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Students' cognitive load in online education, under the lens of learning theories

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ABSTRACT. There is a link between learning theories and online education in the sense that the use of certain e-Tools available in educational platforms could be biased by the epistemological beliefs of the teachers. The complexity of the educational message, in relation to the biased e-Tools selection for the learning task, together with the information processing that derives from the learning activity contributes to the intrinsic cognitive load. In order to optimize this cognitive load that can reach a high and an undesirable level for learning, this article aims to bridge online learning with the main theories of learning and cognitive load theory. The triangulation of these data, based on several sources from the specialized literature, provides an extended picture of the dominant cognitive processes determined by the tools used in the online learning space. This article could represent a source for the theoretical foundation of an online learning instructional design and for placing the online education closer to methodology, rather than technology.

Keywords: online learning, instructional design, cognitive load, information processing, learning theories

ZUSAMMENFASUNG. Es besteht eine Verbindung zwischen Lerntheorien und Online-Bildung in dem Sinne, dass die Verwendung bestimmter auf Bildungsplattformen verfügbarer E-Tools durch die erkenntnistheoretischen Überzeugungen der Lehrer verzerrt sein könnte. Die Komplexität der sich daraus ergebenden pädagogischen Botschaft in Bezug auf die voreingenommene E-Tools-Auswahl trägt zusammen mit der Informationsverarbeitung, die sich aus der Lernaktivität ergibt und in direktem Zusammenhang mit den Lernzielen steht, zur intrinsischen kognitiven Belastung bei. Um diese kognitive Belastung zu

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optimieren, die ein hohes und für das Lernen unerwünschtes Niveau erreichen kann, zielt der Beitrag darauf ab, Online-Lernen mit Theorien zum Lernen und zur kognitiven Belastung zu verbinden. Die Triangulation dieser Daten, die aus verschiedenen Quellen der Fachliteratur entnommen wurden, liefert ein erweitertes Bild der vorherrschenden, nicht erschöpfenden kognitiven Prozesse, die durch die im Online-Lernraum verwendeten Tools bestimmt werden. Die neue Ausrichtung des Beitrags kann eine Inspirationsquelle für die Gestaltung von Lehrverfahren für das Online-Lernen sein, wobei die Online-Ausbildung eher mit der Methodik als mit der Technologie in Verbindung gebracht wird.

Schlüsselworte: Online-Lernen, Unterrichtsdesign, kognitive Belastung, Informationsverarbeitung, Lerntheorien

Introduction

Nowadays, the education process replaces its 2D educational resources with the 3D ones. For example, a geography lesson uses or will use virtual reality to present mountains, computer-based media being more meaningful than illustrating a landscape of the same mountains, which represents an operational connection of the taught content with the practical aspects that can derive from it. Not only in this case, but in any domain, the use of digital technologies promises to be a contributor to the construction of knowledge but does not provide assurances that this will be fulfilled. It is not enough for a school to be equipped with digital technologies and to emphasize technical aspects, so that teaching increases in quality and learning becomes faster and more efficient (Glava, 2009; Koper 2014).

However, when such achievements are realized, the teaching-learning process has been improved, and the introduction of digital technologies in the didactic activity comes with this premise. The facilitation of communication through the development of the Internet and the possibilities of sharing information, has led to more frequent and varied possibilities of interaction than in any other period of humanity (Woo & Reeves, 2007). Online education finds itself in this framework where it is said that the interactions are not necessarily better, but they are more frequent, but in order to be as good or better, something more is needed.

Conducting education online is not enough to benefit from the opportunities offered by the use of technologies, which is why the usual teaching practices need to be upgraded. There is a consensus among researchers, professionals, teachers that the approach of introducing technologies in the teaching act, for

example to support creativity, both in thinking and in practice, is not an approach that is limited to technical aspects. The development of digital technologies is an opportunity for the development of innovative pedagogical practices, which are adopted in the didactic activity, in a student-centred teaching approach and which is reflected in the development of transversal skills (Kempylis & Berki, 2014). In essence, a logistics of material resources adapted to online education is not enough, but this education must be delivered in the parameters that nurture the highest thinking skills so that the didactic activity leads to effective learning, but which also takes into account of the cognitive load that the workload entails, given the fact that in modern life it is talked about "burnout", and in study, about "academic fatigue".

