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Students' Metacognition and Cognitive Style and Their Effect on Cognitive Load and Learning Achievement

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ABSTRACT

The present research's objective is to examine the effects of metacognitive scaffolding and cognitive style in the Field Dependence - Independence (FDI) dimension on cognitive load (CL) and learning achievement (LA) in high school students, when they interact with a hypermedia environment on philosophy (logic). Fifty-four students belonging to two eleventh grade courses from a public school in Bogotá - Colombia participated in the study. One of the student courses interacted with a hypermedia environment that contained, within its structure, the metacognitive scaffolding. The other course interacted with the hypermedia environment that did not have the scaffolding. Students were given the Embedded Figures Test (EFT) to classify them into field dependent, intermediate, and independent subjects. A Repeated Measures Analysis was conducted with two intra-subject variables: (1) CL and (2) LA. Findings indicate that significant differences exist between intrinsic and extraneous cognitive load because of the effect of the metacognitive scaffolding. Students that interacted with the metacognitive scaffolding exhibited significantly greater achievements than those that did not use it. The field independent students also exhibited significant differences in CL with respect to their field independent and intermediate classmates.

Keywords

Metacognitive scaffolding, Cognitive load, Cognitive style, Learning achievement, Hypermedia environment

Introduction

In recent decades, different computer-based learning environments (CBLE) have been used in an educational context to provide support for the teaching-learning process in different levels of schooling. The use of these environments in the classroom has generated high expectations among the academic community since it is believed that when students interact with these scenarios, they can take on a more active role in their own learning process and thus achieve more successful and motivating learning experiences (Clark & Meyer, 2008; Mayer, 2005; McNamara & Shapiro, 2005; Shapiro, 2008). However, some studies indicate that little empirical evidence exists to support these expectations since in some cases, students do not accomplish the desired learning nor do they all equally benefit from these environments (Alomyan, 2004; Beserra, Nussbaum, Oteo, & Martin, 2014; Calandra & Barron, 2005; López-Vargas, Hederich-Martínez, & Camargo-Uribe, 2012).

In this research field, some studies explain that LA obtained by students when intercting with computational environments may be directly related to student's cognitive style and CL. Regarding cognitive style, for example, in the Field Dependence - Independence –FDI- dimension, most of the studies show that field independent novices, when interacting with hypermedia environments, organize and process information more efficiently and obtain greater LAs in comparison to their field dependent classmates (Alomyan, 2004; Altun & Cakan, 2006; Chen & Macredie, 2002; Handal & Herrington, 2004; López-Vargas & Valencia-Vallejo, 2012).

With respect to CL, some research show that the characteristics in the design of computational environments can favor or limit students' learning process. Thus, the mental effort employed by a subject when developing a learning task may be negatively affected if the organization of the information presented overloads the limited resources of the working memory. This situation efficiently affects knowledge building (Artino, 2008; Clark & Mayer, 2008; Mayer, 2005; Sweller, Ayres, & Kalyuga, 2011; Sweller, van Merriënboer, & Paas, 1998).

On the other hand, studies show that the use of scaffolding favors subjects' performance when they undertake learning tasks in an autonomous manner in computational environments (Greene, Moos, Azevedo, & Winters, 2008; Delen, Liew, & Willson, 2014; Kim & Hannafin, 2011; Lehmann, Hählein, & Ifenthaler, 2014; Zhang, 2013). In this research area, the use of metacognitive scaffolding in computational environments is an aid for the student when managing and regulating cognitive processes during the learning process. Thus, the subject plans activities, monitors and controls the progress of proposed goals, and evaluates the obtained results (Molenaar, Boxtel, & Sleegers, 2010; Quintana, Zhang, & Krajcik, 2005; Zhang, 2013; Zhang & Quintana, 2012).

Literature review

Field Dependence - Independence (FDI)

In an educational context, the most studied cognitive style is the Field Dependence - Independence (FDI) dimension proposed and developed by Witkin and his colleagues (Witkin & Goodenough, 1981). In an information technologies context, research on cognitive style in the FDI dimension systematically show that students referred to as Field Independent (FI) obtain better LAs than their Field Dependent (FD) classmates when interacting in hypermedia environments. Studies evidence that FD students prefer their study material to be organized sequentially (linear) since they are easily disoriented and they do not know where to begin, nor in what direction to continue; situation that makes it harder for them to effectively structure and restructure the information. Additionally, they prefer the browsing process in the computational scenario to be in groups and guided by external agents, and that the control over the learning process be exercised by the own computational environment (Alomyan, 2004; Chen & Macredie, 2002; Handal & Herrington, 2004).

In contrast, FI students prefer autonomy to browse throughout the whole structure of the computational environment and effectively handle hypermedia environments. They can establish browsing routes in a structured fashion. Similarly, while browsing they are not easily distracted with irrelevant information and they can effectively use most of the computational environment's resources. On the other hand, they like to work individually (Alomyan, 2004; Chen & Macredie, 2002; Chou, 2001).

