Journal of American Science

Websites:
http://www.jofamericanscience.org
http://www.sciencepub.net

Emails:
editor@sciencepub.net
sciencepub@gmail.com

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

The Effectiveness of Instructional Design Principles on learning issues Cognitive Load in Multimedia Learning Environments

Hussein Zare [1], Mohammad Reza Sarmadi [2], Hashem FarDanesh [3], Awat Feizi [4], Taher Mahboobi [5]

[1.] Associate Professor, Department of Psychology, Faculty member of Payam Noor University, Tehran, Iran
[2] Associate Professor, Department of Educational Sciences, Faculty member of Payam Noor University, Tehran, Iran.
3. Associate Professor, Department of education, faculty member of Tarbiat Modarres University, Tehran, Iran
4. Assistant Professor, Department of Statistics, Faculty of Medical Sciences, Isfahan, Iran
5. Lecturer, Department of Educational Sciences, a PhD distance learning programs, faculty member of Payam Noor University, Bokan, Iran.
(***Corresponding Author***)-- m_taher858@yahoo.com(09141841806

Abstract: This study is aimed at determining the effectiveness of instructional design principles (14 multimedia principles of van Merriënboer and Kester) on cognitive load in multimedia learning environments. This is a quasi -experimental study supported by parallel or control groups. The statistical population of the research includes all the students of the Educational Science at Payam-e-Noor University, Boukan Branch, including 540 people. The sample was determined to be 180 people (110 male and 70 female students), divided into experimental group (55 male and 35 female) and control group (55 male and 35 female). They were selected by simple random sampling. The research tool was instructional design principles of instructional design software based on 14 principles of Multimedia by Van Merriënboer and Kester (2005) whose internal and external validity are .94 and .81, respectively; these were achieved by a researcher –designed questionnaire including 72 questions. The cognitive load was measured by a 9 grade scale of Paas and Merrienboer (1994) and Paas and Merrienboer and Adam (1994) whose internal and external validities are .86 and .83, respectively. Results showed that compliance with the principles of instructional design has a significant effect ($p \leq 0/01$) in reducing the load on cognitive tests of test group compared to the control group.

[Hussein Zare, Mohammad Reza Sarmadi, Hashem FarDanesh, Awat Feizi , Taher Mahboobi. **The Effectiveness of Instructional Design Principles on learning issues Cognitive Load in Multimedia Learning Environments .** *J Am Sci* 2022;18(7):59-68]. ISSN 1545-1003 (print);ISSN2375-7264 (online).
10.7537/marsjas180722.08. 08. doi:http://www.jofamericanscience.org

Key words: instructional design principles, Cognitive Load, multimedia learning environments

Introduction:

One of the trends in modern education is the use of rich learning tasks in learning environments (Van Merriënboer and Kester, 2007). Cognitive capacity, especially for beginners, in learning a complex cognitive task, is considered as a limiting factor. Undesirable effects of high cognitive load on learning has been reported in a diverse range of relatively complex cognitive domains such as mathematics (Paas, 1992, Sweller, 1989, Tarmizi, 1988), numerically controlled computer programming (Chandler & Sweller et al., 1992) electrical engineering (Chandler & Sweller)and Statistics . Issues in this field have a hierarchical goal structure, i.e., the ultimate goal can be achieved only through the successful realization of all sub-goals. Most beginners can not adapt themselves with the issues, they usually give up due the high volume of information and choosing poor problem-solving strategies. Cognitive load theory (Sweller 1988, Sweller and others, 1998, Van Merriënboer and Sweller, 2005), and 14 multimedia principles of instructional design in multimedia learning environments (Van Merriënboer and Kirschner, 2007, Van Merriënboer and Kester, 2005), provide guidelines for reducing the cognitive load associated with learning rich tasks. Cognitive load theory is based on the assumption that optimal learning occurs in humans when the load on working memory is at its lowest level, and it facilitates long-term memory (Sweller, 1988). Value and ease of processing information in working memory and adaptation of teaching strategies with learners' cognitive limitations has been the main concern of cognitive load theory, raised by John Sweller et al. (Pass and others, a 2003, 2004, Pass and van Gog, 2006, Sweller, 1999, 2003, 2005, Sweller and Chandler 1994, Sweller et al. 1998).