In this sense, the present article gives a three-dimensional perspective for the didactic process, on three dimensions applied in pedagogy: online education – cognitive load – learning theories. The conjunction of learning theories with online education through the lens of thinking skills involved in this intersection is a revised version of the two-dimensional conjunction made in 2021 (Andronache & Bănuț, 2021), which tries to provide teachers with leverage to increase the quality of education delivered digitally. In the first form, the use of digital technologies in didactic methodology had two dimensions (online education and learning theories), to which the third dimension is added in this article, the cognitive load derived from the work load, because a wider and more detailed range of learning determinants supports instructional design work and its implementation in the classroom. "We need to invent Digital Native methodologies for all subjects, at all levels" (Prensky, 2001), and the bridging of learning theories with online school supports this statement, considering certain limits of students, technology and methodology. In this sense, the purpose of this paper is to relate the tools and the possibilities that the Learning Management System (LMS) offers, with the type of cognitive effort that the use of those tools implies, along with the instructional implications that derive from this, through the perspective of the most frequently employed theories of learning.

The online educational process, between methodology and technology

Learning theories determine epistemological beliefs, and teachers embrace some of them. Depending on the epistemological beliefs someone enters the classroom with, learning and learning experiences will be influenced. This way, the adoption of a learning theory modifies, to some extent, educational opportunities and experiences, and influences in this regard are both the way the courses are organized, whether they are face-to-face or online, as well as the cognitive load that must be to be taken up by the student in the resulting

learning framework. The present paper brings these three dimensions into harmony, to evaluate possible effects of online learning on cognitive processes.

The specialized literature highlights various explanations regarding the realization of the learning process, explanations which are synthesized in various theories of learning. Because learning is an extremely complex process and can be studied from various points of view: pedagogical, psychological, neurological, sociological, philosophical, or even by reference to technology, since it is stated that educational materials incorporating new media are superior to traditional presentations (Wong et al., 2007), it is obvious that the explanatory theories of this process can also be multiple.

Analysing the specialized, psychological, and pedagogical literature, we can find that the most consistent theories from a scientific point of view and that offer the strongest explanatory models on learning are the behaviourist theory, the cognitivist theory, the constructivist theory and the social-constructivist theory. Although these theories of learning offer diverse and complex explanatory perspectives, behaviourism, without mentioning its exponents, even if recognizing its significant contributions in psychology, has been criticized for various limits, the most important of them being that it sees learning only through the lens of observable and measurable behaviours, hence most studies had animals as subjects (Mayer, 2019), without focusing on explaining the intrinsic experiences of the individual. For these reasons, in the present paper, increased attention will be paid only to cognitivism, constructivism and social constructivism, aiming to highlight how they can lead to a certain cognitive load in a framework for conducting online courses. The resulting interrelationships could be capitalized in the online education process, by adapting online training practices to solutions advanced by learning theories, to develop instructional procedures that do not put pressure on limited human working memory capacities, in terms of information processing (Sweller, 2011).

Online learning

Because the paper represents an approach from the perspective of instructional design specific to online learning, the role of digital technologies in this process will be discussed, especially since the number of university-level online courses is on a strong upward trend, and universities are registering requests in offering new such courses where students learn online (Dao, 2020).

Online learning is defined as instruction delivered and facilitated through digital devices (Mayer, 2019) and which determines multimedia learning environments using computer, mobile, virtual reality (Mutlu-Bayraktar et al., 2019), along with internet connection (Mbati, 2012), thus we can say about online

learning that it is learning that takes place in a technology-rich environment. Considering that today's children, teenagers and young adults have grown up with digital technologies, there is a common characteristic in their development for which online education is now considered a necessity (Mbati, 2012). As this form of education is expected to continue to grow, the theoretical and practical aspects of online teaching will continue to be important for the future, not just for now (Mayer, 2019).

Through an analogy between online learning and the one carried out in a traditional classroom, in the school space, which is based on arguments derived from research carried out in the field, it is stated that online learning provides more support for conceptual learning and less for procedural learning (Parker & Gemino, 2001, as cited by Swan, 2005). In this regard, the following section is dedicated to some aspects that have the potential to facilitate learning carried out in the online environment, to achieve the same learning objectives that could be established for educational processes carried out traditionally.

The theoretical relationship between learning objectives and cognitive load, on the way of multimedia learning

Cognitive Load Theory (CLT) is a framework in educational psychology and instructional design that explores how the cognitive load imposed on a learner's working memory affects their ability to learn and retain new information. The theory was first developed by John Sweller in the late 1980s and since then it has been widely studied and applied in various educational contexts.