In this research field, few studies inquire into the possible relationships that may exist between students' stylistic characteristics and CL as a function of LA (Angeline, 2013; Angeli, Valanides, & Kirschner, 2009). Knowledge of these relationships help explain and understand the differences in LA in subjects when interacting with CBLE.

Cognitive load theory

Cognitive Load Theory (CLT) studies the existing relationship between working memory capacity and knowledge building that novices achieve when interacting in computational scenarios. In this manner, LA shall be affected if the structure and organization of the digital content overloads subjects' limited memory resources. Consequently, the student is unable to effectively relate new information to the one stored in the long-term memory (Clark & Mayer, 2008; Sweller, 2006). Following this line of thought, it could be asserted that CL is all the mental activity imposed on the working memory when an individual is solving a learning task (Andrade-Lotero, 2012; Paas, Tuovinen, Tabbers, & van Gerven, 2003; Sweller, 2010).

CL is divided into three classes: (1) intrinsic, (2) extraneous, and (3) germane. With respect to Intrinsic Cognitive Load (ICL), it is inherent to the type of task to be developed. In other words, it considers the difficulty of domain knowledge to learn and the student's prior knowledge. On the other hand, Extraneous Cognitive Load (ECL) is related to the information available in the computational environment that is irrelevant to task development and acts as a distraction that may divert the student's attention. Finally, the Germane Cognitive Load (GCL) is directly responsible for knowledge building and is represented by actual LA (Andrade-Lotero, 2012; Sweller, 2006). The sum of the three loads is equal to total CL; thus, GCL will be favored when reducing both ICL and ECL (Chong, 2005; Sweller, 2006; Van Merriënboer & Sweller, 2005).

In CBLE, ICL cannot be manipulated by instructional design. However, in the design of computational environments, the objective is to reduce ECL and thus increase space in working memory to maximize GCL (Mayer & Moreno, 2003; Paas, Renkl, & Sweller, 2003; Sweller, 2010). Thereon, Medula (2012) found that ECL increases when audio, video, and text is articulated because of the overstimulation of the senses. In a more recent study, Andrade, Huang, and Bohn (2014) found that students exposed only to visual formats exhibited a lower ECL in comparison to those that combined visual and auditory information.

In another study, Cheon, Crooks, and Chung (2014), asked one group of students questions on content as they read texts (active segmentation), while another group was asked questions at the end of the interaction (passive segmentation). Results showed that in active segmentation students achieved better academic performances, probably when ECL decreased. More recently, Chen, and Wu (2015) reported a greater CL in students when interacting with videos that contain PowerPoint presentations and voice, compared to live conference and MOOC-type recordings.

Based on CLT, these studies contribute empirical evidence with respect to the use of some tools in the design of hypermedia environments that reduce CL. However, few studies focus on the use of scaffolding within the structure of web environments to favor students' learning and reduce CL (Andrade-Lotero, 2012).

Metacognitive scaffolding

The concept of scaffolding was defined based on the Zone of Proximal Development (ZPD) posited by Vygotsky in his sociocultural theory of learning, which refers to the aid that an adult can give a child with the purpose of fulfilling the latter's learning objectives (Tuckman, 2007; Wood, Bruner, & Ross, 1976; Wu & Pedersen, 2011). The scaffolding provides support to the student to successfully complete a learning task (Wood et al., 1976). Metacognitive scaffolding favor conscientious planning, monitoring, self-evaluation, and control of cognitive processes during learning task development in computational environments (Kim & Hannafin, 2011; Molenaar et al., 2010; Zhang & Quintana, 2012).

To that respect, Quintana et al. (2005) and Molennar et al. (2010) posit that metacognitive scaffolding are characterized for managing and regulating cognitive processes. This type of scaffolding is useful to the student to: (1) plan what they want to learn, in other words, it proposes defining learning goals, strategies, and timetables; (2) execute and monitor the progress of the proposed goals; and (3) reflect on the obtained results in order to review the effectiveness of the planning and adjust the strategies that have not been effective in achieving the learning goals. This process allows the student to acquire knowledge on how they learn, strategies to use, and time to invest according to the learning task.

Statement of the problem

In line with these statements, questions arise regarding the design of CBLE insofar as the use of scaffolding may be associated to the CL that the student experiences when interacting with these scenarios. Similarly, CL may be associated to the subject's cognitive style. In this order of ideas, the present study posits the following research questions:

How does the metacognitive scaffolding influence CL and LA in students that learn in a hypermedia environment covering philosophy content? Do significant differences exist in CL between students with differing cognitive styles in the FDI dimension when they learn in a hypermedia environment?

