A Cybernetic Method to Deal with Cognitive Load in U-Learning Environments: Conceptual Proposal

Leonor Adriana Cárdenas-Robledo and Alejandro Peña-Ayala

***Abstract*— This research focuses on u-learning environments settings where learners are immersed and inherently face a variety of simultaneous stimuli coming from diverse sources such as: professor, classmates, equipment, digital and physical learning objects, as well as ubiquitous devices and physical environment. When the learners are situated in such environments, they could be overwhelmed by the diversity of stimuli resulting in an increment of their cognitive load. It is thought that if the mental activity of the individuals is saturated, their cognitive performance could be reduced and their learning achievements might be compromised. The present research aims at counteracting the negative influence of cognitive load in the individual's learning. Hence, a cybernetic method to deal with cognitive load in u-learning environments (CMCLU-LE) is proposed. Such a method fosters learners to self-regulate their learning process by means of metacognitive strategies which help them to regulate the effect of cognitive load and stimulate the acquisition of knowledge.**

***Index Terms*—ubiquitous learning environment, cognitive load, metacognition, self-regulated learning, cybernetic method,** CMCLU-LE.

I. INTRODUCTION

In recent years, u-learning paradigm has become very important for delivering educational contents at indoor and outdoor learning scenarios. Due to the main characteristics of u-learning [1]: permanency, accessibility, immediacy, interactivity, and situating of instructional activities Learners have the opportunity to take advantage of this kind of enhanced learning experiences in order to accomplish their academic goals.

The learning environment plays an essential role in the learners' knowledge acquisition. However, when learners are situated in u-learning environments, there are diverse stimuli that need to be faced by learners to achieve successful and meaningful learning. Thus, they might be overwhelmed by the stimuli, resulting in an increment of their cognitive load [2] (e.g. split attention, distraction, noise, multitasking, etc.).

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In this paper, we introduce the conceptual design of our proposed cybernetic method oriented to stimulate the mental activity of learners, by means of following self-regulating learning strategies [3] and using metacognitive skills [4], which both regulate the cognitive load and facilitate the learning of educational contents delivered in u-learning environments.

This paper is organized as follows: Section 2 provides a brief overview of related works with a focus on cybernetics [5] and activity theory [6]. Section 3 presents the context of the research. Furthermore, the underlying concepts that support the proposal are introduced in Section 4, whilst, a profile of the cybernetic method proposed is described in Section 5. Finally in section 6 a conclusion is outlined.

II. RELATED WORKS

In the following paragraphs a short sample of related works is introduced. Regarding cognitive load, Liu et al. study split attention and redundancy effects [7], where cognitive load theory is used as a framework to compare three different mobile learning conditions. Similarly, the present research addresses the split attention as a type of disturbance that affect cognitive load. Moreover, due to the nature of u-learning environments additional issues (e.g. mental demands, distractions, stimuli, multitasking, etc.) are also considered.

Chang et al. study the effects of English proficiency and material presentation mode (single channel vs. dual channel) on English listening comprehension [8]. They take into account cognitive load and learning attitude in a u-learning environment, and implement an activity using a personal digital assistant. Likewise in this proposal mobile devices are considered as a learning tool to facilitate learning and a mean to deliver contents using different presentation modes.

Concerning cybernetics, Abdulawahed and Balid propose a cybernetic model of self-regulated learning from a perspective of control systems in terms of closed cycle [9]. Whereas this research proposes a cybernetic method in order to provide self-regulated learning guidance for learners by means of metacognitive strategies.

Westera provides a theoretical description of the arrangement of adaptive, a machine generated learner feedback which relies on cybernetic principles [10]. The author explores how cybernetic principles could be implemented in complex learning environments. Also this research takes into account the cybernetic elements to develop the proposed method to be applied in u-learning environments.

In the light of activity theory, Brevern and Synytsya propose a systemic-structural theory of activity from a holistic point of view supported by learning technology [11]. In the same way, such a theory offers to the ongoing research a paradigm to develop the architecture of the proposed cybernetic method.

III. RESEARCH SETTING

The present research encompasses the *domain* of u-learning, where the *object* of study is the cognitive load produced on the learners' brain as result of diverse and simultaneous stimuli that surround the u-learning environments. Therefore, the *problem* is that cognitive load could affect the learning of educational contents. A proposed *solution* is to train learners to become aware of and exercise their metacognitive abilities under the guidance of self-regulation learning.

In this case, the *hypothesis* is defined as follows: The cognitive load in u-learning environments can be triggered by distractors coming from different sources (e.g. digital and physical learning objects, teaching and learning styles, devices, environment settings, etc.), as well as the learners themselves (e.g. motivation, level of knowledge, attention, etc.). In consequence, while learners are performing complex learning tasks in this kind of scenarios, they might feel overwhelmed by the amount of information that have to be processed simultaneously to acquire meaningful learning.

