Chapter 7
Understanding and Identifying Cognitive Load in Networked Learning

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7.1 Introduction

Cognitive load theory (CLT) focuses on human cognition and the limitations of short-term memory. CLT seeks to appreciate the cognitive effort required to complete a learning task relative to the capacity of the short-term memory (Sweller 1988, 1994). It provides a framework for understanding practical implications for both the design of learning situations (sometimes called 'instructional design' or 'learning design') and the support and facilitation of learning (often called 'teaching'). As De Jong (2010) points out, CLT has supported the advancement of educational theory and practice by aiding in the explanation of a large set of experimental findings. The premise that underpins the application of CLT is as follows: by recognising and addressing (reducing or eliminating) instances of cognitive load in learning situations, educators can improve learners' ability to acquire and develop schema and, in doing so, support learning.

This chapter considers CLT in networked learning (NL) and seeks to provide guidance in the identification and description of instances of cognitive load in NL so that they can be addressed through design and teaching practices that specifically aim to reduce cognitive load in NL situations. This chapter is guided by two broad questions:

- How does cognitive load manifest in learning (in general)?
- How does cognitive load manifest in in networked learning (in particular)?

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This chapter is structured in three main sections: the first section provides the background to our exploration of CLT in the context of NL. It includes an overview of CLT and its development, an overview of NL and a definition of the problem that this chapter investigates, namely, that NL situations include instances of cognitive load that may not be present in other (e.g. face-to-face or on-campus) learning situations and therefore need to be identified and understood so they can be addressed. The second section explores common features of NL and identifies key sources of cognitive load in NL situations, thereby providing a basis for, firstly, understanding cognitive load in NL and, secondly, addressing it. The third section identifies a potential research agenda to guide further explorations of CLT in NL.

7.2 Background

7.2.1 Cognitive Load Theory

CLT postulates that the short-term memory has a limited capacity and exceeding this capacity may hinder learning (Chandler and Sweller 1991; Sweller 1988, 1994). The theory attempts to resolve the issue through the development of instructional techniques that are designed to reduce the demands placed on the working memory and maximising the available resources of the working memory when processing information (Sweller et al. 1998).

CLT suggests three types of cognitive load: intrinsic, extraneous and germane (De Jong 2010). Intrinsic cognitive load is the essential load associated with achieving intended learning outcomes in a specific learning task. It is the cognitive load that is necessary to acquire the skills and knowledge associated with the task. Once considered relatively fixed and not subject to influence, intrinsic cognitive load is now viewed as more dynamic than previously understood. As a feature of the relationship between the subjective learner and the task, intrinsic cognitive load can be altered through careful attention to the relationships between the learner, task and subject matter (Paas et al. 2003). Extraneous cognitive load is the load that is evoked that is not associated with the intended learning outcomes (De Jong 2010). Extraneous cognitive load is generated as a consequence of the presentation of the learning material as the learner attempts to make sense of information presented to them. This form of cognitive load can be altered by changing the design and presentation of the learning materials and tasks. Germane cognitive load is the load associated with processing information, the development of schemas and the automation of information processing tasks. Skills such as interpreting, differentiating and organising information are considered germane load (Mayer 2002). Germane cognitive load can be beneficial to the acquisition of knowledge and may enhance the learning process (Ayers 2006). It can also hinder learning when the addition of germane load exceeds the capacity of learners' working memory. As germane load is induced by learners' efforts to process and comprehend, it can be altered through the design of materials and activity (Brunken et al. 2003).

Significant in the development of CLT has been the investigation and clarification of the term *load* within a CLT paradigm. Recent work highlights two variations of the notion of load. The first variation centres on the learner and defines cognitive load in terms of effort that is exerted by the learner within the context of a learning task. The second variation centres on the task itself and defines load in terms of the complexity of the learning activity and the instructional constraints of the context (de Jong 2010, Paas 1992). Although these two views of load are related, it is important to differentiate between them to be able to identify cognitive load in NL.