Following this line of thought, the hypotheses that guide the present study are: (1) A reduction in CL exists and student performance increases because of the effect of the metacognitive scaffolding and (2) significant differences exist in CL between students with differing cognitive styles in the FDI dimension because of their stylistic differences.

Method

Design

The research was quasi-experimental with two eleventh (11th) grade groups from a public school of Bogotá – Colombia. The hypermedia environment is taken as the study's independent variable with two values: group with metacognitive scaffolding and group without metacognitive scaffolding. The study's dependent variables were: LA and CL. The latter with three values: ICL, ECL, and GCL.

Participants

This research was conducted with 54 eleventh grade students (26 women and 28 men) from a public school of the city of Bogotá – Colombia. The range of ages varied between 15 and 19 years (M = 16.87, SD = 0.953).

Instruments

Metacognitive scaffolding

The web-based learning environment on logic consists of three learning modules: (1) Definition and classification, (2) Aristotelian Logic: Parts, prepositions, and syllogisms, and (3) Symbolic Logic: Prepositions and classes, symbols and laws and connectors, as shown in Figure 1. The metacognitive scaffolding was implemented within its computational structure, which is displayed as pop-up windows. It is based on the model proposed by Winne and his colleagues (Hadwin & Winne, 2001). The scaffolding has the following characteristics:

Figure 1. Main browsing menu in the computational scenario

Stage 1. Introduction to the learning task: The general content of each learning module is presented to the student, who is informed of schedules and spaces available to them for their development. In the first module, a general test on prior knowledge on philosophy was given to the student to get them to reflect on how much they know about the subject matter and on the learning strategies they could implement during the learning process.

Stage 2. Learning Planning: During this stage, the novice imposes on himself a learning goal based on his prior knowledge considering the following scale: (1) basic level; provides introductory and general information about the module's subject matters; (2) intermediate level; examines in greater detail the content of each module, and (3) advanced level: in-depth study of each one of the subject matters. The scale's objective is to consider their individual differences, as shown in Figure 2.

Figure 2. Learning goal selection window

Subsequently, the novice establishes a work plan to achieve said goal. They set study times and choose the learning strategy according to the environment's content and structure. This encourages reflection from the novice as a function of fulfilling the proposed goal.

Stage 3. Execution of the work plan: This stage begins with the implementation of the learning strategy. This activity has the objective of inducing the novice into metacognitive monitoring of the lessons learned, as shown in Figure 3. According to this valuation, the student is in the capacity to make the necessary corrections regarding the self-imposed learning goal. This stage concurs with the metacognitive control process.

Figure 3. Lesson self-evaluation window

Stage 4. Learning Results: During this stage, the novice conducts the lesson's final evaluation. They also reflect on the whole learning process. In other words, they evaluate the level of achievement reached, the planning of activities, and the chosen learning strategy to perform the corresponding adjustments in future learning modules, as shown in Figure 4.

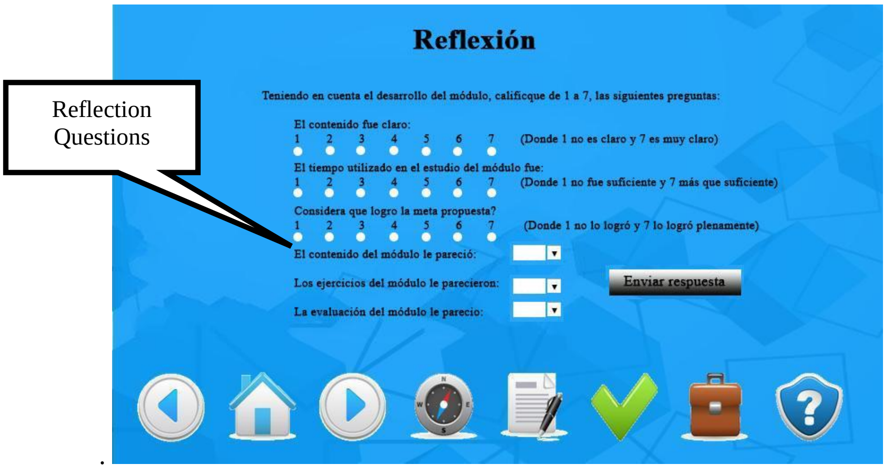

Figure 4. Lesson module final reflection window

Cognitive load questionnaire

The cognitive load questionnaire developed by Leppink, Paas, van Gog, van der Vleuten, and van Merriënboer (2014), which allows identifying students' perception on CL through 13 items, was employed to determine students' CL. For ICL, items 1 to 4. For ECL, items 5 to 8. Regarding GCL, items 9 to 13. The instrument is a self-reporting questionnaire and presents a Likert scale of 0 to 10, where 0 is "completely disagree" and 10 is "completely agree." To obtain the grade in each load, the valuations were averaged. In this research, the instrument had a Cronbach's alpha for ICL of 0.796; for ECL of 0.727, and finally, GCL of 0.816. Students answered the questionnaire three times, one for each lesson module.