This theory claims that the effectiveness of instructional design will be unpredictable if there is no knowledge about human cognitive learning processes. Cognitive load theory tries to join the knowledge about the structure and function of the human cognitive system with the instructional design principles. Cognitive load represents the load imposed by certain task on the cognitive system (Pass and Merriënboer, 1994a). Working memory load can be influenced by the intrinsic nature of training (Intrinsic cognitive load) and provided training practices (Extraneous & germane cognitive load). Kirschner (Kirschner, 2002) has proposed a brief description of each of these three aspects of cognitive load. Intrinsic cognitive load is the difficulty level of task content and instructional design can not have any influence on it. Intrinsic cognitive load is the load imposed on the memory by simply thinking to the task (Chipperfield, 2004). Extraneous cognitive load depends on the instructional design used to express the content (Kirschner and others, 2006). Germane Cognitive load refers to the cognitive capacity required for actively building knowledge or schema integration (. Brunken, Pass and Leutner, 2004). In multimedia learning environments, providing frameworks, perceptual processes and higher cognitive processes are considered as important aspects of learningo curring during the interaction with the environment (Ainsworth and Van Labeke, 2004, Mayer 2001, 2005, Schnotz, 2001, 2005). Mayer and Moreno (2003) have defined multimedia learning as learning by words and images, and multimedia instruction as presenting words and pictures to improve learning. Some researchers have concluded that following a defined solution in a worked example would impose lower cognitive load on the learner's working memory in comparison with self-learning solutions for the problem (Cooper & Sweller, 1987, Renkl, 1999, 2002, Sweller and Chandler, 1991, 1994, Cooper and others, 2001, Pass and Merriënboer, a1994,). Van Merriënboer and Pass (1994) studied the high variabilityof learning from worked examples, in arithmatics problemsof high and low variability. They showed that better learning occures when the variability is low. Pass and Merriënboer the better attributed these better learning results to the additional load imposed by tissue variability, which was considered as a germane load. The level of cognitive load can be inferred from the results of the knowledge test. Then, it is claimed that when the results are lower than the knowledge post-test, there is a much higher cognitive load, (Mayer and others, 2005, DeLeeuw and Mayer, 2008, p 225) . Also, Stull and Mayer (2007, p 808) have pointed out: "Although we do not have direct measures of generative and extraneous processing during learning in these studies, we use transfer test performance as an indirect measure. In short, higher transfer test performance is an indication of less extraneous processing and more generative processing during learning" Characteristics of study subjects and research time within cognitive load studies has been considered by Van Merriënboer and Ayres (2005) and they have suggested to investigate students working on real assignments and consider real-time of the study. Modality principle has been observed in a wide range of studies, and various reviews conducted in observance of this principle have demonstrated that it lowers the cognitive load . (Ginns, 2005, Mayer, 2001, Moreno, 2006, Kalyuga and others, 1999, 2000, Mayer & Moreno, 1998, Moreno and Mayer a 1999, Mousavi, and others, 1995, Mayer and others, 2003). Completion problems are a specific type of educational approach that reduce extraneous cognitive load. Completion problems, are especially useful in areas such as software design and designing electronic circuits. On the other hand, completion problem are reduce extraneous cognitive load by providing incomplete examples (Van Merriënboer, and Kester Kirschner, 2003). Studies have shown the superiority of completion problems to the conventionals(Pass, 1992, Van Merriënboer, 1990, Van Merriënboer and De Croock, 1992). A research work conducted by Kalyuga, Chandler and Sweller (1999), Tabbers, Martens, and Van Merriënboer, (2004) confirmed the superiority of audio presentation with charts to the visual presentation. The effect of split attention occurs when the learners should pay attention to more than two different sources and integrate them in order to understand the contents, and trying to prevent split attention, reduces the cognitive load (Yeung, Jin, Sweller, 1998). It has been observed that this is one of the major problems in some educational projects, which causes interference in effective learning (Chandler, Sweller, 1992, 1991, Sweller and Chandler, 1994, 1991) As a result of split attention, the cognitive load increasesand learning is undermined. If your resources are limited (for example, a chart which can be understood independently), a text devoted exclusively to describe the information in the chart, would be superfluous (Redundancy information). In such a situation, extra text information, imposes a double cognitive load. In contrast, elimination of Redundancy information resources would be beneficial to learning (Chandler and Sweller, 1991, Kalyuga, Chandler, and Sweller, 1999). A recent study, using a computer simulation of the ideal gas law, showed that the intrinsic load can be reduced through the presenting the content in two separate sequences on the computer (Lee, Plass & Homer, 2006). McDaniel and Donnelly (1996) in their research found that question approach leads to more objectivity and realizes learning. In other words, adding the question imroved the new knowledge. In another study, a number of studies were summarized and it was concluded that trained learners ask questions to enhance their understanding of the content (Rosenshine, Meister, and Chapman, 1996). In another research, self-explanatory of students was compared while reading physics problems. Students who had more self-explanatory, gave a coorect answer to 86% of the questions, while the students with limited self-explanatory, could answer only to 42% of problems (Chi, 2000; Chi and others, 1989; Chi and others 1994). Also, the limitations of past studies is that all of them have considered short multimedia training in well-defined technical subjects like geometry (Mousavi and others, 1995 Jeung and others, 1997); scientific explanations of how lightning develops (Mayer and Moreno, 1998; Moreno and Mayer, 1999) and electrical engineering (Kalyuga and others, 1999; Tindall-Ford and others, 1997). This raises the question whether it can be used outside the scope of multimedia in teaching technical and longer? Therefore, the researcher has chosen this course of education statistics as to the control group and test content. Because, of course, has a hierarchical structure and is outside the technical domain. The main issue in this study is whether these principles can reduce the cognitive load issues are multimedia learning environments?