Various tools have been developed to measure the multidimensional nature of cognitive load (Brünken et al. 2003, Daneman and Carpenter 1980, De Jong 2010). Both analytical and empirical methods have been developed. Analytical methods draw upon expert opinions or analysis of tasks and provide a subjective framework of data. Empirical methodologies use introspective rating scales, psychophysiological data (heart rate), pupil dilation and electroencephalography (EEG) to assess cognitive load (Paas et al. (2003). Some measures such as the NASA-TLX have been developed to quantify mental demand, as well as physical demand, temporal demand, performance and frustration (Sweller et al. 2011). CLT researchers have in general focused on introspective scales to rate mental effort (Paas 1992) or task difficulty (Ayres 2013). In particular, the use of a self-perceived reporting scale such as a Likert scale has become a common methodology (Ngu et al. 2015, Paas and Van Merriënboer 1993).

Two strategies are commonly used to address cognitive load. The first strategy is to reduce cognitive load. Careful attention to instances of cognitive load and alteration to the design and presentation of instructional materials can reduce the levels of cognitive load (see, for example, Chandler and Sweller 1991, De Jong 2010, Mayer and Moreno 2003, Paas et al. 2003). The consideration of CLT in educational design is a key to using this strategy. Educational design includes the overall conceptualisation of the learning process, the sequencing of learning tasks, the design of individual tasks and the presentation of both learning materials and tasks. Consideration of cognitive load in each of these stages of educational design and development can help reduce cognitive load. We expand on these points below.

The second strategy is to increase the cognitive capacity of the learner in order to maximise the acquisition schema. CLT draws upon dual-process theories to explain cognition operating on parallel 'controlled' and 'automatic' pathways (Paas and Van Merriënboer 1990, Sweller and Chandler (1994). The controlled pathway is conscious and slow and requires relatively more effort. The automatic pathway is faster, non-conscious and relatively effortless (Feldon 2007). In automatic processing, the effect of a particular automatised activity on cognitive load is present but limited, reducing 'working memory load by effectively bypassing working memory' (Mousavi et al. 2004, p. 319).

7.2.2 Networked Learning

As described by Goodyear et al. (2004), networked learning is 'learning in which information and communication technology is used to promote connections: between one learner and other learners; between learners and tutors; between a learning community and its resources' (p. 1). As the name implies, NL seeks to leverage the power of networks to facilitate learning as an active, social process.

The network component of NL refers not only to technology but also to social structures (i.e. 'networks') (see Fox 2002) in which relationships are structured by 'networked logic' and the accompanying notions of culture, production and experience (Castells 1996). Networked learners rely on connections with both resources and people (Steeples et al. 2002) because both are necessary for efficient and effective learning (Collins and Berge 1996).

The learning component of NL is informed by socially oriented learning theories, such as situated learning, situated cognition, socio-cultural approaches and community-based learning models (Jones and Asensio 2002). Learning in this context is inherently active, and learners' energy and attention are focused on production within connected community (or network) structure. Learning is a process of developing individual and shared understandings that inform changes in attitudes, beliefs, capabilities, knowledge structures and skills. Learning activity is facilitated by the connectivity provided by the network. Knowledge is embodied in practice, which is socially reproduced, supervised and modified over time (Brown and Duguid 2000). Notably, networked practices may represent a significant departure from more 'traditional' didactic, teacher-centric approaches, which remain commonplace on university campuses. The learner-centric orientation, and the associated attention to the learner, learner activity and learner experience (Jones and Steeples 2002) in NL, implies a different set of roles for course participants than in more traditional approaches (Hammond et al. 2002). The change in roles is not without its inherent conflicts related to power relations associated with the practicalities of assessment and educational administration (Trehan and Reynolds 2002). Understanding NL practice requires a careful unpicking of potentially new systems of activity. Moreover, extrapolating findings of educational research drawn from non-networked contexts requires a careful analysis of contextual factors, including the social and cultural systems in both contexts, in order to support decisions about the transferability of findings.