Cognitive style test

EFT was used to determine cognitive style in the FDI dimension. The instrument proposed by Sawa (1966) consists of five subtests presented in separate pages. Each page has one simple figure and ten complex figures, which must be found within a given timespan. Previous applications of this test have shown an internal consistency varying between 0.85 and 0.9. (López-Vargas & Valencia-Vallejo, 2012; López-Vargas, Ibañez-

Ibáñez, & Chiguasuque-Bello, 2014). The EFT sample average was 24.72; standard deviation (*SD* = 8.886). Over a maximum grade of 50; the minimum value was 6 points and the maximum value was 41 points.

Students were grouped into FDs, intermediates, and FIs. This was done defining tertiles for the test's total grade; hence, three grade ranges were identified: (a) 20 FD students (first tertile), (b) 16 intermediate students (second tertile), and (c) 18 FI students (third tertile).

Learning achievement

Students took three evaluations, one for each lesson module contained in the computational environment. All the evaluations consist of 10 multiple-choice points. The evaluations presented a high reliability of the instrument, Cronbach's alpha was 0.872.

Procedure

To conduct the research, the educational institution's board was contacted, who agreed to allow the eleventh-grade students' participation in the study. Subsequently, students and teachers of philosophy were presented with the proposal. Then, parents were requested to give their informed consent regarding their children's participation in the study, previously clarifying that the results would be confidential and for research purposes. Once the informed consents from all parents were gathered, the group was given the EFT.

Two computer labs were used to install the two hypermedia versions. One student course worked with the software version that contained the metacognitive scaffolding and a second course interacted with the software without the scaffolding. Students were assigned an identification password to access the software. The philosophy (logic) content was distributed in seven work sessions, each one with a duration of one hour per week. During each one of the work sessions, participants could not access Internet or other computer programs.

Results

Effect of the metacognitive scaffolding on CL

A repeated measures ANOVA is used. There are two intra-subject variables: (1) CL with three values: intrinsic (I.L.), extraneous (E.L.), and germane (G.L.), in each one of the three lesson modules, and (2) LA in each one of the three modules. On the other hand, there are two inter-subject variables: (1) Hypermedia environment with two values: with metacognitive scaffolding and without scaffolding and (2) Cognitive scaffolding, with three values: field dependent, intermediate, and independent.

Table 1 shows a summary of the descriptive statistics of total CL in each one of the study modules of the students that worked in the hypermedia environment with and without scaffolding. Similarly, the novices' cognitive style was considered.

Table 1. Results of total CL in each module: Mean scores and standard deviations in parenthesis

Software	Cognitive style	No.	Total load Module 1	Total load Module 2	Total load Module 3
With scaffolding	Field dependent	10	19.09(2.57)	20.76(1.28)	21.35(1.18)
	Field intermediate	7	19.58(2.88)	21.59(0.64)	21.95(1.17)
	Field independent	10	15.60(2.32)	19.89(1.62)	19.01(2.06)
	Total	27	17.92(3.07)	20.65(1.43)	20.64(1.98)
Without scaffolding	Field dependent	10	22.56(3.85)	23.75(2.07)	23.59(2.44)
	Field intermediate	9	21.74(2.85)	22.71(2.75)	22.29(2.41)
	Field independent	8	22.06(4.14)	22.02(3.48)	20.84(3.24)
	Total	27	22.14(3.52)	22.89(2.76)	22.34(2.82)

Firstly, total CL is obtained by adding the intrinsic, extraneous, and germane load. Mauchly's test indicated that the sphericity assumption does not hold. The data show that the main effect of the total load variable is: ($X^2(2)$ = 30.54, $p < .05$). Therefore, the degrees of liberty were corrected with Greenhouse-Geisser ($\varepsilon = .68$). Results show a significant double interaction between total load and software ($F(1.35, 64.96) = 6.62$, $p = .007$, $\eta^2 = .121$). A significant difference also exists in the total load variable ($F(1.35, 64.96) = 12.04$, $p < .001$, $\eta^2 = .200$).

With respect to the inter-subject variables, significant differences exist between the type of software with CL ($F(1, 48) = 20.73$, $p < .001$, $\eta^2 =.302$) in favor of the subjects that interacted with the software version that included the metacognitive scaffolding. Similarly, significant differences exist between cognitive style with CL ($F(2, 48) = 5.04$, $p = .010$, $\eta^2 = .174$). With respect to the use of the hypermedia environment with and without metacognitive scaffolding, the data show significant differences in total CL ($F(1, 48) = 27.73$, $p < .001$, $\eta^2 = .312$) in module 1. In module 2, significant differences also exist in total CL ($F(1, 48) = 12.28$, $p = .001$, $\eta^2 = .204$). Finally, in module 3, significant differences are found between the two student groups ($F(1, 48) = 5.97$, $p = .018$, $\eta^2 = .111$) as shown in Figure 5.