Furthermore, the aforementioned cognitive load can be manifested in diverse ways, for instance, the inherent complexity of the educational topic, the presentation of the learning materials and the mental effort demanded for the assimilation of educational content.

IV. UNDERLYING ELEMENTS FOR THE PROPOSAL

The basic elements, which are presented in this section, shape the solution proposal and provide a theoretical context for this research. Therefore, an essential construct is Metacognition which is employed to regulate learning and cognitive load. According to Efklides and Misailidi, metacognition is "cognition of cognition [12, 13]", and it has two main functions named monitoring and control of cognition [14].

On the other hand, Vanderswalmen, Vrijders, and Desoete point out that: Metacognition is composed of three phases: 1) metacognitive knowledge, which constitutes knowledge and deep understanding of cognitive processes and products [4, 15]; 2) metacognitive experiences that refer to conscious experiences of the use of metacognition; 3) metacognitive skills are manifested as the deliberate use of strategies (procedural knowledge) to control cognition [16]. The purpose is that learners become aware of their mental activities in order to improve their academic performance.

According to Tsai, Shen and Fan self-regulated learning is one of the most important abilities required for online learning, and because of the social, electronic, and self-directed nature is essential to investigate the learners' self-regulation in this kind of environments [17]. This learning paradigm encourages learners to take control of their own knowledge acquisition process. Thus, self-regulation is the individual's ability to plan, monitor, and regulate the behavior in changing situations [18].

Moreover, Zimmerman express that: "...Learners can be described as self-regulated to the degree that they are metacognitively, motivationally, and behaviorally active participants in their own learning process [19]. Besides, Zimmerman highlights three important elements: students' self-regulated learning strategies, self-efficacy perceptions of performance skill, and commitment to academic goals.

In addition, cybernetics and activity theory are constructs equally important employed in the ongoing research, which are interwoven in the conception of the proposed method. Regarding cybernetics, Wiener defines it as: "the science of control and communication, in the animal and the machine" [20]. In this context, Heylighen and Joslyn state that: "Cybernetics focuses on how systems use information, models, and control actions to steer towards and maintain their goals, while counteracting various disturbances". The previous authors claim that due to the inherent transdisciplinary nature of cybernetics, it can be applied to understand, model, and design systems of any kind, such as: psychological, technological, biological, ecological, physical, social, or any combination [21].

As for activity theory, Peña et al. express that: "...it is a useful framework to design e-learning systems and provide student-centered education" [22]. The authors indicate that: "activity theory defines principles oriented to shape a conceptual and general activity used as foundations for specific theories". Moreover, Pachler et al. point out that: "...activity theory is a construct highly sophisticated which has a philosophical and scientific multifaceted base..." [23]. In this context, activity theory serves as a support for the development of the cybernetic method which is an object of interest for this research.

V. A PROFILE OF THE CMCLU-LE

The proposed solution consists of a *cybernetic method* that enables in a personalized manner learners to follow a holistic model of self-regulated learning as well as become aware of and use their metacognitive abilities in order to deal with their cognitive load in u-learning environments.

The method takes into account the user characteristics in order to exploit metacognitive strategies. As a general schema of the elements considered in the proposed solution, Fig. 1 shows that learners' characteristics, level of knowledge and behavior are inputs considered in order provide a suitable self-regulated learning guidance supported by metacognitive strategies. These strategies are meant to help learners to deal with cognitive load while they are performing activities in u-learning environments. In this figure the context (i.e., represents the u-learning environment and distractions) and the feedback (i.e., information derived from the interaction) are depicted with bidirectional lines.

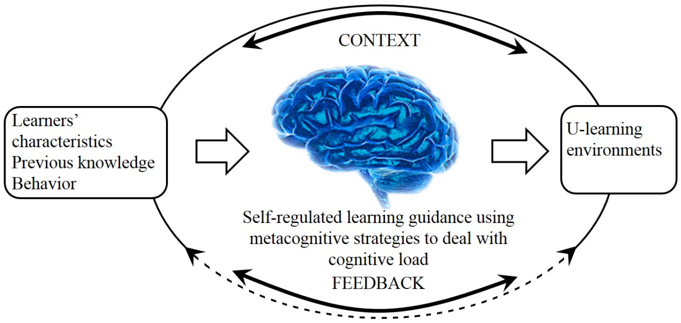

Fig. 1 General schema of the proposed solution

A. *Proactive and reactive regulatory mechanism*

In this research a cybernetic method is conceptualized with the aim at fostering learners to self-regulate their cognitive load and their learning process in u-learning environments. With this in mind a general description of the method is provided, as well as its conceptual architecture.

Since the perspective of cybernetics, the proposed method has to do with the way in which learners apply the method and control their actions towards the awareness of their metacognitive skills in order to acquire new knowledge. Meanwhile the learners themselves counteract the effect of cognitive load and the distractions in u-learning environments. The basic unit of the proposed method is called: the Proactive and Reactive Regulatory Mechanism (PRRM). This mechanism considers as a part of its regulation function the following components depicted in Fig.2.

