Information Overload in Technology-based Education: a Meta-Analysis

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ABSTRACT

Educational technology has transformed learning by facilitating collaboration with peers and teachers, enabling quick access to a wide range of information resources and the ability to create new information content. However, the ubiquitous nature and ease of use of technology leads to a plethora of recorded information. Processing this varied and often redundant information has overloaded students, which is detrimental to learning. The purpose of this paper is to review the literature related to the problem of information overload in the online educational domain, including causes, available solutions and its influence on knowledge construction. The results show that until recently the research focus has been on cognitive technological solutions rather than collaborative learning. New themes such as collaborative approaches for managing information overload and its implications on knowledge construction are emerging.

Keywords

Information overload, Information complexity, Cognitive overload, Cognitive load, E-learning, Multimedia, Hypermedia

INTRODUCTION

The use of technology in education has been widely adopted and is effectively being used as a medium of transmission of courses. However, the problem of information overload significantly impacts knowledge construction and student learning in online environments. The main purpose of this review is to achieve a deeper understanding of information overload in the educational domain and to highlight gaps in current research. We begin with an overview of educational technologies and of studies that report information overload as a problem.

E-learning, Computer Mediated Communication (CMC), Asynchronous Learning Networks (ALN), Multimedia Learning, and Hypermedia Learning are terms which are found in the research literature with respect to technology-based learning. E-learning is defined as instruction delivered on a digital device such as a computer or mobile device that is designed to support learning (Clark and Mayer, 2011). CMC provides a means of communication and interaction using computer networks among individuals and groups (Chen, Pedersen, and Murphy, 2011; Paulo, 1999). “An ALN is a teaching and learning environment located within a CMC system designed for anytime/anyplace use through computer networks” (Hiltz and Wellman, 1997). ALN is a student centered approach that facilitates virtual work space and virtual group interactions among the students in a class. Mayer and Moreno (2003) defined multimedia instruction as the design of instruction presenting words (printed text on screen, narration) and pictures (graphs, charts, photos, videos) that are intended to promote deep learning. Hypermedia is a computer-based application for accessing multimedia information resources. It supports use of multimedia resources and facilitates flexibility by offering numerous types of navigation support (Dunlap and Grabinger, 2012).

Many researchers have been able to demonstrate the problem of information overload or cognitive load with the use of educational technology (Burge, 1994; Chen et al., 2011; Harasim, 1987; Kear and Heap, 2007; Paulo, 1999). Information overload occurs when a large amount of information beyond one’s capacity to process is communicated. The use of advanced features of educational technologies has provided access to a richer and more complex information environment in a variety of formats and from different types of information resources. This proliferation of information has imposed information overload on students (Kalyuga, 2011; Sweller, Ayres, and Kalyuga, 2011).

The next section provides a description of the methodology used to find relevant papers. This is followed by a review of definitions of information overload, and a theoretical framework used to categorize the literature. Then we classify and discuss different causes of information overload and solutions to overcome this situation, and review the influence of...
Information overload on students’ learning and knowledge construction. The final section of this paper highlights the implications and recommendations for information overload research in the educational domain.

METHODOLOGY

Information overload is a critical problem that affects one’s ability to comprehend the subject matter because of communication of a large amount of information. To search for the relevant articles within the literature on information overload in the educational domain, the electronic database ERIC (Educational social science) VALE provided by EBSCO was used. This database links to more than 323,000 full-text documents. Information overload is interchangeably referred to in the literature by the terms “Information load” and “Cognitive load”. Therefore, the following keywords were used to search in the title with keywords: information overload, information load, cognitive overload, and cognitive load. The search retrieved 151 peer reviewed articles. An initial perusal of the abstracts indicated that not all of the papers retrieved by the keyword searches were related to educational technology. Some of the articles were related to applications of cognitive load theory and discussed information overload in very specific domains such as library science, the military, and mathematics. Keeping the focus of the paper in mind, 63 papers were selected for analysis.

OVERVIEW OF INFORMATION OVERLOAD

The problem of Information overload is frequently noted in the literature of various disciplines such as education, library science, MIS, organization science, accounting, and marketing. The following section presents a brief summary of various definitions of information overload in the educational domain.

Definitions of Information Overload

Information overload is defined by multiple authors in the literature within different contexts. In the context of educational technology, Fournier (1996) defined information overload as a condition resulting from an excess amount of information beyond an individual’s capacity. Chen, Pedersen, and Murphy (2011) in their investigation of the phenomenon of information overload in CMC education defined information overload as the point at which students’ working memory capacity is exceeded, and excessive information and stimuli from the CMC learning environment interfere with their learning.