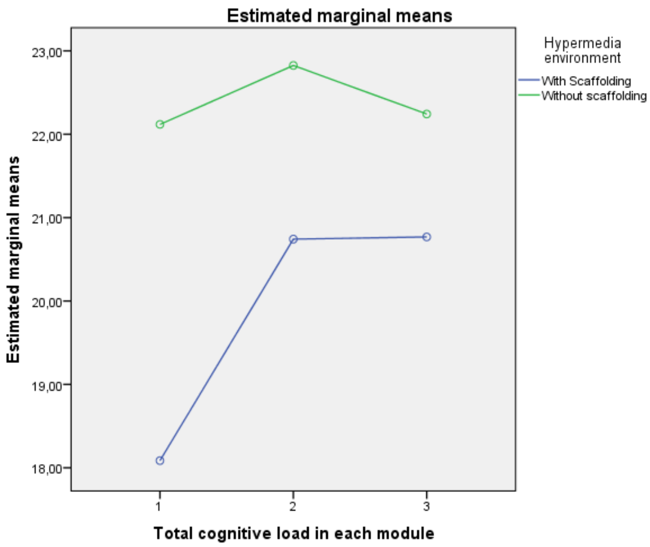

Figure 5. Effect of hypermedia environment on total cognitive load in each module

To conduct a more detailed analysis of each one of the CLs (intrinsic, extraneous, and germane) in each module, Table 2 shows the following descriptive data.

Table 2. Results of the different cognitive loads in each module: Mean scores and standard deviations in parenthesis

Software	Cognitive style	No.	Module 1			Module 2			Module 3		
			I.L.	E.L.	G.L.	I.L.	E.L.	G.L.	I.L.	E.L.	G.L.
With Scaffolding	Field Dependent	10	5.4	6.23	7.46	6.70	6.38	7.68	6.85	6.58	7.92
			(1.35)	(1.81)	(1.12)	(1.43)	(1.17)	(0.96)	(1.39)	(1.10)	(0.64)
	Field Intermediate	7	5.89	6.00	7.69	7.00	6.64	7.94	7.25	6.79	7.91
			(1.76)	(1.59)	(1.04)	(0.99)	(0.72)	(0.47)	(1.15)	(1.36)	(0.51)
	Field Independent	10	4.38	4.30	6.92	6.80	5.83	7.26	6.15	5.50	7.36
			(1.62)	(0.91)	(0.53)	(1.48)	(0.39)	(0.54)	(2.19)	(0.69)	(0.39)
	Total	27	5.15	5.45	7.32	6.81	6.24	7.59	6.69	6.23	7.71
			(1.63)	(1.68)	(0.94)	(1.31)	(0.88)	(0.74)	(1.69)	(1.16)	(0.57)
Without Scaffolding	Field Dependent	10	7.4	7.30	7.86	7.70	8.03	8.02	7.88	7.78	7.94
			(1.51)	(1.70)	(1.19)	(0.84)	(0.65)	(1.13)	(0.96)	(0.95)	(1.06)
	Field Intermediate	9	7.28	7.08	7.38	7.22	7.67	7.82	7.39	7.31	7.60
			(0.81)	(0.87)	(1.60)	(1.11)	(0.74)	(1.21)	(0.83)	(0.69)	(1.31)
	Field Independent	8	7.72	7.56	6.78	7.66	7.31	7.05	7.34	6.88	6.63
			(1.53)	(1.04)	(2.24)	(1.41)	(0.53)	(1.77)	(1.04)	(1.02)	(1.49)
	Total	27	7.45	7.31	7.38	7.53	7.69	7.67	7.56	7.35	7.44
			(1.29)	(1.25)	(1.68)	(1.10)	(0.69)	(1.38)	(0.94)	(0.94)	(1.35)

Mauchly's test indicated that the sphericity assumption does not hold. The data show that the main effect of the module variable is: ($X^2(2) = 30.54$, $p < .05$) and of the CL variable is: ($X^2(2) = 14.634$, $p < .05$). The double interaction between module and CL yielded: ($X^2(9) = 59.30$, $p > .05$). Therefore, the degrees of freedom were corrected with Greenhouse-Geisser for module ($\varepsilon = .68$), CL ($\varepsilon = .79$), and for the interaction between module and CL (ε = .64). The results show a triple and significant interaction between module, CL, and software (F(2.56, 122.90) = 4.54, p = .007, η^2 = .086). Significant differences exist between the following double interactions: module and CL (F(2.56, 122.90) = 2.98, p = .042, η^2 = .058); between CL and software (F(1.58, 75.74) = 12.61, p < .001, η^2 = .208); and between module and software (F(1.35, 64.96) = 6.62, p = .007, η^2 = .121). Finally, significant differences exist in CL components (F(1.58, 75.74) = 12.28, p < .001, η^2 = .204) and module (F(1.35, 64.96) = 12.04, p < .001, η^2 = .200).