Materials and Methods

This is a quasi - experimental study supported by parallel or control groups. The study population included all 540 students of Educational Sciences Research Center, in Bokan University of Payam-e-Noor. The study sample included 180 subjects, (110 males and 70 females) selected via simple random sampling to be tested in two testing group (55 males and 35 females) and control group (55 males and 35 females). Research tools included a scale to measure cognitive load (Pass and Van Merriënboer, 1994; Pass and Van Merriënboer and Adam, 1994) which is prepared in 9-point Likert scale. In the present study, multimedia learning (web-based) statistics course has been prepared based on the instructional design model of Kester and Merriënboer (2005) that Includes: Sequencing principle (Presenting the content from simple to complex), Coherence principle (Removing interesting but irrelevant content, such as background music, video clips etc. will lead to better learning) , Variability principle (Learning tasks are well distinguished), Individualization principle (Selection of learning tasks based on individual characteristics of the learner), worked examples principle (Provide examples and their solutions), Completion-strategy principle (Providing completion assignments that offer a part of the solution to the learners and let them complete the solution), Redundancy principle (Additional or “redundent" information to learners), Self-explanation principle (Learner explains the steps of a solution through worked examples), Self-pacing principle (Transfer the learning pace to the learner), Temporal split-attention principle(presentin information simultanously, ex. Simultanously narrating & presenting the animation), Spatial split-attention principle (Combining different data sources in a unified source), Signaling principle (Focusin learner’s attention on the main aspects of the learning task by highlighting a certain part of the image), Modality principle (Presenting both audio and text versions in comparison with mere visual mode leads to a better learning), Component-fluency principle (Rehearsing and repeating on a few aspects of the learning task). This model describes a design strategy for the training of complex cognitive skills . Training CDs (educational websites) starts with a short introduction to introduce with this model. The content is divided to four small training unit based on 14 principles described above, so that each small learning units, is assigned to a specific section of the content . The time devoted to study four small training units was about 40 minute. It should be noted that the above procedure has been implemented on the control group by designed CD without notcing the fourteen principles of instructional design. After each training unit, a separate page with a 9 point scale (1 to 9) was given to students, so they could scale their level of mental effort for the small training course of that unit. When students clicked on one of these 9 points, The program would continue automatically and display the next small training unit. In the end, all selected scale scores of the four stages of designed content were added and average was considered as an estimate of cognitive mental effort of students spent on learning these four training stages . The experiment was conducted in 8 sessions, approximately one-hour spent for each. In each session from 1 to 20 students were evaluated simultaneously. The sessions were held in the multimedia lab with 20 computer systems connected to the University network. When students log into the computer system, they were randomly assigned to use one of the systems.

