external responsibilities, physical and mental health, or time constraints. These influences, though external to the learning activity itself, still detract from the cognitive resources available for processing instructional material and thus directly impact learning outcomes. Failing to account for these peripheral factors may cause existing cognitive load measures to underestimate the total mental demand experienced by students and may limit inferential capability, particularly in high-stakes or cognitively intensive learning environments.

This paper describes an ongoing instrument development study situated in undergraduate engineering education that integrates qualitative item generation with content and response-process validation efforts. The expected outcome is a theoretically coherent instrument capable of distinguishing between different dimensions of cognitive load, including peripheral aspects that may play a critical role in student engagement and mental effort during engineering instruction. The refined measure will equip researchers and instructors with a more precise tool for identifying cognitive barriers in STEM learning and for designing instruction that optimizes student comprehension and promotes more effective learning.

Introduction

Cognitive Load Theory (CLT) is grounded in the premise that working memory has limited capacity and that instructional design should minimize unnecessary demands so that learners can focus on processing new material and integrating it with prior knowledge [1]. Traditionally, cognitive load has been categorized into three types: intrinsic load, reflecting the inherent complexity of the material; extraneous load, reflecting inefficiencies in instructional design; and germane load, representing cognitive effort devoted to schema construction [2].

After CLT had existed for several decades, researchers began to question whether germane load constitutes its own distinct construct, or if it would fit better as a subcategory under intrinsic load [3], [4]. In this updated view, instructional design cannot directly influence germane load; rather, it can reduce extraneous load so that learners' cognitive resources are redirected toward learning-relevant processing. Despite this conceptual clarification, many widely used psychometric instruments continue to operationalize germane load as a distinct measurable factor, often producing inconsistent or theoretically ambiguous results [5].

In addition to measuring an outdated construct, existing measures of cognitive load also fail to account for recent theoretical developments acknowledging that cognitive load and learning can be influenced by contextual factors, such as mental health, non-academic responsibilities, emotions, and identity related factors [6], [7]. Research in engineering education has revealed that students, particularly those from marginalized groups, often experience learning under conditions of chronic stress, stereotype threat, discrimination, disability-related barriers, or competing work and caregiving responsibilities [8], [9], [10]. These conditions impose ongoing cognitive demands that shape learners' ability to allocate working-memory resources, yet they are largely invisible within traditional CLT measurement frameworks. As a result, current measures may underestimate the total cognitive burden students experience, limiting both theoretical understanding and instructional intervention.

Although many of these conditions have been examined extensively within diversity, equity, and inclusion (DEI) scholarship, this body of work is often treated as conceptually separate from dominant learning theories such as CLT. This separation has contributed to challenges in demonstrating measurable, instruction-adjacent impacts of equity-oriented research on learning processes and outcomes [11], which has contributed to the recent increase in scrutiny of DEI in the United States. At the same time, engineering education scholars have emphasized the need for clearer accountability structures to translate DEI research into sustained departmental and curricular transformation [12].

This tension highlights the importance of extending established learning theories in ways that are both empirically rigorous and socially responsive. Expanding CLT measurement provides one pathway for integrating insights from DEI scholarship into a framework already widely used to inform instructional design decisions.

The traditional conceptual boundaries of CLT largely exclude the influence of emotional, social, cultural, and structural factors on learning. This is especially apparent when viewing the items in the most commonly used psychometric measures [13], [14], [15], an example of which is given in Table 1. These conditions impose cognitive burdens that directly affect learning, yet they fall outside CLT's traditional categories of intrinsic and extraneous load.

Table 1. The items from one of the most commonly used cognitive load instruments [14].

Load Type	Item Used in Survey
Intrinsic Load	1. The content of this activity was very complex. 2. The problem/s covered in this activity was/were very complex. 3. In this activity, very complex terms were mentioned. 4. I invested a very high mental effort in the complexity of this activity.
Extraneous Load	5. The explanations and instructions in this activity were very unclear. 6. The explanations and instructions in this activity were full of unclear language. 7. The explanations and instructions in this activity were, in terms of learning, very ineffective. 8. I invested a very high mental effort in unclear and ineffective explanations and instructions in this activity.
Germane Load	9. This activity really enhanced my understanding of the content that was covered. 10. This activity really enhanced my understanding of the problem/s that was/ were covered. 11. This activity really enhanced my knowledge of the terms that were mentioned. 12. This activity really enhanced my knowledge and understanding of how to deal with the problem/s covered. 13. I invested a very high mental effort during this activity in enhancing my knowledge and understanding.