The multiple comparisons according to Bonferroni indicate that statistically significant differences exist (p < .05) in total CL, between FD (M = 7.28, SD = .15) and FI students (M = 6.63, SD = .16) and between intermediate (M = 7.21, SD = .17) and FI students (M = 6.63, SD = .16). No significant differences exist in total CL between FD and field intermediate subjects as shown in Figure 6.

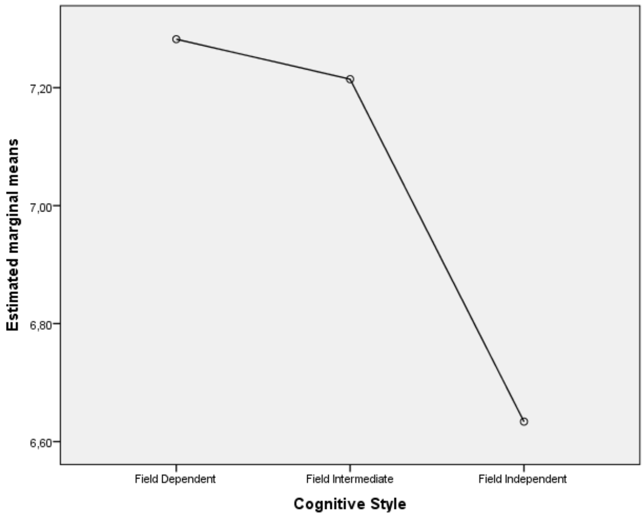

Figure 6. Effect of cognitive style on total cognitive load

Regarding the student groups' use of the hypermedia environment with and without scaffolding and the different CLs, the data show that in module 1, significant differences exist in ICL (F(1, 48) = 31.75, p < .001). Significant differences also exist in ECL (F(1, 48) = 22.70, p < .001) and no significant differences exist in GCL. In module 2, significant differences exist in ICL (F(1, 48) = 4.12, p = .048). Similarly, significant differences exist in ECL (F(1, 48) = 45.27, p < .001) and, as in Module 1, no significant differences exist in GCL. Finally, in Module 3, the same trend is identified; in other words, significant differences exist in ICL (F(1, 48) = 4.37, p = .042), in ECL (F(1, 48) = 14.85, p < .001), and no significant differences are present in GCL, as shown in Figure 7.

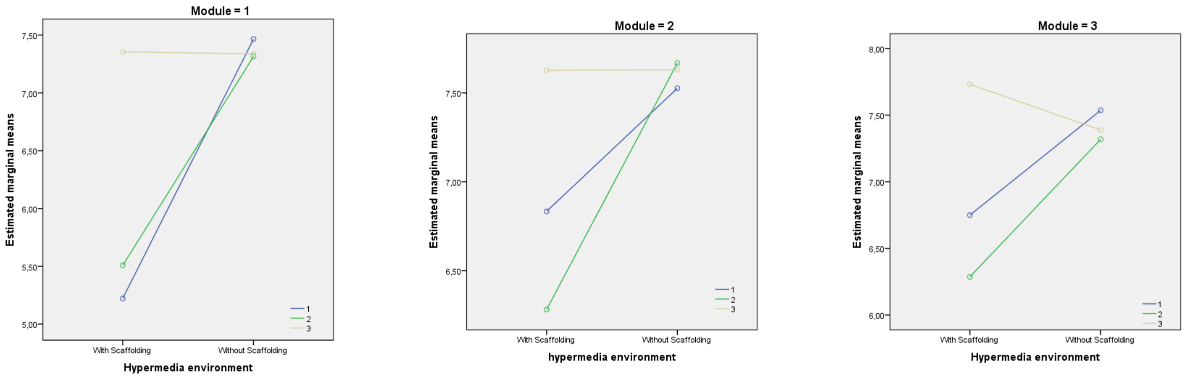

Figure 7. Effect of hypermedia environment on cognitive load (1 = intrinsic cognitive load, 2 = extraneous cognitive load, 3 = germane cognitive load)

Effect of the metacognitive scaffolding on learning achievement

A repeated measures ANOVA is used. The intra-subject variable is students' performance in each one of the three lesson modules. There are two inter-subject variables: Hypermedia environment with three values: field dependent, intermediate, and independent. Table 3 shows a summary of the descriptive statistics of LA in each one of the study modules considering the inter-subject variables.