In an online learning environment, the technologies and the teacher have a common role, as a facilitator of learning (Huang, 2002), but both elements of the didactic process can bring an unwanted cognitive load in the learning process, described by Cognitive Load Theory (Sweller, 2011; Sweller, 2020). The teaching practices that can lead to such an effect must be known so that, indeed, both digital technologies and the instructor have a role of facilitator in learning.

The cognitive load is the amount of information that the educational message contains, and that the working memory must process before sending it to long-term memory storage (Sweller, 2011; Sweller, 2020). The theory addresses the instructional process by the fact that it aims for facilitating the absorption of information from the environment, under the conditions of a working memory limited in capacity and duration (Mayer, 2019; Mutlu-Bayraktar et al., 2019; Sweller, 2020). The efficiency of learning being conditioned by these limits, the instructional design involves filtering the information to be transmitted, by identifying and eliminating those that are not necessary, so that the acquisition of new knowledge is facilitated by a reduction of the working memory load (Sweller, 2020). So, the main idea behind Cognitive Load Theory is that working

memory, the cognitive system responsible for temporarily holding and processing information, has limited capacity. When learners are exposed to instructional materials or tasks that exceed their working memory capacity, it can lead to cognitive overload and hinder effective learning. To optimize learning outcomes, instructional designers and educators aim to manage and minimize cognitive load. The Cognitive Load Theory emphasizes the importance of building mental schemes or mental structures that help learners organize and process information efficiently. As learners become more familiar with a subject, they can automate certain cognitive processes, reducing the cognitive load associated with basic tasks and freeing up cognitive resources for more complex learning (Mayer, & Moreno, 2003; Kirschner, Sweller, & Clark, 2006).

In the teaching-learning process, a series of information interferes, resulting in an interactivity of the elements that is reflected in the total cognitive load perceived in learning and which is presented to be of three types: extraneous cognitive load, intrinsic cognitive load, and germane cognitive load (Sweller, 2020). The biggest load comes from extraneous cognitive load (Sweller, 2020), determined by the teaching practice and the way the course topic is presented, with reference to the information the student has to process and which does not support the learning objectives (Dao, 2020; Lewis, 2016; Mayer, 2019; Sweller, 2020), the mentioned authors and the specialized literature discussing this aspect quite a lot, trying to identify effects of excessive presentations. The intention of this paper is to discuss another side of the cognitive load originating from the didactic process, less debated, namely intrinsic cognitive load. This type of cognitive load is determined by the complexity reached by the didactic materials, and which involuntarily increases the informational volume that subsumes the learning objectives. This is the inherent complexity of the material being learned and depends on the nature of the content (Dao, 2020; Mayer, 2019; Sweller, 2020).

Learning is a complex process that involves various types of information processing: psychomotor (written), visual (reading), auditory (spoken), and this information is not only taken through various sensory channels, but also processed differently (Lehmann & Seufert, 2018). The emergence and development of digital technologies greatly animated the transmission of this information, providing the context for the development of the cognitive theory of multimedia learning (Mayer, 2019), which aims for improving teaching and learning in information environments that stimulate at least two of the mentioned sensory channels (Mutlu-Bayraktar et al., 2019). The online education can be enrolled into this framework.

In the context of multimedia learning and the presence of graphic and text elements, it is argued that learning is achieved better if the narrative presentation of the text elements is used, at the expense of its visual exposure, because otherwise both elements should be exposed to the same sensory

memory, the eyes (Mayer, 2019). When this interference is avoided at the level of sensory channels, from the perspective of cognitive load theory, it translates into a modality effect, with effects on working memory, the information fitting better within its limits (Sweller, 2020). Therefore, in online education, the way the content is presented is very important. To minimize extraneous cognitive load, instructional materials should be organized, clearly, and easy to navigate. Information should be chunked into manageable segments, and multimedia elements (videos, images etc.) should be used judiciously to enhance understanding without overloading students. (Kalyuga, Ayres, Chandler, & Sweller, 2003; Sweller, Kirschner, & Clark, 2007)

In direct relation to the specificities of working memory, it is stated that auditory processing leads to better understanding, and visual processing (reading) to greater attention to details (Lehmann & Seufert, 2018), which favours the analysis and evaluation of the materials presented, and these are learning objectives within the revised version of Bloom's Taxonomy (Krathwohl, 2002). In this revised version, on the dimension of cognitive processes, six categories are described, in the following hierarchy: remember, understand, apply, analyse, evaluate, and create. The belief behind these categories is that they differ in complexity, with the hierarchy starting from the least complex, remembering and understanding requiring less cognitive activity, and gradually moving towards more and more complex levels (Krathwohl, 2002; Jensen et al., 2019).