The study of computer-mediated education by Burge proposed two causes of information overload: (1) the quantity and fragmentation of incoming information to be processed by students exceeds the time limit, and (2) students feel pressured to log on frequently to keep up with online discussions (Burge, 1994). Similarly, Hiltz and Turoff (1985) identified two main reasons for information overload in the context of organizational CMC: 1) communication of information beyond individuals’ processing capacity; and 2) information entropy, which occurs when communication is not organized and structured so that the relevance of the information can be recognized.

Bawden and Robinson (2009), in their meta-analysis article, have noted different “pathologies of information” in relation to the changing information environment with the advent of Web 2.0. “Information anxiety” is stress caused by the inability to access, understand, or make use of necessary information. This situation can occur as a result of information overload or insufficient information. Furthermore, it can also be caused by inadequately organized or presented information, or by a lack of understanding of the information environment in which one is working.

Sweller, van Merrienboer, and Paas (1998) used the term “cognitive load” to refer to the information load imposed on students’ working memory while learning. Their cognitive load theory proposes that an individual’s brain has limited working memory with respect to the amount of information it can hold and process at one time without overloading its processing capacity. Cognitive load theory classifies cognitive load into three different categories: intrinsic, extraneous, and germane (Paas, Renkl, and Sweller, 2003). Intrinsic cognitive load is associated with the stress on working memory capacity imposed inherently by the difficulty of the learning material. This type of load cannot be reduced by instructional manipulations. The second category is extraneous cognitive load which occurs due to instructional procedures. This type of load can be reduced by implementing alternative instructional designs and procedures. Germane or effective cognitive load refers to the load imposed by the presentation of information to learners and learning activities of learners. In contrast to extraneous cognitive load that interferes with learning, germane cognitive load enhances learning. Intrinsic, extraneous and germane cognitive load constitute total cognitive load, which should not exceed working memory.
Theoretical Underpinnings and Classification Framework

To provide a more comprehensive and complete review of the research conducted on information overload in educational technology, a classification framework is developed. Figure 1 shows the framework that has three main components associated with information overload: the factors causing information overload, solutions for information overload, and knowledge construction. Eppler and Mengis (2004), in their review of management-related publications on information overload, proposed a conceptual framework. This framework classified literature on information overload into topic clusters of factors, symptoms, and countermeasures of information overload. However, the proposed framework shown in Figure 1 classifies studies on factors causing information overload in education literature into three groups: cognitive, affective and psychomotor factors. Similarly, studies on solutions for information overload are classified into three groups: cognitive, collaborative and meta-cognitive tools. Furthermore, this framework identifies the relationship between factors and solutions of information overload and knowledge construction.

Factors of information overload refer to various causes of information overload and are classified based on Bloom’s taxonomy into three domains: cognitive, affective, and psychomotor (Bloom, 1956). The affective domain includes the way in which an individual deals with things emotionally, such as feelings, values, appreciation, enthusiasms, motivations, and attitudes. The cognitive domain is related to the development of intellectual skills and the acquisition of knowledge. The psychomotor domain includes physical movement, coordination, and the use of the motor-skill areas.

The next component of the framework comprises solutions for information overload. In the review of the literature it was found that solutions to reduce information overload are studied in the three areas: cognitive, collaborative and meta-cognitive. Therefore, as shown in Figure 1, solutions for information overload are classified into these three categories. Cognitive tools refer to the computer-based tools or application that scaffold and facilitate knowledge construction by engaging learners in complex cognitive activities and higher order thinking (Kirschner and Erkens, 2006). Collaborative tools include tools that facilitate learning from collaboration with peers (Dillenbourg, 1999). Collaboration among peers generates additional critical thinking activities that result in effective learning and reduces cognitive load. Meta-cognitive tools or strategies refer to learners’ ability to apply existing knowledge and take control of their learning process, including planning, monitoring, and evaluating processes.

The final component of the framework is knowledge construction, a process whereby learners make sense of the information. It involves organizing information, generating ideas, and building understanding of concepts. The arrow between factors and knowledge construction indicates that the factors causing information overload also affect knowledge construction. Similarly, the arrow between solutions and knowledge construction signifies that tools or strategies created to reduce information overload may in turn influence effective learning or knowledge construction.

Figure 1 Classification framework for research
Factors causing Information Overload

The main causes of information overload can be classified into three main categories: cognitive factors, affective factors and psychomotor factors, as shown in Figure 1. Factors within the affective categories are mainly related to personal beliefs such as attitude towards the subject and an individual’s epistemological beliefs. Factors related to the cognitive domain include lack of prior subject knowledge, task complexity, lack of technical skills, and lack of English proficiency. In the psychomotor domain methods of instruction, redundant information, and time constraints were found to influence information overload in technology-based education. Table 1 provides a consolidated list with references for factors causing information overload, classified based on the framework shown in Figure 1.