7.2.3 Defining the Problem

Throughout this chapter, cognitive load in NL is identified and explored to provide insight into how cognitive load may be addressed through specific attention to practical aspects of design, delivery and facilitation. Of interest are aspects of NL that have the potential to introduce additional cognitive load based on the nature of NL environments and networked activity. Identifying key features of NL that distinguish it from other learning situations, particularly placed-based contexts that may have been the subject of previous CLT research, has the potential to help NL practitioners to identify and address sources of cognitive load and thereby support and facilitate learning.

7.3 Discussion: Identifying Cognitive Load in Networked Learning

CLT provides a lens for understanding and addressing challenges that confront learners in NL situations. In terms of improving learning outcomes for networked learners, the focus of CLT is twofold: first, there is a responsibility for designers and teachers to identify, reduce or eliminate instances of cognitive load. By rationalising the cognitive load that learners experience, educators have an important opportunity to structure and support learning processes with less cognitive load. Second, there is an opportunity to support learners' cognition by supporting the development of automaticity in cognitive processes and thereby reducing the load learners' experience when confronted with complex tasks.

Steeples et al. (2002) describe an architecture for networked learning that centres on an educational setting in which the following are also situated: a) the learning environment, which may include both physical and virtual spaces in which learning activity takes place; b) learning tasks, which provide a specification for learner activity; and c) learner activity, which is the actual activity undertaken by learners in response to tasks. These features of NL architecture provide a framework to describe the sources of cognitive load that networked learners encounter. 'NL environments' is considered as the broad technical and social context for networked learning. Learning tasks are conceived as discrete units of specific learning activity (as opposed to 'learning' in general). While there is clearly an overlap among the learning environment (where learning activity takes place), the specific learning tasks (what learners are asked to do) and the learning activity (what learners *actually* do), these ideas have been separated in the analysis of the application of CLT to NL according to 'broad' (course-wide) considerations and task-specific considerations when distinguishing between the learning environment and learning tasks.

7.3.1 Cognitive Load in Networked Learning Environments

When contrasted with place-based learning environments, NL environments present learners with several challenging features. These include the use of mediating technologies; the demands of operating in highly connected, media-rich environments; a potentially unfamiliar social environment; and the demands of computer-mediated communication.

First, the use of mediating technologies represents a source of cognitive load as technologies add manifold demands on learners' cognitive processing. Networked learning environments, by definition, rely on the use of technology not only to connect learners but also to mediate activity.

Cognitive load can impact novice learners in unexpected ways – even before they enter the NL environment. For novice learners, a computer that simply does not turn on or freezes as it boots up may prove to induce cognitive load. Not knowing how to diagnose the problem and to find a solution may raise the level of cognitive load as the learner searches to find out what is happening. A failing modem or an unplugged keyboard, a mouse that is not correctly connected all require the use of valuable working memory resources in the attempt to operationalise the technology and answer the question: 'why isn't it working?' For an experienced user, this situation is generally easily remedied with the minimum use of working memory as both the solution to the problems and the problem-solving heuristic are automated in the long-term memory.

For novice learners, the experience of multiple technology interfaces in different software applications may add to their apprehension and possible cognitive load even before they attempt to engage with the interfaces. Learners who do not have the skills to navigate the multiple interfaces are more likely to experience significant demands on their cognitive functioning and problem-solving ability due to high levels of cognitive load. This load also inhibits their ability to make sense of and use a variety of technological tools that comprise the learning environment. As highlighted by Morrison and Anglin (2005), the load of learning about technology concurrent with learning about the subject matter should not be underestimated. Learners can be overwhelmed by multiple additional loads introduced by the demands of navigating hypertext environments with complex non-linear relationships between information (Kalyuga and Liu 2015, Zumbach and Mohraz 2008) and the possibility of technical failure with one or more of the required technologies. By contrast, for experienced users (or relative 'experts'), engaging with learning management systems, computer-mediated communications tools, social media platforms and content-specific computing applications does not add significant cognitive load.