Therefore, cognitive involvement in tasks aimed at different educational objectives also means different cognitive activity and even if the presentation of multimedia materials approaches the sphere of extraneous cognitive load, when the information depends on the complexity of the materials created and is closely related with the educational objectives, its volume fits better into the intrinsic cognitive load category (Mayer, 2019; Sweller, 2020). Online learning abounds in multimedia materials that transform cognitive load into a permanent variable, which is why the need for a new taxonomy created at the border between Bloom's Taxonomy cognitive skills and cognitive load has been suggested (Philips et al., 2019). There have even been attempts to intrinsically reduce cognitive load through reporting and using the levels of Bloom's taxonomy (Dao, 2020) in which the positive aspects resulting from the research were presented and discussed.

Thus, the effort made to achieve different educational objectives can present different cognitive loads, and the educational process can be directed towards different educational objectives depending on the epistemological beliefs, derived from various learning theories, with which the teacher enters the classroom. Because "the ultimate goal of all teachers should be to facilitate the use of computers and computing technologies as mind tools (cognitive tools) to accompany thinking, reasoning, creating, learning, and inventing" (Hamza et al., 2000, p. 73), and online learning cannot be achieved without digital

technologies, any effort to reduce unnecessary cognitive load means an opportunity to maximize learning. Since the approach and the matrix of the work also include learning theories, we will refer to them in the following.

Implications of cognitive theory in online learning

Looking to investigate the importance of cognitive processes and their consequences on learning behaviours, cognitivism aims a better correspondence between them. Therefore, the research of the representatives of the cognitivist current, such as Bruner (1966), Sternberg (1984), Piaget (2008) etc. argue that learning occurs through the direct involvement of the learner, being the result of the individual's attempts to *make sense of the world* (Reed & Bergemann, 1992). In this sense, the learner processes the stimuli (data, information) and creates mental representations, being an active agent in the learning process by trying to consciously process and classify the flow of information from the external environment (Fontana, 1981), adding information to memory, most studies carried out in the field of cognitive learning theory being based on remembering processes (Mayer, 2019).

Starting from these basic assumptions of cognitivism, in the case of online education, the relevant teaching-learning activities are those that focus on the organization of information in such a way that it results in an efficient processing of it. Thus, in an online learning context where an LMS is used, the teacher will focus on organizing the instructional-educational contents so that the students operate with them and assign meanings to them (Andronache & Bănuț, 2021).

From a pragmatic point of view, in order to improve learning based on cognitive principles, in online education, the teacher can pay more attention to the following e-Didactic actions:

- Constant creation of tasks/ assignments respecting instructional design concepts, such as gradually increasing their complexity and making sense of the addressed content (Wilson & Cole, 1991).
- The use of multimedia messages of educational platforms that allow the recording of systematic progress in learning, from simple to complex (Mutlu-Bayraktar et al., 2019; Wilson & Cole, 1991), these tools that provide a sense of progress, imprinting gamification features on the teaching process.
- Designing stages of learning assessment by carrying out quizzes, retention and transfer tests, tests with automatic scoring, to evaluate results of both rote and meaningful learning (Mayer, 2019; Mutlu-Bayraktar et al., 2019)

- Providing the possibility to see the results in a general catalogue, leading to self-reflective processes, to counterbalance those situations when it is supplemented by constant feedback (Wilson & Cole, 1991), such as assignments feedback.
- Organization of the presentation of instructional-educational content and other types of documents, considering the organization of words and images, as this will lead to the organization of mental representations (Mayer, 2019).
- The design of questionnaires, pools, surveys to take feedback from the students and thus obtain useful data in assessing the cognitive load on the instructional-educational process carried out (Mutlu-Bayraktar et al., 2019).

Therefore, a cognitivist approach in the online didactic process uses the premises of a learning focused on the involvement of the entire arsenal of cognitive mechanisms, which in fact determines a conscious learning and an educational act with meaning and significance for the student, in which the probability that the students will escape from the task, "hidden" behind the monitor, decreases more and more (Andronache & Bănuț, 2021).