Scheiter, Gerjets, Vollmann, and Catrambone (2009) examined several affective factors causing information overload in technological education. One of the important factors is learners’ epistemological beliefs: beliefs related to certainty of knowledge, knowledge acquisition as an orderly process, and beliefs related to quick learning. Furthermore, attitude towards the subject such as values, motivation, enjoyment and confidence was found to be influencing the formation of information overload. Specifically, learners with negative epistemological beliefs and low motivation for the subject were found to be more vulnerable to information overload.

Cognitive skills such as insufficient prior subject knowledge and inadequate English proficiency were found to be other important factors in determining the cause of information overload. Several researchers noted that insufficient prior subject knowledge increased perceived information overload (Artino, 2008; Chen et al., 2011; Scheiter et al., 2009).

A pair of papers by Chen, Pedersen, and Murphy (2011, 2012) is based on a study of 12 students in two graduate courses in Education. Courses that were reading and writing intensive, and integrated required discussions. Though based on a small number of students, the study is notable for combining data from questionnaires, interviews, and analysis of discussion transcripts, and also for its investigation of both the causes of information overload in online courses, and its effects on learning in terms of knowledge construction. The first of the papers (2011) reports that several learner characteristics were associated with reporting information overload including inadequate prior knowledge of the course topic, inadequate English proficiency, and lack of technical skills for participating in computer-mediated communication.

Psychomotor factors involve physical factors such as gender, age and motor-skills required to deal with redundant information, time compressed instruction and method of presentations. Chang and Yang (2010) explored gender differences in multimedia-enabled instruction and found that males felt more overload while reading scientific articles as compared to females. Murray and Thomson (2011) found that cognitive load increases with age; in audio-visual tasks, younger-age groups performed better than the older-age groups. Other psychomotor factors are related to motor-skills required to deal with redundant information and time compressed instruction. Several studies found that learners presented with redundant information or multiple resources for information perceived higher cognitive load (Pastore, 2012; Sweller, Ayres, and Kalyuga, 2011). Furthermore, other factors include motor-skills required to deal with minimally guided instruction and method of instruction (visual or acoustic).

<table>
<thead>
<tr>
<th>Domain</th>
<th>Factors</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affective</td>
<td>Epistemological beliefs - Certainty of knowledge, Orderly process, Quick learning</td>
<td>(Scheiter et al., 2009)</td>
</tr>
<tr>
<td></td>
<td>Attitudes towards subject- Value, Motivation, Enjoyment, Confidence</td>
<td>(Scheiter et al., 2009)</td>
</tr>
<tr>
<td></td>
<td>Satisfaction</td>
<td>(Bradford, 2011)</td>
</tr>
<tr>
<td>Cognitive</td>
<td>Inadequate prior knowledge</td>
<td>(Artino, 2008; Chen et al., 2011; Scheiter et al., 2009)</td>
</tr>
<tr>
<td></td>
<td>Inadequate English proficiency</td>
<td>(Chen et al., 2011)</td>
</tr>
<tr>
<td></td>
<td>Task complexity</td>
<td>(Chang and Yang, 2010)</td>
</tr>
</tbody>
</table>
Table 1 Summary of factors causing information overload

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<thead>
<tr>
<th>Domain</th>
<th>Factors</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Lack of technical skills</td>
<td>(Chen et al., 2011)</td>
</tr>
<tr>
<td>Psycho-motor</td>
<td>Gender</td>
<td>(Chang and Yang, 2010)</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>(Murray and Thomson, 2011)</td>
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<tr>
<td></td>
<td>Method of presentation- acoustic, visual</td>
<td>(Artino, 2008; Murray and Thomson, 2011)</td>
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<tr>
<td></td>
<td>Minimally-guided</td>
<td>(Artino, 2008)</td>
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<tr>
<td></td>
<td>Time compressed instruction</td>
<td>(Pastore, 2012)</td>
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<tr>
<td></td>
<td>Redundant Information</td>
<td>(Pastore, 2012; Sweller et al., 2011)</td>
</tr>
<tr>
<td></td>
<td>Split attention due to multiple sources of information</td>
<td>(Sweller et al., 2011)</td>
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Solutions for Information Overload

The solutions for information overload are classified into three categories: cognitive, collaborative and meta-cognitive tools. Cognitive tools include software tools: animation tools, concept maps, and computer simulations. Collaborative tools include computer mediated conferencing and weblogs which facilitate teamwork among groups of people. Finally, meta-cognitive tools refer to the strategies to manage personal information. Table 2 provides a consolidated list of solutions for information overload in the literature of technology-based education.