Here, experts advices and also reviewing similar research works have helped the researchers to design questions to measure the level of knowledge of the participants about the educational content. The questions were reviewed and accepted by specialists after some modifications.In two studies, Pass et al. (1992) and Pass and Merriënboer (1994b) reported Cronbach's alpha measure of cognitive load, to be 90% and 82% . load In the present study, Internal validity of the cognitive load was measured by through Cronbach's 86/0. Also, once the retest method was used to measure external validity of the cognitive load. So that, before the main test 30 people were trained and cognitive load scale was given to the subjects during the training questionnaire. After 15 days, the same group was re-trained; And again the questionnaire measured the cognitive load during training. Retest correlation coefficient was 0/83.

The formal validity and content of the software designed based on the 14 principles were evaluated by the researcher using a 72 item questionnaire. Therefore, the educational software was developed by the researchers and software experts based on 14 principles and then, the educational software and a questionnaire was designed with 72 questions based on 14 principles. Testing and multimedia professionals were asked to confirm the formal validity and content and after a series of modifications, the appearance and content validity were confirmed. Internal validity of the questionnaire was obtained by Cronbach's alpha of 0/94. The software was used to measure external validity questionnaire via test-retest method. So that, before the main test, 30 people were trained by educational software based on 14 principles, and the subjects were asked to fill the questionnaires based on the software. And again, after 15 days, the group was trained through educational software, and again they filled the questionnaire related to software. Retest correlation coefficients obtained from the credit was 0/81. For data analysis, descriptive statistics (frequency, mean and standard deviation) and statistical analysis (t-test and ANOVA) have been used.

Results:

Table 1: Mean and standard deviation of cognitive load in both control and experimental groups (CL, cognitive load, Ex, Experimental, co, Control)

variable	groups	M	SD
CL	Ex	9/62	2/36
	Co	16/97	4/21

Table 2: Mean and standard deviation of variable cognitive load of the two groups according to sex(V, variable CL, cognitive load, Ex, Experimental, co, Control)

V	Group	Gender	M	SD
CL	Ex	Man	10/20	2/81
		Female	9/25	1/95
	co	Man	15/97	4/49
		Female	17/61	3/57

Table (3): independent- t variables between control and treatment groups in cognitive load(c, Cognitive, l, load, E, Equal. V, variances)

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Cl	E.V	22.964	.000	-14.336	178	.000

As shown in Table 3, Leven test data shows significant variance equality. It also shows that implementing educational design principles based on cognitive load is different between control and experimental groups ≤ 0/01) (P. This means that instructional design principles in multimedia learning environments Will reduced cognitive load and its failure to observe an increase in cognitive load.

Table (4): One-way analysis of variance in the variable cognitive load between women and men in experimantal and control groups.(c. Cognitiv, l, load, B, Between, G, Groups, W, Within, G, Groups, T, Total)

Cl	Sum of Squares	df	Mean Square	F	Sig.
B. G	2510.12	3	836.70	73.52	.000
W. G	2002.88	176	11.38		
T	4513.012	179			

As shown in Table 4, One-way analysis of variance table shows that the principles of instructional design has a significant effect on the cognitive load of women and men in the control group $P \leq 0/01$)). To show that there are significant differences between any group of men and women, bonferroni correction post-hoc t-test has been used.

Table (5): Bonferroni test to compare pairs of groups based on cognitive load score(M, Man, F, Female, Ex, Experimental, co, Control)

Bonferroni				
(I) Gender	(J) Gender	Mean Difference (I-J)	Std. Error	Sig.
M. E	F. E	.95714	.72942	1.000
	M. Co	-5.76429*	.80640	.000
	F. C	-7.40649*	.72942	.000
F. E	M. Ex	-.95714	.72942	1.000
	M. Co	-6.72143*	.72942	.000
	F. Co	-8.36364*	.64329	.000
M. Co	M. Ex	5.76429*	.80640	.000
	F. Ex	6.72143*	.72942	.000
	F. Co	-1.64221	.72942	.154
F. Co	M. Ex	7.40649*	.72942	.000
	F. Ex	8.36364*	.64329	.000
	M. Co	1.64221	.72942	.154

As it can be seen in Table 5, there is no significant difference in cognitive loads of men and women in the experimental group. This shows that the principles of instructional design have the same effect on reducing the cognitive load for both men and women in the experimental group. But a significant difference (0/01) P ≤ was found for cognitive loads of women in experimental group and both men and women of the control group. This indicates that these principles of instructional design have a greater impact on men in Experimental group compared to men and women in control group. Also, there is a significant difference between women in Experimental group with women and men in control($P \leq 0/01$). But there were no significant difference between women and men in control group in cognitive load, because none of them received Instructional Design Principles in a systematic way.