Implications of constructivist theory in online learning

Starting from cognitivist principles and the research of authors such as Piaget (1970, 1973), Flavell (1992) or Sternberg, Wagner and Okagaki (1993) etc. and marking a firm opposition to explaining cognition by associating the functioning of the brain with that of a commercial computer (Searle, 1990), constructivism, seen from a pedagogical perspective, claims that effective learning is achieved through the systemic relation of new acquisitions with previous ones. From a constructivist point of view, it is the learner who actively forms his representations in the brain (Mayer, 2019), by formulating hypotheses, confronting misconceptions, constantly calling on previous experience and determining discrepancies between what he knows and what he discovers through direct exploration of the environment (McLeod, 2018), thus developing new knowledge structures. So, in a synthetic formulation, it can be stated that, in fact, the more we know, the more we can learn, and knowledge in this sense becomes an instrument of experience, because it does not aim to produce only a mental copy of reality, but contributes more notably to adaptation (Piaget, 1967, as cited by Von Glasersfeld, 1985), learning being treated more heuristically.

Considering the basic principles of constructivism, in the online educational process, learning situations must be structured in such a way as to take into account the particularities of the students and give them the opportunity

to go through the contents posted by the teacher at their own pace and according to the own organization of the study time (Andronache & Bănuț, 2021), instruction subjecting itself to problem-solving contexts (Wilson & Cole, 1991). This aspect is, in fact, the major advantage of asynchronous didactic activities, which ensures flexibility in learning, increases students' ability to reflect and develops their information processing skills (Hrastinski, 2008).

In the online implementation of instructional procedures based on constructivist theory, the teacher can use e-Didactic actions such as:

- Providing students with less structured content/data, in a raw version, which will bring the opportunity to interact with them, by editing documents or other types of media (Green & Gredler, 2002).
- Providing the opportunity for students to organize their learning time independently by making available some facilities of educational platforms, such as electronic calendars, because well-planned and well-scheduled activities are determining factors in increasing the success rate in learning (Toraman & Demir, 2016).
- Rigorous organization and storage, in the cloud, on specific topics, of instructional-educational content for each educational discipline, but also the possibility of transferring information from possible sources available in real life to one's own person (Huang, 2002).
- Predefining learning tasks in which the student can act without support from the teacher, using the assignment options of various educational platforms (Green & Gredler, 2002; Swan, 2005).
- Constantly conducting test and quizzes to provide, from the students' perspective, opportunities to confront misconceptions (Swan, 2005), and from the teacher's perspective to play the role of facilitator in learning (Amineh & Asl, 2015; Doolittle & Hicks, 2003), monitoring learning and identifying the current level of acquisitions to facilitate the development of new ones.
- Alternation of the instructional-educational process carried out synchronously with that carried out asynchronously, monitoring progress and thus promoting autonomy in learning (Huang, 2002), in a process of progressive reorganization of thought processes, in the spirit of the constructivist theory of cognitive development because of biological maturation and the experience of exploring the environment (McLeod, 2018).

In conclusion, the valorisation of the constructivist theory in the online teaching-learning process represents a scientifically based approach, with multiple training implications, from the promotion of an integrative type of learning to the development of transversal skills, such as the autonomy of learning (Andronache & Bănuț, 2021). With these underlying reasons, there are

opinions that consider it the most relevant theory for academic learning (Mayer, 2019), some states taking this approach as a central curricular benchmark, such as Turkey where, starting with 2005, it has been adopted at national level (Durmuş, 2016; Toraman & Demir, 2016).

Implications of social constructivist theory in online learning

Having researchers like Bandura (1986) or Vîgotsky (1978) as representatives, whose studies are based on essential principles of constructivism, social constructivism aims at demonstrating that the learning process is fundamentally supported by the social nature of the human psyche. Therefore, the social constructivist approach emphasizes the importance of the social environment in which learning occurs and the importance of the interaction between individuals and between the individual and the environment. So, a first important element in promoting learning, in the social constructivist view, is represented by social interactions (Swan, 2005), the construction of knowledge being related to the circumstances, which determine a learning through observation and modelling. A second important element is related to the contributions of L.S. Vygotsky, who, through the *theory of the zone of proximal development*, emphasizes the importance of the intervention of others, of more experienced people, in favouring the child's learning (Driscoll, 1994; Swan, 2005). Therefore, by interacting with adults or even with other more "experienced" colleagues, the child, starting from what he is already able to do on his own, from what he already knows, can also perform more complex tasks, which exceed his current level of development.

Considering the foundations of the social constructivist theory, in the online teaching-learning process, it remains extremely important to favor cooperative learning, which facilitates student-student and student-teacher interaction. In the digital age, carrying out the online teaching-learning process comes with the premise of valuing the students' informal experiences, the teacher being able to develop authentic learning communities, giving them the chance not only to develop cognitively, but also to develop social and communication skills, to learn to express their own ideas and to listen to others, to learn to give and receive feedback (Andronache & Bănuț, 2021).