Table 3. Results of learning achievement in each module: Mean scores and standard deviations in parenthesis

Software	Cognitive style	No.	Achievement Module 1	Achievement Module 2	Achievement Module 3
With scaffolding	Field dependent	10	76.40(5.74)	80.40(6.02)	77.50(8.89)
	Field Intermediate	7	75.29(4.68)	82.29(4.15)	76.00(6.00)
	Field Independent	10	71.80(7.66)	78.50(6.33)	75.80(6.92)
	Total	27	74.41(6.41)	80.19(5.72)	76.48(7.27)
Without scaffolding	Field dependent	10	61.30(5.54)	66.60(5.91)	64.60(10.21)
	Field Intermediate	9	59.56(7.57)	58.78(6.53)	59.78(10.40)
	Field Independent	8	59.13(8.18)	63.88(4.29)	59.38(16.76)
	Total	27	60.07(6.87)	63.19(6.45)	61.44(12.29)

Mauchly's test indicated that the sphericity assumption does not hold. The data showed that the main effect of achievement is: ($X^2(2) = 80.09$, $p < 0.05$). Consequently, the degrees of freedom were corrected with Greenhouse-Geisser ($\varepsilon = .86$). Results show that significant differences exist only in the achievement variable ($F(1.73, 82.89) = 7.16$, $p = .002$, $\eta^2 = .130$). With respect to the inter-subject variables, significant differences exist only between the hypermedia environment and LA ($F(1, 48) = 90.64$, $p < .001$, $\eta^2 = .654$). Students that worked with the metacognitive scaffolding obtained a greater achievement ($M = 77.11$, $SD = 1.17$) compared to students that did not use it ($M = 61.44$, $SD = 1.16$), as shown in Figure 8. No significant differences were found in LA between students with different cognitive styles.

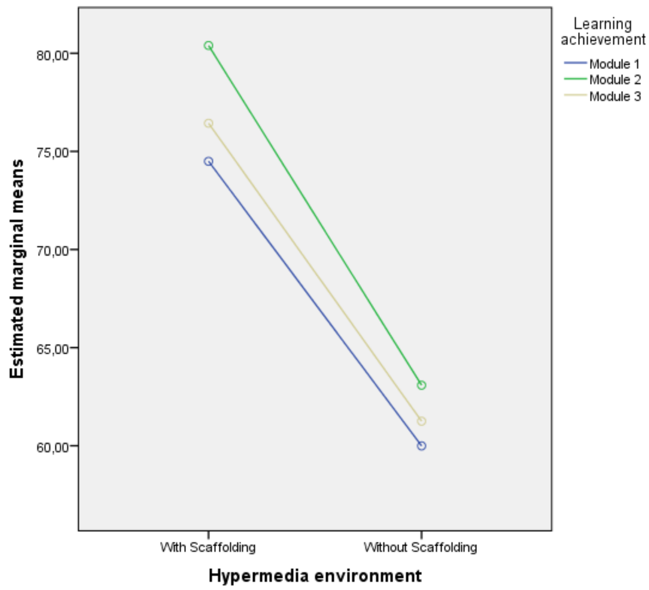

Figure 8. Effect of hypermedia environment on learning achievement

Discussion and conclusions

First research question

The results showed that the implementation of the metacognitive scaffolding, within the structure of a hypermedia environment, positively influenced students' LA.

The study's analyses indicate that LA was significantly greater in students that used the metacognitive scaffolding in comparison to the achievement of their classmates that did not. Hence, in each lesson module the scaffolding favors metacognitive monitoring and process control insofar as the student learns to plan their study activities as a function of a self-imposed learning goal and to conduct a constant monitoring of their actual learning process, action they execute through different self-evaluations.

The self-evaluations carried out by the student leads them to reflect on the knowledge they have acquired throughout the modules. Accordingly, they can establish what concepts are still pending to be studied or reinforced to achieve the self-imposed learning goal. Thus, they can perform metacognitive control to review the content, change the learning goal, or adjust the learning strategy they have implemented to understand concepts and definitions. Hence, the scaffolding provides them with options and favors student's autonomy, while the student undertakes the responsibility of their learning process.

In this sense, the study evidenced that the use of the metacognitive scaffolding fosters a more structured and systematic behavior in the student, which, probably, allows them to browse and perform different study activities in an organized fashion, adjust learning strategies, and process information in more detail with the objective of achieving a self-imposed goal.

With respect to CL, the results show that the metacognitive scaffolding reduced the perception of total CL in students that interacted with this hypermedia version. A separate analysis of each one of the CLs showed that the scaffolding significantly reduced ICL and ECL. The students' perception of GCL was expected to decrease and enable a greater unloading of the working memory (Andrade-Lotero, 2012; Paas, Renkl, & Sweller, 2003); however, the scaffolding did not have any effect on the GCL.