Discussion:

The results showed that the implementing the principles of instructional design has a significant effect on cognitive load in multimedia learning environments. The systematic implementation of principles of instructional design (14 principles) resulted in a significantly lower cognitive load in experimental group compared to the control group, Which is consistent with research results of Sweller & Cooper (1987), Renkl (2002,1999), Sweller and Chandler (1994,1991), Cooper and others (2001), Pass and Merriënboer (1994a), Mayer and others (2005) , DeLeeuw and Mayer (2008), Stull and Mayer (2007), Van Merriënboer and Ayres (2005), Ginns (2005), Moreno (2006), Mayer and others (2003), Van Merriënboer, Kirschner and Kester (2003), Pass (1992), Kalyuga, Chandler and Sweller (1999), Tabbers, Martens, and Van Merriënboer, (2004), Yeung, Jin, Sweller, (1998), Sweller and Chandler (1994), Lee, Plus, Homer (2006), Rosenshine, Meister and Chapman (1996), Mousavi and others (1995). This article explains how the instructional design principles reduce cognitive load. According to research works conducted in cognitive science, there are three assumptions about how human mind works: dual-channel assumption, limited capacity assumption, active processing assumption. First, based on the dual coding theory of Paivio (1986), and working memory theory of Baddeley (1998), human information processing system is composed of two separate channels, one auditory / verbal processing channel for the auditory and verbal representations and one visual / image processing channel for visual representations of the input image. So, it can be concluded that based on instructional design principles, providing information to the learner through a dual channel, instead of one channel would reduce cognitive load. Secondly, according to cognitive load theory of Chandler and Sweller (1991), Sweller (1999) and working memory theory of Baddeley (1998), each channel has a limited capacity of information processing system, and only a limited amount of cognitive processing can occur at any time in the verbal or visual channel. So, instructional design principles manage the limited capacity of working memory for cognitive processing. Thirdly, meaningful learning requires a considerable amount of cognitive processing in verbal and visual channels. This is the central assumption of Wittrock's (1989) generative-learning theory and Mayer's (1999, 2002) selecting–organizing–integrating theory of active learning.. These processes include paying attention to the presented material, mentally organizing the presented material into a coherent structure, and integrating the presented material with existing knowledge.. Multimedia learning is a potential problem in a situation where words and images are presented to the learner. Processing demands of the learning task exceed the processing capacity of the cognitive system, a state which is called cognitive overload. Cognitive demands is composed of Essential processing (aimed at understanding the presented content, including selecting, organizing, and integrating words and selecting, organizing and integrating the images), Incidental processing (non-essential aspects of the provided content) and Representational holding (maintaining verbal or visual representation of the maintenance in working memory). Cognitive overload occurs when the total processing exceeds cognitive learning capacity. Instructional design principles in multimedia learning environments, help learners reduce the cognitive load required for redistribution Essential processing, reduce Incidental processing or reduce Representational representations. (Mayer and Moreno, 1998, Experiments 1 and 2, Moreno and Mayer, 1999, Experiments 2 and 1, Moreno, Mayer, Spires, 2001, experiments 5 and 4) conducted a study to remove the overload imposed on a channel through extra essential processing demands. They considered a student who is interested to know how lightning works. He refers to a multimedia encyclopedia and clicks on the subject of the thunder. A two-minute animation appears on the screen that shows the steps of lightning formation along with a text that describes the same steps. Text appears at the bottom of the screen, so when he reads the text, he cannot see the animation or when he watches the animation, he does not read the text. This leads to a situation that Sweller (1999) has called the impact of split- attention. The visual learner attention splits between watching animation and reading text on screen. The eyes receive equally substantial information, but only one part of the information can be selected for further processing in working memory. A solution to this problem is presenting words as a narrative voice. Thus, the words, at least initially, are processed in the verbal channel. While the animation is processed in the visual channel. Therefore, the processing demands imposed on the visual channel are reduced, so that the learner is able to choose the most important aspects of animation for further processing. Processing demands imposed on the verbal channels are moderate, so, the learner is able to choose the most important aspects of the narrative for further processing. And briefly, the use of animation with narration helps removing the load (or redirects it). Some of the processing demands of visual channels are transferred to the verbal channel. So, it can be concluded that the scientific description via animation and narration leads to a better performance in students compared to describing via animation and text. A similar effect has been reported by Mousavi, Lowe and Sweller (1995) in a book-based multimedia environment. The robustness of the modality effect provides strong evidence for the viability of off-loading as a method of reducing cognitive load. What has cognitive load theory brought to the field of educational design? The three main recommendations that come from cognitive load theory are: present material that aligns with the prior knowledge of the learner (intrinsic load), avoid non-essential and confusing information (extraneous load), and stimulate processes that lead to conceptually rich and deep knowledge (germane load). These design principles have been around in educational design for a long time (see e.g., Dick and Carey 1990; Gagne´ et al. 1988;Reigeluth 1983).