From a practical point of view, in order to value the social constructivist paradigm in an online teaching-learning environment, the teacher can undertake e-Didactic actions of the type:

- Initiating videoconferences (Huang, 2002; Mbati, 2012) and encouraging students to keep the webcam open, so that there is also non-verbal communication and to obtain immediate feedback, aspects that improve interaction.

- Proposing learning tasks that recognize the importance of collaboration, using options such as breakout-rooms, which are available in many educational videoconferencing applications (Huang, 2002) or carrying out learning tasks in working groups (Amineh & Asl, 2015; Green & Gredler, 2002).
- Initiating chats or forums on various topics (Huang, 2002; Mbati, 2012; Woo & Reeves, 2007), leading the process towards interactive learning where students can have the opportunity to debate certain learning tasks.
- Using those functions of LMS platforms that can capitalize on students' experiences with social networks, by making frequent posts, publishing announcements and enabling replay options on announcements, so that students can express their point of view, which confirms the social presence in the learning activity (Mbati, 2012).
- Capitalizing on the potential of participation in social interactions, with the aim of developing a dynamic of the student group, through the elaboration of group assignments (Woo & Reeves, 2007), with the provision of permanent and prompt feedback, an important aspect in maintaining student motivation (Mbati, 2012).
- Creating collaborative documents (wiki-type), which students can access and edit jointly and synchronize, resulting in collaborative projects and activities (Huang, 2002; Swan, 2005; Woo & Reeves, 2007) where learning can benefit from the input of more capable peers.

Therefore, the realization of the teaching-learning process in the online environment highlights how the learning behaviour and the environment in which it is acted on are in a systemic and social interaction, which is based on the specificities of socio-constructivist learning.

Triangulating learning theories with cognitive load and online education

Naturally, the suggestions in the previous sub-chapters should not be seen as exhaustive, nor their corroboration with the cognitive load associated with the LMS e-Tools used and which will be treated in this sub-chapter, but they can be capitalized according to individual and age specificities of the students, the specifics of the study discipline, the specifics of the contents or the operational objectives of the lesson. Given the fact that the electronic sub-tools available in online learning are implemented in the form of modules (internal or external), LMSs have a modular design, and they could be applied fragmentary. The present paper comes to help the teaching staff to avoid being seduced by subsets of electronic tools, giving them concrete directions to delimit the instructional design from the modular design of educational platforms, placing online education closer to methodology, rather than to technology.

In this regard, the collection of suggestions above is not a rigid one, because, for example, each of the models of learning can benefit from communication, not just the socio-constructivist one, just as any of the models can benefit from practical explorations, not only the constructivist one. Each model can incorporate concepts from another model, turning into common points such as assessment and feedback, the importance of which is recognized by most learning theories (Swan, 2005). Also, the assignment tasks, from the previous findings, support the implementation of each learning theory, differing by certain accents such as a more pronounced gradual progression of the learning task from simple to complex in the cognitivist perspective (Wilson & Cole, 1991), individual elaboration, without support from the teacher in the constructivist perspective (Green & Gredler, 2002; Swan, 2005) and engaging in group assignments to develop interactions between colleagues in the socio-constructivist perspective (Woo & Reeves, 2007). This type of asynchronous activity offers flexibility in approaching the didactic activity from any perspective of learning theories, flexibility being a common feature in thinking and action between them. Therefore, this paper encourages the interrelationship of e-Didactic actions specific to all learning theories, described above, this way promoting an effective and student-centred online education, and in order to make this desire a more accessible one, the previous actions will be completed by monitoring the cognitive load in online courses for students.

For increasing teaching in quality and learning in efficiency and for being more deeply centred on the student, in addition to examining the impact of the epistemological beliefs which teachers operate with in online teaching environments, we will also refer to the cognitive load which involves the use of some LMS functions. These e-Tools represent an empirical reality of cognitive organizers, in the online environment, for information processing, which together with learning theories and cognitive load, will provide data from several sources, the technique being specific to triangulation (Russek & Weinberg, 1993), to get a broad picture of best practices for teaching online.

Bloom's Taxonomy in the revised version (Krathwohl, 2002), specifies how information is processed through the lens of six cognitive processes, the first of them being remembering. Regarding the teaching-learning process, the appropriate use of images in multimedia materials can have a good impact on memorization, superior to written words (Lewis, 2016). Also, regarding the evaluation process, it is known that it is associated with the lowest cognitive process because, most often, it measures what had been memorized (Ben-Jacob, 2017), and quizzes or tests are such an example (Mutlu-Bayraktar et al., 2019).