It is noteworthy that the average GCL, in comparison to ICL and ECL, is greater and tends to be constant in the different lesson modules. This result is promising insofar as it is a first approach that indicates that metacognitive scaffolding may have positive effects on LA and, in addition, reduce ICL and ECL.

From the results, it is possible to assert that the students' reflection on their own learning process can trigger them to change or adjust the chosen learning strategy, the manner of browsing, to read different content, etc. Thus, the use of the scaffolding helps the novice organize in a structured and systematic fashion their own learning process.

Because of the foregoing, it is possible to assert that the perception of the student's ICL and ECL is lower in comparison to the group that did not use the scaffolding. These results evidence that the reduction in ICL, when beginning a learning task, helps the student easily learn the subject. Regarding ECL, it is possible that the scaffolding could be considered a distraction since it presents pop-up windows that aim to encourage the student to reflect on their own learning process; but, it is not so. The results show that ECL was reduced, which shows that the inclusion of scaffolding in hypermedia environments does not act as a distraction, but rather the scaffolding is a structural part of the computational environment.

On the other hand, no significant differences were found in GCL. A possible explanation for these results is that the perception of the two groups of students, with respect to content comprehension, in general, vas highly valued, despite LA being significantly greater in the group that used the scaffolding.

This could indicate that the perception of the mental effort employed to comprehend the concepts and definitions covered in the hypermedia environment is always highly valued, independently of the LAs obtained in the evaluations the participants took at the end of each lesson module. It is noteworthy that the perception of learning difficulty was the same for both group of students. Thus, the scaffolding that was used did not exhibit any effect on GCL. It is likely that beginning a new learning process will always imply a high level of difficulty for novices and therefore germane load tends to be high. In accordance to the foregoing, it is suggested that this subject be studied in more detail insofar as other associate variables probably exist that influence these results. These results validate the first working hypothesis.

Second research question

With respect to the second research question, the results evidence that no differences exist in LA between students with different cognitive styles. It was verified that FD and field intermediate students achieve lessons equivalent to those obtained by their FI classmates. These results complement the findings of other studies that show that the use of computational scaffolding reduce individual differences in LA (López-Vargas, Hederich-Martínez, & Camargo-Uribe, 2012; López-Vargas & Valencia-Vallejo, 2012; López-Vargas & Triana-Vera, 2013).

With respect to total CL, the results show that significant differences exist between FI and FD students, and similarly, between FI and field intermediate students. No significant differences exist between FD and field intermediate students. These results contradict the findings of Angeli (2013) and Angeli et al. (2009), who did not find significant differences between students with different cognitive styles in the FDI dimension with respect to CL. These contradictory results demonstrate the need for further research, especially when dealing with self-reporting instruments in which students tend to provide socially accepted answers and possess a high subjective component. Similarly, subject matter content and the type of software can have differential effects in students.

However, the results of the present study are coherent with the findings of Jia, Zhang, and Li (2014), who through contralateral delay activity, measure the brain's electrical activity in visual working memory tasks in subjects with different cognitive styles in the FDI dimension. The study found that FI subjects have a greater capacity of isolating and filtering irrelevant elements in visual memory tasks in comparison to FD subjects. This situation could indicate that FI students have greater selective attention insofar as they more effectively inhibit the distractions present in computational scenarios and can probably process information in the working memory more efficiently.

Consequently, total CL employed in learning task development in FI students is smaller in comparison to their FD classmates, who are more prone to distractions and have a lower selective attention (Avolio, Alexander, Barrett, & Sterns, 1981; Hasher, Zacks, & May, 1999). The results of the present research may correspond with the efficient management of the working memory insofar as FI subjects are better at choosing relevant information and inhibiting distractions during learning task development in computational scenarios, situation that likely reduces CL. These results allow accepting the study's second hypothesis.

In conclusion, studies suggest that the use of scaffolding may help reduce differences in LA in students with differing cognitive styles in the FDI dimension (López-Vargas, Hederich-Martínez, & Camargo-Uribe, 2012; López-Vargas & Valencia-Vallejo, 2012, López-Vargas & Triana-Vera, 2013) and favor CL reduction. Consequently, it is necessary to continue developing studies that provide empirical evidence in order for CBLE designers to develop more equitable and flexible computational scenarios, which favor subjects' autonomy in learning and their performance in different levels of schooling.

Limitations and forecasts

The study was not an experimental-type research, considering that the groups that participated in the experience were previously constituted and were not randomly organized; therefore, the results cannot be generalized or extended to all students in the secondary educational system.

Another limitation refers to the initial characterization of the students to provide them differentiated support during the learning process based on their individual learning needs. In this sense, future research could consider including in the scaffolding elements that adapt to subjects' stylistic characteristics to determine their effect on CL.

Considering that the instruments used so far to measure CL are based on self-reporting questionnaires, it is necessary to develop other indicators that allow objectively evidencing students' cognitive effort.

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