Second, networked learners have the additional cognitive load of managing large amounts of rich, multi-modal information that is associated with highly connected networked environments. The additional load is a result of complexity. This point is significant because novice learners are attempting to deal with new and rich information. They have already used some of their working memory resources to understand and use the NL environment, so their cognitive resources are depleted. This depletion of working memory resources is further exacerbated when there is a potentially excessive number of elements or there are complex interrelationships between the elements (high element interactivity). This may further overload the working memory, impairing the ability to acquire and automate schemas (Paas et al. 2003). Network learning situations that have *low* element interactivity are less difficult to process and require fewer working memory resources. For network learners that engage in *high* element interactivity, the task is more difficult (in terms of information processing) and requires more working memory resources. Where a learner is processing several elements simultaneously such as a rich, multi-modal task, larger amounts of working memory are required. As Sweller (2010) suggests, 'The more elements that interact, the heavier the working memory load' (p. 124). Therefore, there is the potential for networked learners to experience overload when dealing with both the quantity and quality of information available, making discerning choices difficult about which information to use and the management of that information for ongoing use.

Third, in addition to the more 'technical' requirements of NL, there are important social and cultural implications of mediating technologies. Technologies introduce social and psychological distance between participants in interactive exchanges (Riva 2002). This distance creates a need for learners to reconsider the degrees of structure in their interactions; the type, amount and focus of their interactions; and the levels of autonomy that they are required to exercise in managing their learning activity (Dron 2007; Moore 1972, 1973). Orienting to this new social space and overcoming the social and psychological distance introduced by technology add cognitive load. For novice networked learners, additional cognitive load exists in every communicative and social act. Learning simple socially and culturally accepted communicative responses in an unfamiliar NL environment places additional stress on the learner. Within individual communications, concentrating attention on whether the salutation is acceptable or whether the interjection is correct takes away not only working memory resources but also the focus on the learning taking place. In wider communicative situations such as asynchronous discussions or synchronous conferencing, there are many social and cultural features that place demands on learners' cognitive resources, for example understanding the social and cultural conventions of participation, interpreting others' messages in the absence of familiar social cues and understanding and taking on particular roles in dynamic NL environments driven by social activity.

Fourth, computer-mediated communication, which may be the only communication channel available to networked learners, poses a risk of cognitive overload. Online communication requires familiarity with computer-mediated communications tools, often across different media. It requires a different set of communication skills, understanding of different communication protocols and interpretative skills. Researchers in online learning have documented the demands of technology-mediated communication, including the need to learn to read and interpret online social cues (Kehrwald 2008, Kreijns et al. 2004, Murphy 2004), the establishment of communication protocols (Palloff and Pratt 1999, 2001; Preece 2001), the development of social-relational mechanisms in online interpersonal interaction (Kehrwald 2010, Murphy 2004) and the pressure of goal-oriented online collaboration. As Kehrwald (2008) points out, online communication is a learned activity, and thus it represents an additional load to learning the intended subject matter. Abbreviations, acronyms, emojis and other mechanisms that 'humanise' the NL interaction are communication skills that need to be learnt. In some respect, it is akin to learning to speak a new language. For novice networked learners, communication comes with the same uncertainty as to whether the learner is using the correct tenor and tone of a language, whether the words and meaning they are using make sense, all while attempting to mediate a new technology.

Notably, these sources of cognitive load are *additional to* the cognitive load associated with learning the subject matter (Morrison and Anglin 2005). The important implication of this point is that in order to keep learners' effort and attention oriented toward the intended learning outcomes, educational designers have a responsibility to mitigate the potentially massive additional load introduced by networked learning environments.

7.3.2 Cognitive Load in Learning Tasks

Learning tasks represent a critical opportunity to influence learner activity. Thus, they are a key mechanism to address cognitive load with attention to the presentation of information, the creation of supportive structure, anticipation of learners' needs and the facilitation of productive learning activity.