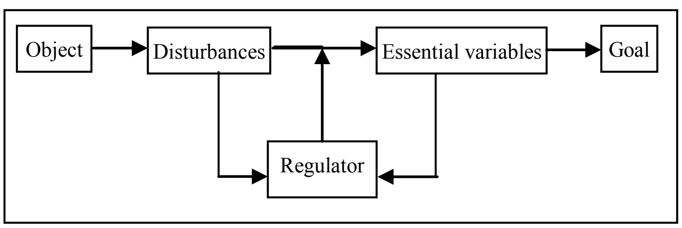

Fig. 2 Regulatory mechanism of the cybernetic method

Where: *disturbances* are inputs such as stimuli and the alterations that might change the state of the system. These come from the u-learning environment (e.g. digital content, motivation, physical objects, learning environment). *Essential variables* are variables of interest which are important to maintain the balance of the system (e.g., state variables, cognitive load, and acquired educational content). *Regulator* represents the essence of the cybernetic method because takes over the proactive and reactive information flows. *Goal* identifies the products, the results, or the observable behavior of the learner such as knowledge acquisition and skill use. *Object* refers to the ultimate purpose of the system: the learning acquisition in a particular domain of knowledge.

The PRRM employed in the cybernetic method allows to monitor the general state of the system. Hence, it takes into account the activity in progress to oversee the accomplishment of the object and the goals, the estimation of essential and state variables; with the aim at successfully fulfilling the activity, it is possible to make suitable adjustments when it is needed.

B. *Architecture of the cybernetic method*

The cybernetic method proposed in this research to activate metacognitive activity, counteract cognitive load, and stimulate learning is organized as a hierarchical structure architecture based on the activity theory.

The architecture consists of four levels, sketched in Fig. 3, where each level contains one or more elements, and each element includes the regulatory mechanism presented earlier in this section. The levels are described as follows:

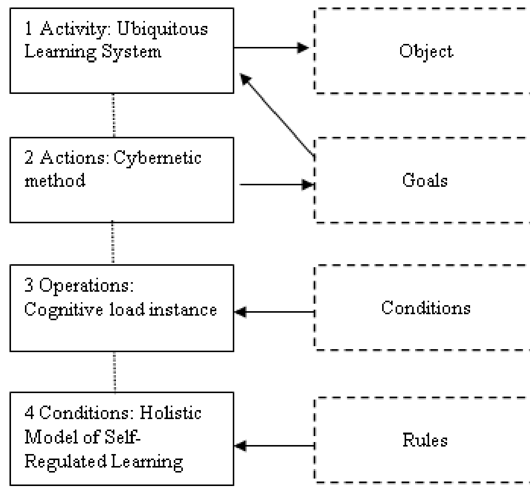

Fig. 3 Architecture of the cybernetic method

Level 1, Activity: Ubiquitous Learning System (ULS) is the first level of the architecture and depicts the whole system. The main object of this system is learning and it considers the diversity of stimuli surrounding the u-learning environment while the learning experience happens.

Level 2, Actions: Cybernetic method is the second level of the structure, which is represented as a set of actions based on established goals, where each action includes its own PRRM oriented to regulate a particular cognitive load effect.

Level 3, Operations: Cognitive load instance is the third level of the architecture, whose operations are constrained by conditions oriented to regulate a cognitive load effect.

Level 4, Conditions: Holistic Model of Self-Regulated Learning (HMSRL) is a set of rules that are specified in the fourth level of the hierarchical structure with the purpose to perform a particular operation.

The actions of the cybernetic method are linked to the cognitive load instances considered in this research. This instances come from the inner and outer world of the learner immersed in a u-learning environment, e.g.: emotional state, mental demands, distractions, stimuli heterogeneity and parallel processing. The treatment for each cognitive load instance is characterized by the HMSRL which provides the guidelines to deal with the cognitive load effect through regulatory actions to be performed by the learner. The cybernetic method is intended to be embedded in the digital content pertaining to a theoretical and practical subject addressed to undergraduate learners in a laboratory environment. The learners will perform their activities supported by the self-regulated learning guidance delivered by means of mobile devices.

VI. CONCLUSIONS

The ultimate goal of the ongoing research is to foster cognitive activity oriented to knowledge acquisition in a particular educational domain, and trigger learners' mental activity in a ubiquitous-learning environment.

Furthermore, the research is mainly focused on learning in ubiquitous environments and the ways used for dealing with cognitive load. In this context, the cognitive load is understood as an extra mental effort that learners face while perform their learning activities.

The current research aspire to contribute to the solution of the cognitive load problem through the application of self-regulated learning strategies and the exercise of metacognitive skills by means of the proposed cybernetic method.

As a future work, this research considers to implement the cybernetic method in a u-learning system. Such a system will take into account the user model in order to deliver suitable and personalized training to learners, with the aim at fostering the use of the strategies to face cognitive load.

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