To escalate the scale of cognitive processes and aim for understanding the contents of the teaching, teachers could design a series of assignments that require students to deepen the topics covered in class. This way, students could

correct their preliminary understanding from the classroom and evolve in this direction with each feedback received (Swan, 2005). In the same sphere of cognitive processes and in the spirit of social constructivist theory, students are in a process of searching for meanings when they engage in synchronous or asynchronous discussions (Huang, 2002), communication and interactions with peers and adults leading to the development of understanding (Amineh & Asl, 2015; Green & Gredler, 2002; Swan, 2005; Woo & Reeves, 2007). Also, a better understanding of the information can be obtained by using hypermedia solutions (Huang, 2002), collaborative wiki documents providing hyperlinks between various multimedia elements.

The foundations of constructivist theory start from the premise that the application of knowledge supports learning (Green & Gredler, 2002), and this type of actions coincides with engaging in a way of thinking specific to the third stage of cognitive processes (Krathwohl, 2002). In an asynchronous scenario, such as assignments or editing documents, students might apply a formula or definition (Jensen et al., 2019). In a synchronous scenario, for example, one could implement various educational objectives to improve learning, approaches to a certain learning theory, reciprocal teaching method, a game according to a certain scenario, etc.

A concept that emerges from the assumptions of cognitive theory is the sequencing of learning, which leads to analysis tasks and processes (Wilson & Cole, 1991), favouring not only the transition from simple to complex, but also the reverse, from complex to simple, for those students who learn by decomposition, the technique helping to reduce the degree of difficulty for a given task. Thus, for teachers inspired by cognitivist approaches to teaching, the tasks designed for the didactic activity should have a greater correspondence with the analysis and challenge students to such processing of information, such as the use of surveys of opinion that involves an analysis of the perception of a certain phenomenon. But students can also conduct discourse or content analyses (Woo & Reeves, 2007), processes that can be related to speeches from online meetings or content made available to students through cloud storage. Also, in this sphere of cognitive processing comes the ability to reflect, for which tools are needed that challenge students to look back at the effort made and analyse the achieved performance (Wilson & Cole, 1991), and one such tool is the catalogue noting all the activities the student has engaged in or other forms of recording progress in learning.

It is known that in online educational environments, learning is consistently supported by the fact that students can approach the contents at their own pace and as their time allows, the existence of a calendar with the programming of all activities asking them to evaluate their personal schedule in relation to the study program, to achieve the desired learning outcomes. Evaluation is the fifth

dimension of cognitive processes that requires a critical approach (Krathwohl, 2002). So, this type of processing involves critical thinking, which from a socio-constructivist perspective is present in collaborative environments through critical reflections carried out at group level (Huang, 2002; Mbati, 2012; Wilson & Cole, 1991; Woo & Reeves, 2007) or by referring to the communications made through posted announcements, and from a constructivist perspective it is present in independent learning (Amineh & Asl, 2015), students evaluating most of the time the content made available, in the cloud or stored in another form, through the lens of personal criteria and standards: easy/difficult, pleasant/ unattractive, relevant/irrelevant, etc.

The highest level of cognitive processing involves the ability to create (Krathwohl, 2002), and people have had to, over time, show off their creativity to solve various problems. Creative thinking and problem solving are connected to the principles of social constructivist theory through collaborative learning (Amineh & Asl, 2015; Mbati, 2012), benefiting from the creative force of the group. Thus, students can be engaged in group work to generate ideas (Woo & Reeves, 2007) and record them in the documents produced.

Considering the principles and characteristics of the analysed learning theories, certain working tools, that various educational platforms may have, find a better correspondence with them, but each of these e-Tools challenges students to different types of information processing and can bring a different degree of cognitive load when interacting with other elements in the learning situations that the teacher generates. From this perspective, the data collected from the specialized literature, triangulated, and analysed before, were synthesized in Table 1, the result obtained representing a possible useful tool for the conception of an online instructional design scientifically based on theories such as those described previously. The triangulation of these data taken from several sources in the specialized literature provides an extended picture of the prevailing cognitive processes regarding the influence of the tools used in the online space, without being seen as exhaustive processes for the given context.