This work-in-progress study seeks to address this gap by expanding cognitive load measurement to include a new construct: peripheral load, which is defined as the cognitive load arising from social, emotional, and contextual factors external to instructional design and the inherent complexity. By developing and validating new items grounded in students' lived experiences, this study aims to provide a more comprehensive and socially responsive model of cognitive load.

Researcher Positionality and Paradigm

As a current graduate student who recently finished a bachelor's degree in mechanical engineering, I have experienced firsthand the detrimental effect of cognitive overload on learning. Due to my own bias in this area, I must be especially careful as I approach this research. To ensure impartiality, I will seek the feedback of experts in the fields of both cognition and DEI while developing items to update a pre-existing measure of cognitive load. This study is grounded in a pragmatic and transformative research paradigm. I view knowledge as socially constructed and valuable insofar as it improves educational practice and reduces inequity. This stance supports methodological flexibility and justifies the integration of critical theory into instrument development. I position this work as intentionally equity-oriented, but with the overarching goal of improving learning conditions for all students instead of solely for any one group or demographic.

Research Questions

RQ1: How do undergraduate engineering students describe the cognitive burdens that arise from factors external to the focal learning activity?

RQ2: How do described burdens manifest as distinct dimensions of peripheral load?

RQ3: How can identified dimensions of peripheral load be translated into survey items that are clearly understood and easily interpreted by undergraduate engineering students?

Theoretical Expansion

While extraneous load has historically been defined as the cognitive load imposed by inefficient instructional design [4], more recent publications have broadened this definition into an umbrella category that includes any cognitive load that is "unnecessary for learning" [6]. This broader framing creates space to include emotional, social, and contextual stressors that detract from cognitive resources but are not tied to task design or content complexity.

To clarify this distinction, this study proposes refining extraneous load into two subcategories as seen in Figure 1. **Didactic load** refers to instructional inefficiencies and task design characteristics, in line with the traditional definition and previous psychometric measures of extraneous load. **Peripheral load** refers to any cognitive burdens generated by factors external to the learning process, such as identity-related stressors, sociocultural pressures, external responsibilities, and physical or mental health concerns.

Dividing extraneous load allows CLT to retain its emphasis on the importance of optimizing instructional design, which has been supported by dozens of studies [2], while simultaneously encouraging future research to delve into other factors that influence learning. Making peripheral load measurable also enables instructional and institutional decision-makers to distinguish between learning barriers that can be addressed through pedagogy and those that require additional flexibility, coordination with support services, or structural intervention.

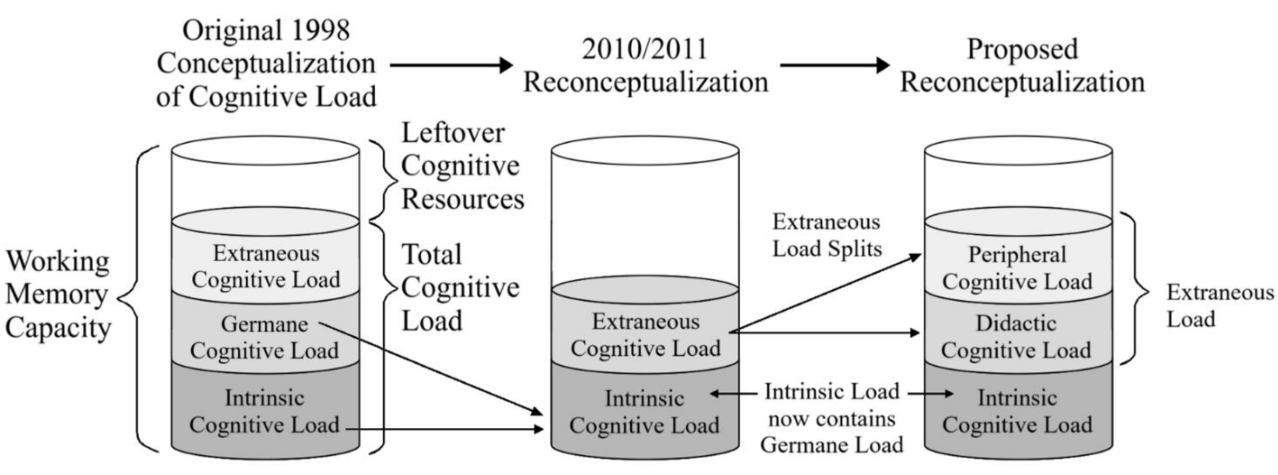

Figure 1. Historical and Proposed Reconceptualizations of Cognitive Load Theory.