In terms of cognitive tools, many studies investigated the use of different interfaces and presentation modes to reduce cognitive load and support effective learning. Martin-Michiellot and Mendelsohn (2000) studied the effects of a graphical user interface on students’ learning and cognitive load and found that a graphical interface that integrated visuals and text was more effective and provided faster learning. In addition to various interfaces, cognitive tools include various instructional strategies employed to manage cognitive load. For example, Gerjets, Scheiter, and Catrambone (2004) found that cognitive load can be reduced by using modular examples i.e. by dividing a complex solution into small meaningful solutions. Explanatory feedback is another strategy that provides deeper learning and helps in reduction of working memory load of students (Moreno, 2004). Electronic portfolios (eportfolios) is another strategy; Shepherd and Bolliger (2011) reported that the task of eportfolios increased workload, and mental demands, but cognitive load was reduced with time. Furthermore, this study suggested that the eportfolio can reduce extraneous cognitive load and advance learning by providing a way to organize, archive and reflect on the learning material.

In regard to collaborative tools, Harasim (1987) studied the use of computer conferencing in online education. In this study students reported that learning via computer conferencing provided them access to group knowledge and interaction resulting in effective learning. Furthermore, students reported information overload as one of the major concerns in computer conferencing. Hiltz and Turoff (1985) suggested various behavioral strategies: filtering and scanning features, voting structures, length limitation, and notifications, to manage information overload. More recently, Huang, Huang, and Yu (2011) investigated the effects of the use of a weblogging system in higher education to provide students with asynchronous cooperative learning environments. The results of the study indicated that various features of the weblog facilitated cooperative learning from peers, reduced cognitive load, reduced time-lag, and increased effective learning. For example, the
RSS feature of a weblog reduced time lag in delivering materials and the keyword search feature provided filtering of redundant information.

Another important strategy to manage cognitive load is the use of meta-cognitive skills, referring to an individual’s consciousness, knowledge, and control of cognitive processes. Kalyuga (2009) reported that students with advanced meta-cognitive and self-regulation skills may significantly benefit from learning environments. Cognitive load theory (CLT) introduced by Sweller et al. is an instructional design theory that provides many instructional design strategies to reduce cognitive load in instruction (Sweller et al., 1998). Some of these techniques help in reducing extraneous cognitive load by reducing redundant information.

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Strategies/Tools</th>
<th>References</th>
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<tbody>
<tr>
<td><strong>Cognitive/Software Tools</strong></td>
<td>Multimedia (Mixing auditory and visual presentation modes)</td>
<td>(Verhoeven, Schnott, and Paas, 2009)</td>
</tr>
<tr>
<td></td>
<td>Graphical Computer Interface</td>
<td>(Martin-Michiellot and Mendelsohn, 2000)</td>
</tr>
<tr>
<td></td>
<td>Modular instructional examples</td>
<td>(Gerjets et al., 2004)</td>
</tr>
<tr>
<td></td>
<td>Explanatory Feedback</td>
<td>(Moreno, 2004)</td>
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<tr>
<td></td>
<td>Computer based simulation</td>
<td>(Lee, Plass, and Homer, 2006; Liu and Su, 2011)</td>
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<tr>
<td></td>
<td>Animations</td>
<td>(Schar and Zimmermann, 2007; Wouters, Paas, and van Merrienboer, 2008)</td>
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<tr>
<td></td>
<td>Integrated instructions with text and illustration</td>
<td>(Haslam and hamilton, 2010)</td>
</tr>
<tr>
<td></td>
<td>Eportfolio</td>
<td>(Shepherd and Bolliger, 2011)</td>
</tr>
<tr>
<td></td>
<td>Metaphorical interface</td>
<td>(Cheon and Grant, 2012)</td>
</tr>
<tr>
<td><strong>Collaborative Tools</strong></td>
<td>Computer conferencing</td>
<td>(Harasim, 1987; Hiltz and Turoff, 1985)</td>
</tr>
<tr>
<td></td>
<td>Collaborative Learning</td>
<td>(F. Kirschner, Paas, and Kirschner, 2009)</td>
</tr>
<tr>
<td></td>
<td>Cooperative Weblog</td>
<td>(Huang et al., 2011)</td>
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<td></td>
<td>- RSS feed</td>
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<td></td>
<td>- Keyword search</td>
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<tr>
<td><strong>Meta-cognitive Tools</strong></td>
<td>Meta-cognitive skills</td>
<td>(Kalyuga, 2009)</td>
</tr>
<tr>
<td></td>
<td>Instructional design principles</td>
<td>(Sweller et al., 1998)</td>
</tr>
<tr>
<td></td>
<td>Cognitive Load in Multimedia Learning</td>
<td>(Mayer and Moreno, 2003)</td>
</tr>
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</table>