The triangulation of learning theories with cognitive load and online education is the result of a qualitative analysis through which their descriptors were collected, from several sources, and which were correlated in such a way as to support the realization of an instructional design at the border between methodology and technology. Thus, certain tools of the virtual environment can be prioritized not only to frame the didactic act in the epistemological beliefs derived from learning theories which the teaching staff resonates with, but also to anticipate the impact of instructional design on the cognitive effort that appears as a consequence of teaching. The relationships established through this triangulation can contribute to the configuration of a system of effective didactic tools and practices, developed both according to the characteristics and needs of the student

and, why not, those of the teacher and his teaching style, so that the learning is one in depth. By integrating students' prior knowledge and elaborated content with the thought processes, deep processing of information can benefit.

Table 1. Results of qualitative analysis of possible cognitive load factors in online learning at the border between technology and methodology

e-Tools	Cognitive domain	Learning theories
Videoconference	Understanding Apply Analyse	Socio-constructivism
Calendar	Evaluate	Constructivism
Chat/ Forum	Understanding	Socio-constructivism
Announcements	Evaluate	Socio-constructivism
Documents (create & edit)	Apply Create	Cognitivism Constructivism
Assignments	Understanding Apply	Cognitivism Constructivism Socio-constructivism
Tests/ Quizzes	Remembering	Cognitivism Constructivism
Surveys/ Polls	Analyse Evaluate	Cognitivism
Catalogue/ Attendances	Analyse	Cognitivism
Wiki	Understanding Apply Create	Socio-constructivism
Groups	Understanding Apply Evaluate	Socio-constructivism
Course progress	Analyse	Cognitivism Constructivism
Cloud storage with file sharing	Analyse Evaluate	Constructivism

In an e-Learning paradigm where it is not the educational platform used that matters, but the possibilities and options it offers, trends in their use may arise that deviate from instructional design and develops through the lens of the options that digital technologies provide. In the instructional design, behavioural specific learning objectives are specified, which will be organized in relation to the conceptual models forwarded by learning theories and types of learning, systematizing the training conditions to subordinate them (Wilson & Cole, 1991). In this regard, the resulted article, thus, develops the links that online education makes between learning theories and learning objectives, related through a series of e-Tools specific to educational platforms with various types of learning. Thus, the use of these e-Tools can be calibrated to better address certain

sensory dimensions, to process distinct multimedia materials or to be as feasible as possible with certain preferences or thought processes and reduce intrinsic cognitive load, which is in direct relation with the achievement of learning objectives, increasing the probability of their achievement.

Conclusions

Digital technologies provide an environment suitable to learning, but online instruction must be thought, planned, designed, and coordinated by the teacher (Glava, 2009). The triangulation of theories of learning with cognitive load and online education, carried out by this paper, helps precisely in this sense by providing guidelines for how digital technologies should be used with applicability in online education. Any instructional model dedicated to online learning must not only consider the procedural aspects closely related to the functions that a LMS can provide, but also the methodological and conceptual aspects, in order to be functional from educational policies to their implementation. Optimizing the use of e-Tools of online educational platforms to trigger certain cognitive processes, depending on epistemological beliefs that have their source in various learning theories, on the theoretical landmarks centralized by this paper, highlights the application of educational sciences in online learning.

By referring to the basic principles of constructivism, in the online teaching-learning process, learning situations must be structured in such a way as to generate a problematic framework that allows students to build knowledge through their own experimentation. On such a framework as online learning and compared to traditional learning, it is considered that conceptual learning is supported more and procedural learning less (Parker & Gemino, 2001, as cited by Swan, 2005). The Internet of Things (IoT) should bring about a change in this regard. Because IoT grows, the online activities could have a more pronounced socio-cultural component, relating to objects and establishing new forms of communication and collaboration. These objects and information from the internet can be integrated into the supplementary materials that a course makes available to students. The teacher will select the information from the internet and help the students relate to this information and process it, because raw information is not knowledge.

This paper focused on information processing and suggested, from a didactic perspective, useful ways to examine the cognitive processes that underlie the successful completion of tasks in learning situations typical to online education. Educational processes that do not identify cognitive objectives and cognitive efforts that students should make in the interaction with educational stimuli, risk cognitively loading their processing capacity and adversely impacting the achievement of educational objectives.

For a person involved or interested in the design of instructional procedures, the article can be a source of inspiration to design authentic learning activities, but updated to the present time, through the lens of learning that takes place in a technology-rich environment. Online learning activities carried out through various tools of educational platforms and inspired or guided by the principles of certain learning theories, challenge students to various cognitive processes in direct relation to the learning objectives, which, through the interaction with other teaching elements, contribute to total cognitive load. Knowing some ways to optimize information processing in relation to the facilities offered by educational platforms can, on the one hand, support the reduction of the cognitive load necessary to achieve the learning objectives, and on the other hand, support the increase in deep learning.

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