Acknowledgments

Praise to Allah, the Merciful, the Compassionate for all the gifts I have been offered. One of these gifts is the accomplishment of this work. Authors specially indebted to the students who participated in this work.

Corresponding Author:
Taher Mahboobi
Department of Educational Sciences
Payam Noor University
Bokan, Iran 09141841806
E-mail: m_taher858@yahoo.com

References

[1]. - Ainsworth, S., & Van Labeke, N. (2004). Multiple forms of dynamic representation. Learning and Instruction, 14(3), 241–255.

[2]. - Baddeley, A. (1998). Human memory. Boston: Allyn & Bacon.

[3]. - Brunken, R., Plass, J. L. & Leutner, D. (2004). Assessment of cognitive load in Multimedia Learning with Dual task Methodology: Auditory Load and Modality Effects: Instructional Science 32, 115 -132.

[4]. - Chandler, P. & Sweller, J. (1991). Cognitive load theory and the format of instruction. Cognition and Instruction, 8, 293-332.

[5]. - Chandler, P. & Sweller, J. (1992). The split-attention effect as a factor in the design of instruction. British Journal of Educational Psychology, 62, 233-246.

[6]. - Chi, M. T. H., De Leeuw, N., Chiu, M., and LaVancher. C. (1994). Eliciting self-explanations improves understanding. . *Cognitive Science*, 18,439-477.

[7]. - Chi, M. T.H. (2000). Self-explaning expository texts: The dual processes of generating inferences and repairing mental models. In R. Glaser (Ed). *Advances in instructional psychology: educational design and cognitive science*. Hillsdale, NJ: Lawrence Erlbaum Associates.

[8]. - Chi, M. T.H., Bassok, M., Lewis, M. W, Reimann, P., and Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science*, 13, 145-182.

[9]. - Chipperfield, B. (2004). Cognitive load Theory and Instructional Design, University of Saskatchewan. Retrieved May 25, 2007, from

[10]. - Cooper, G., & Sweller, J. (1987). The effects of schema acquisition and rule automation on mathematical problem-solving transfer. Journal of Educational Psychology,79, 347–362.

[11]. - Cooper, G., Tindall-Ford, S., Chandler, P., & Sweller, J. (2001). Learning by imagining. Learning of Experimental Psychology: Applied, 7, 68–82.

[12]. - DeLeeuw, K. E., & Mayer, R. E. (2008). A comparison of three measures of cognitive load: Evidence for separable measures of intrinsic, extraneous, and germane load. Journal of Educational Psychology, 100, 223–234.

[13]. - Dick, W., & Carey, L. (1990). The systematic design of instruction (3rd ed.). New York: Harper Collins College Publishers.

[14]. - Gagne´, R. M., Briggs, L. J., & Wager, W. W. (1988). Principles of instructional design (3rd ed.). Fort Worth, TX: Harcourt Brace Jovanovich.