The literature of CLT is rife with examples of extraneous load that emanates from the presentation of information (Brunken et al. 2003, Mayer and Moreno 2003, Moreno and Valdez 2005). As described by Chandler and Sweller (1991), the presentation of information without careful attention to cognitive load theory frequently results in high levels of extraneous cognitive load. Given the wide variety of media and modes of presentation that are employed in NL, the presentation of information is a potentially common source of extraneous cognitive load. Specific research has been undertaken investigating the relationship between cognitive load and multimedia. Of interest for NL is the effect upon learning when multiple sources of information were concurrently being treated by the working memory. The use of text, video, audio, still imagery and interactive multimedia derived from a variety of sources and used in combination as part of comprehensive packages of learning materials presents a significant risk in terms of the introduction of cognitive load (Brunken et al. 2003, Mayer and Moreno 2003, Moreno and Valdez 2005).

An important aspect of schema acquisition in multimedia learning is the splitting of a learner's attention across mutually dependent information sources. Research suggests that schema formation and learning can be negatively affected when even one more source of data is used concurrently (Chandler and Sweller 1991, Kalyuga et al. 1999). Notably, this occurs when the sources of information do not synchronise or support each other, and the learner is therefore required to search for semblances of connectivity between the data sources. Where text and diagrams are used, the 'split attention effect' can be overcome by strategically placing the text at an appropriate position, in relation to the diagram, synchronising both the text and diagram in a single integrated source of data, maximising the reinforcing effect of the text+visual combination and supporting meaning making.

A further effect upon schema acquisition occurs when texts and diagrams are accompanied by an auditory source. This effect is known as the 'modality effect'.

Researchers such as Mayer et al. (1998) found that the 'multi-media learners can integrate words and picture more easily when the words are presented auditorily rather than visually' (p. 312). The 'modality effect' affirms that when information is instructionally designed to minimise cognitive load and is presented from two differing sources, such as an auditory and visual source, schema formation and learning can be enhanced.

As with the use of mediating technologies, the presentation of learning tasks presents an opportunity for the introduction or, indeed the mitigation of, additional cognitive load. As described by Steeples et al. (2002), learning tasks specify and elicit learner activity. Each task 'needs to be sufficiently well-specified that the changes of the learner engaging in unproductive activity are kept within tolerable limits' (Steeples et al. 2002, p. 332). The focus on limiting unproductive activity highlights the potential for learning tasks to introduce additional cognitive load. When considered in combination with the presentation of information, the use of mediating technologies and the skills required for productive online communication, the presentation of learning tasks represents an opportunity to address several potential sources of cognitive load. A key consideration in the design and presentation of learning tasks is the goal of optimising the relationship between the learning activity and the cognitive load that is produced when learners engage with the task.

Central to the design of learning tasks is consideration of a learner's prior knowledge. As suggested by Vygotsky (1978), to successfully acquire schema, learners benefit from tasks that provide them engagement, are sympathetic to their previous experiences and are within their zone of proximal development. More specifically to NL, it is critical to understand the network of relations between a) the subjective learner, who has a unique perspective based on experience and prior knowledge; b) the learning task, which mediates subject matter, introduces structure and influences activity; and c) the networked learning community, which provides a social and cultural context for activity. Ideally, these relations support learning through the development of a network of connections that give the learner access to people, resources and tools that support learning. However, the complexity of these relations and the learner's abilities to make use of the relations (based on their unique combination of experience, skills and prior learning) make it very difficult to cater to each individual. NL designers need a repertoire of strategies to a) appreciate the complex relations present in networked learning situations, b) identify and accommodate the diversity of learners in a given NL situation and c) address instances of cognitive load arising in the learner-task relation. The design of learning tasks should acknowledge their past experiences and activate existing schema that can be recalled automatically. Using the principles of CLT to enhance the design of the technologically based learning while considering the prior knowledge of the learner invites the reduction of cognitive load that may enhance the acquisition of schema.