Table 2 Summary of solutions for information overload

Influence of Information overload on knowledge construction
The framework in Figure 1 shows that the various factors causing information overload also affect knowledge construction. Scheiter et al. (2009) found that factors related to learners’ characteristics (prior knowledge, epistemological beliefs, attitudes towards subject) significantly impacted knowledge construction; higher prior knowledge, positive attitudes and stronger epistemological beliefs resulted in deeper learning. Similarly, Artino (2008) studied the influence of learner’s experience and prior knowledge on learning outcomes. More recently, Pastore (2012) examined the effects of time-compressed instruction and redundancy on learning and found that redundancy in instruction significantly impacted performance of students.

Furthermore, according to the framework, information overload influences knowledge construction or learning of students. Chen, Pedersen, and Murphy (2012) investigated the impact of students’ perceived information overload on their participation and knowledge construction with respect to cognitive and meta-cognitive processing in online discussions. The transcripts of class discussions were coded using Henri’s (1992) methods as modified by Perkins and Murphy (2006), which resulted in counts of the number and length of discussion contributions by each student, and a measure of the level of cognitive skill demonstrated in the contributions. The data suggest that perceived information overload “may” have affected the level of participation negatively as well as the students’ level of cognitive skills (knowledge construction). Also, students with more meta-cognitive skills tended to process a larger amount of information and achieve deeper learning. These results lend support to our model and strongly suggest the need for further studies with larger numbers of students.

Finally, a number of studies have examined the influence of various cognitive and collaborative tools on students’ learning or knowledge Dwyer and Dwyer (2006) found that the use of an animation technique in learning content helped in attaining different kinds of learning objectives of students and facilitated knowledge acquisition. Similarly, Wouters et al. (2008) argued that animated models can be an effective instructional method, provided that they are designed in an optimal way. Amadieu et al. (2009) studied the effects of prior knowledge and digital concept maps on cognitive load and students’ knowledge acquisition. It was found that students having low prior knowledge and those with high prior knowledge gained significant factual knowledge from concept maps and had to invest less mental effort in processing them.

**DISCUSSION AND RECOMMENDATIONS**

This literature review indicates that causes of information overload can be classified in three main categories: cognitive factors, affective factors and psychomotor factors. Prior subject knowledge and redundant information are found to be the most critical factors determining information overload. Many cognitive software tools, including graphical user interfaces, multimedia, and digital concept maps, have been developed to manage information overload. However, few collaborative approaches have been investigated to manage the problem of information overload. Following are specific recommendations for future research.

**Recommendation 1:** Practitioners should explore the different types of meta-cognitive and example utilization strategies to manage cognitive load.

Chang and Yang (2010) found that the instructional activities that involved complex tasks (scientific articles, online notebook) increased cognitive load on students whereas, interactive activities such as video and chat rooms considerably reduced the cognitive load on students. This finding implies that more interactive tasks should be included in the process of learning. Furthermore, the review also showed that few collaborative tools have been studied for managing information overload and deep learning.

**Recommendation 2:** Researchers should explore more interactive and collaborative approaches to manage information overload and increase effective learning.

To understand the problem of information overload and provide better solutions to overcome it, researchers should analyze the relationship between different types of cognitive load (intrinsic, extraneous, and germane) and the process of deep learning and knowledge construction. Our literature review (Table 2) indicates that researchers have focused on developing tools and strategies to reduce intrinsic and extraneous cognitive load. However, the strategies and learning activities that increase germane cognitive load have not been studied in depth.

**Recommendation 3:** Researchers should investigate the learning activities that increase germane cognitive load that will lead to knowledge construction and deeper learning in students.
LIMITATIONS AND CONCLUSION

We searched only one database for keywords (information overload, information load, cognitive overload, and cognitive load), only in the titles. Furthermore, articles related to library studies, military studies, and specific pedagogical subjects were excluded. Though this review cannot claim to be exhaustive, it provides insights into the current state of information overload research. The classification framework and descriptive review can provide a useful reference source for researchers. Furthermore, it provides implications and suggestions for future research to practitioners. Finally, this study contributes to our understanding of the phenomena of information overload and the recent research on countering it.

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REFERENCES