[15]. - Ginns, P. (2005). Meta-analysis of the modality effect. Learning and Instruction, 15, 313–331.

[16]. - Jeung, H., Chandler, P., & Sweller, J. (1997). The role of visual indicators in dual sensory mode instruction. Educational Psychology, 17, 329-343.

[17]. - Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. Applied Cognitive Psychology, 13, 351–371.

[18]. - Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. Applied cognitive psychology, 13, 351-371.

[19]. - Kalyuga, S., Chandler, P., & Sweller, J. (2000). Incorporating learner experience into the design of multimedia instruction. Journal of Educational Psychology, 92, 126–136.

[20]. - Kirschner, P. (2002). Cognitive load Theory: implications of cognitive load Theory on the design of learning, Learning and Instruction, 12, 1-10.

[21]. - Kirschner, P.A., Sweller, J. and Clark, R. E. (2006). "Why minimal guidance during instruction dose not work: an analysis of the failure of constructivitst, discovery". Problem-based, Experientail and inquiry based teaching educational psychologist. 41(2): PP:75-86.

[22]. - Lee, H., Plass, J. L., & Homer, B. D. (2006). Optimizing cognitive load for learning from computer-based science simulations. Journal of Educational Psychology, 98, 902-913.

[23]. - Mayer, R. E. (1999). The promise of educational psychology: Vol. 1, Learning in the content areas. Upper Saddle River, NJ: Prentice Hall.

[24]. - Mayer, R. E. (2001). Multimedia learning. New York: Cambridge University Press.

[25]. - Mayer, R. E. (2002). The promise of educational psychology: Vol. 2, Teaching for meaningful learning. Upper Saddle River, NJ: Prentice Hall.

[26]. - Mayer, R. E. (2005). The cambridge handbook of multimedia learning. Cambridge: Cambridge University Press.

[27]. - Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. Journal of Educational Psychology, 90, 312–320.

[28]. - Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. Educational Psychologist, 38, 43-52.

[29]. - Mayer, R. E., Dow, G. T., & Mayer, S. (2003). Multimedia learning in an interactive self-explaining environment: What works in the design of agent-based microworlds. Journal of Educational Psychology, 95, 806–813.

[30]. - Mayer, R. E., Hegarty, M., Mayer, S., & Campbell, J. (2005). When static media promote active learning: Annotated illustrations versus narrated animations in multimedia instruction. Journal of Experimental Psychology: Applied, 11, 256–265.

[31]. - McDaniel, M.A., and Donnelly, M.C. (1996). Learning with analogy and elaborative interrogation.*Journal of educational Psychology*, 88, 508-519.

[32]. - Moreno, R. (2006). Does the modality principle hold for different media? A test of the method-affectslearning hypothesis. Journal of Computer Assisted Learning, 22, 149–158.

[33]. - Moreno, R., & Mayer, R. E. (1999a). Cognitive principles of multimedia learning: The role of modality and contiguity. Journal of Educational Psychology, 91, 358–368.

[34]. - Moreno, R., Mayer, R. E., Spires, H. A., (2001). The case for social agency in computer-based multimedia learning: Do students learn more deeply when they interact with animated pedagogical agents? Cognition and Instruction, 19, 177–214.

[35]. - Mousavi, S. Y., Low, R., & Sweller, J. (1995). Reducing cognitive load by mixing auditory and visual presentation modes. Journal of Educational Psychology, 87, 319–334.

[36]. - Paas, F. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. Journal of Educational Psychology, 84, 429-434.

[37]. - Paas, F. G. W. C. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive load approach. Journal of Educational Psychology, 84, 429-434.

[38]. - Paas, F. G. W. C., & van Merriënboer, J. J. G. (1994a). Instructional control of cognitive load in the training of complex cognitive tasks. Educational Psychology Review, 6,351-371.

[39]. - Paas, F., & Van Gog, T. (2006). Optimising worked example instruction: Different ways to increase germane cognitive load. Learning and Instruction, 16, 87–91.

[40]. - Paas, F., & van Merrie¨nboer, J. J. G. (1994b). Variability of worked examples and transfer of geometric problem-solving skills: A cognitive load approach. Journal of Educational Psychology, 86, 122–133.