7.3.3 Cognitive Load in Learner Activity

Learner activity is central to the identification of cognitive load because all cognitive load is predicated on learner activity. The very nature of NL activity presents potentially novel demands on learners' cognitive processing abilities, including learners' efforts to 'learn to learn' on the network through the acquisition and automation of skills that support highly connected learning in networked environments.

Learning to learn online (or in NL) is a phenomenon that may be better understood through CLT. In his study of learning to learn online, Arbaugh (2004) highlights that 'while most indicators of online learning quality and effectiveness increase significantly as students take subsequent online courses, much of this increase occurs between the first and second online course' (Arbaugh 2004, p. 179). While Arbaugh did not indicate causality between student perceptions and cognitive load, cognitive load offers possible explanations. Central to the notion of learning to learn in NL is the idea of automaticity and learners' abilities to automate common learning activities, thereby freeing up capacity in their working memory. As learners orient themselves to highly connected, media-rich NL environments, they develop both skills and ways of working, which become automatic as they gain experience. While the initial learning curve may be quite steep for novice networked learners, the automation of NL activity reduces cognitive load as learners become more familiar with and more skilled at working in NL environments.

The second factor is a shift from more traditional roles in teaching-learning relationships to a more learner-centric arrangement with shared control and differing levels of learner autonomy and interdependence (see, for example, Garrison et al. 2000; Palloff and Pratt 1999, 2001). This arrangement creates the possibility of a much wider range of roles that learners may play in networked learning that are potentially more 'open', more democratic, more participatory and even more emancipatory than other more highly educationalised types of learning (Fox 2002). However, with these new, different or novel learning arrangements comes an associated need for learners to identify, understand and learn to act in new roles. So in addition to learning about technology and its application in NL, novice networked learners must also learn to be productive in technology-mediated social environments and take on potentially new roles as they participate in networked learning.

7.4 Conclusion and Directions for Future Research

This chapter explores the usefulness of CLT as a tool to help NL practitioners identify, understand and address difficulties experienced by networked learners. Using CLT as a lens to identify and understand learner experiences in NL environments has the potential to help NL practitioners refine their NL practices and, by extension, support learners. However, the understanding of CLT in NL is far from complete. Further work is needed to understand both the operation of NL environments and the application of CLT to activities in those environments. In order to help researchers continue the important work of applying CLT to NL, further research is needed.

First, investigating how cognitive load can be addressed through NL practices is central to understanding further the impact that CLT may have on improving NL engagement and learning. Research investigating on specific methods applying CLT principles to reduce the levels of cognitive load associated with the presentation of information in highly connected rich-media networked environments will help address what is potentially the most significant area of extraneous cognitive load – the presentation of information. Further work with the development of computer interfaces can provide a mechanism to benefit large numbers of networked learners by simplifying their learning about and interactions with mediating technologies. As suggested by Kalyuga and Liu (2015), 'With this (CL) theory, the technology-based learning environments could be better matched to the nature of human cognition (p. 4).'

Second, research into the use of instructional design techniques sympathetic to CLT and specifically targeting NL and engagement tasks also may provide further insight into improving the learning outcomes of network learners. In particular, the identification of either the split attention or modality effect and levels of element interactivity provide a basis to improve the online network learning experience.

Third, questions specific to NL such as 'What particular germane skills are more likely to benefit network learners and enhance their learning?' may provide insight into the maximising of the development of cognitive processing. While germane load can be generalised as the load associated with the processing information, development of schemas and the automation of information processing tasks there is a need to consider how this might be applied to NL. Researching a) whether there are skills and processes specific to network learning and b) how these might be developed could help inform the design of networked environments and tasks that better support cognitive processing in NL.

Fourth, further work is needed to understand learning to learn in NL from a CLT point of view. Understanding cognitive load experienced by novice learners informs about the development of environments and tasks that address extraneous load and support automaticity, which improves learners' cognitive capacity.

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