Critical theories and other DEI related studies provide conceptual grounding for this reconceptualization. Frameworks such as Critical Race Theory, feminist theory, critical disability studies, and queer theory can be mapped onto the existing architecture of CLT to the emphasize how institutional structures and social norms impose unequal cognitive and emotional burdens on students [16], [17]. These theories explain why certain students must devote additional cognitive resources to navigating environments not designed with their identities or needs in mind.

By integrating these perspectives with CLT, this study reconceptualizes extraneous load to include not only instructional inefficiencies but also the cognitive demands imposed by social and contextual factors. This expanded framework preserves CLT's analytic rigor while extending its relevance to better encompass real-world learning environments.

Methodological Approach

This work-in-progress study employs a qualitative, instrument-development design focused on elaborating and operationalizing a novel construct within Cognitive Load Theory (CLT). Rather than introducing a new measurement framework, the study adapts an existing, widely used cognitive load instrument by retaining validated intrinsic and instruction-focused extraneous (didactic) load items while developing a complementary subscale to assess peripheral load. Data collection and analysis are projected to be completed by December 2026. The study proceeds in two phases: secondary analysis of existing interview data for construct elaboration and item generation, followed by cognitive interviews to evaluate item clarity and response-process alignment.

Secondary Data Sources

Item development is grounded in secondary data analysis of two de-identified interview datasets with undergraduate engineering students. These datasets were originally collected for separate research purposes but are well-suited for reanalysis given their rich descriptions of students' learning experiences and contextual pressures.

Master's Thesis Interviews: The first dataset consists of eight semi-structured interviews conducted by the author with undergraduate engineering students exploring their experiences with cognitive load in engineering courses compared to non-engineering courses [18]. Because participants lacked familiarity with CLT, they frequently described cognitive burdens that could not be explained solely by intrinsic or extraneous load. These patterns motivated further examination of a distinct category of cognitive burden aligned with peripheral load.

Narrative Interviews with Minoritized Engineering Students: The second dataset consists of twenty-one interview narratives drawn from a prior, multi-institutional study focused on the experiences of minoritized engineering students [8]. Although the original project did not explicitly examine cognitive load, participants frequently described identity-related stressors, sociocultural pressures, accessibility barriers, and competing responsibilities that interfered with their ability to focus, engage, or invest mental effort during learning activities. These descriptions align closely with the proposed construct of peripheral load.

Qualitative Analysis and Item Development

The analysis employs techniques commonly associated with grounded theory, including open coding, constant comparative analysis, and memo writing, to identify recurring patterns of cognitive load across both datasets. Rather than generating a new theory of learning, grounded-theory techniques are used here to extend and refine CLT by specifying a previously unmeasured dimension of extraneous load [19].

Secondary qualitative analysis will be conducted across both datasets using open coding to identify segments reflecting cognitive burden unrelated to task design or content complexity. Constant comparative analysis will be used to refine conceptual boundaries and identify recurring dimensions of peripheral load across contexts and student populations. Analytic memos will document emergent insights, boundary decisions, and points of overlap with existing CLT constructs.

Identified dimensions of peripheral load will then be synthesized thematically to generate candidate survey items. Item wording will intentionally reflect students' language and reported experiences while maintaining structural and tonal consistency with the original Leppink et al. instrument.

Expert Review and Cognitive Interviews

The resulting items will be reviewed and refined through expert consultation with scholars in engineering education, cognitive psychology, and critical theory to assess content validity, conceptual alignment, and potential overlap with intrinsic or didactic load. Following expert review, cognitive interviews with undergraduate engineering students will be conducted to examine item interpretation, clarity, and response-process alignment [20]. These interviews will use think-aloud protocols and targeted probes to assess how students comprehend items, retrieve relevant experiences, form judgments, and map those judgments onto response options.

The outcome will be a preliminarily refined peripheral load item set with evidence of content validity and response-process validity, designed to complement the retained intrinsic and didactic load subscales. An example of a preliminary peripheral load item, aligned in structure and tone to existing items, is: "Factors unrelated to the learning activity made it difficult for me to concentrate."

Conclusion

This work-in-progress study proposes and operationalizes a new dimension of cognitive load to capture the social, emotional, and contextual burdens that affect student learning but are not addressed by existing CLT measures. By integrating insights from critical theory with cognitive load research, this study expands the theoretical scope of CLT while preserving its empirical rigor.

Practically, the refined instrument will offer researchers and educators a more precise tool for identifying cognitive barriers to learning that addresses not only instructional design and inherent difficulty but also the broader conditions under which students learn. Ultimately, this work contributes to a more comprehensive and socially responsible understanding of cognitive load.

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