[41]. - Paas, F., & van Merrie¨nboer, J. J. G. (1994b). Variability of worked examples and transfer of geometric problem-solving skills: A cognitive load approach. Journal of Educational Psychology, 86, 122–133.

[42]. - Paas, F., Adam, J. J., Janssen, G. M. E., Vrencken, J. G. P. M., & Bovens, A. M. P. M. (1994). Effects of a 10-months endurance training program on speeded perceptual-motor tasks. Perceptual and Motor Skills, 78, 1267-1273.

[43]. - Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. Educational Psychologist, 38, 1–4.

[44]. - Paas, F., Renkl, A., & Sweller, J. (2004). Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture. Instructional Science, 32, 1–8.

[45]. - Paas, F., Tuovinen, J., Tabbers, H., & Van Gerven, P. W. M. (2003b). Cognitive load

measurement as a means to advance cognitive load theory. Educational Psychologist, 38, 63-71.

[46]. - Paas, F., van Merriënboer, J. J. G., & Adam, J. J. (1994). Measurement of cognitive load in instructional research. Perceptual and Motor Skills, 79, 419-430.

[47]. - Paivio, A. (1986). Mental representation: A dual coding approach. New York: Oxford University Press.

[48]. - Reigeluth, C. M. (Ed.). (1983). Instructional-design theories and models: An overview of their current status. Hillsdale, NJ: Lawrence Erlbaum Associates.

[49]. - Renkl, A. (1999). Learning mathematics from worked-out examples. Analyzing and fostering selfexplanations. European Journal of Psychology of Education 14, 477–488.

[50]. - Renkl, A. (2002). Lerning from worked-out examples: Instructional explanations supplement selfexplanations. Learning and Instruction, 12, 529–556.

[51]. - Rosenshine, B., Meister, C., and Chapman, S. (1996). Teaching students to generate questions: A review of the intervention studies. *Review of Educational Research,* 66(2), 181-221.

[52]. - Schnotz, W. (2001). Sign systems, technologies, and the acquisition of knowledge. In J. F. Rouet, J. Levonen, & A. Biardeau (Eds.), Multimedia learning — cognitive and instructional issues (pp. 9–29). Amsterdam: Elsevier.

[53]. - Schnotz, W. (2005). An integrated model of multimedia learning. In R. E. Mayer (Ed.), The Cambridge handbook of multimedia learning (pp. 49–69). New York: Cambridge University Press.

[54]. - Stull, A. T., & Mayer, R. E. (2007). Learning by doing versus learning by viewing: Three experimental comparisons of learner-generated versus author-provided graphic organizers. Journal of Educational Psychology, 99, 808–820.

[55]. - Sweller, J. (1988). Cognitive load during problem solving: Effect on learning. Cognitive Science, 12, 257–285.

[56]. - Sweller, J. (1989) Cognitive technology: some procedures for facilitating learning and problem solving in mathematics and science. Journal of Educational Psychology, 4, 457-466.

[57]. - Sweller, J., Chandler, P., Tierney, P., & Cooper, M. (1990) Cognitive load as a factor in the structuring of technical material. Journal of Exprimental Psychology: General, 119, 176-192.

[58]. - Sweller, J. (1999). Instructional design in technical areas. Camberwell, Australia: ACER Press.

[59]. - Sweller, J. (2003). Evolution of human cognitive architecture. In B. Ross (Ed.), The psychology of learning and motivation, Vol. 43, (pp. 215–266). San Diego: Academic Press.

[60]. - Sweller, J. (2005). Implications of cognitive load theory for multimedia learning. In R. E. Mayer (Ed.), The Cambridge handbook of multimedia learning (pp. 19–30). New York: Cambridge University Press.

[61]. - Sweller, J., & Chandler, P. (1991). Evidence for cognitive load theory. Cognition and Instruction, 8, 351–362.

[62]. - Sweller, J., & Chandler, P. (1994). Why some material is difficult to learn. Cognition and Instruction, 12(3), 185–233.

[63]. - Sweller, J., van Merriënboer, J. J. G., & Paas, F. (1998). Cognitive architecture and instructional design. Educational Psychology Review, 10, 251–296.

[64]. - Tabbers, H. K., Martens, R. L., & Van Merriëboer, J. J. G. (2004). Multimedia instructions and cognitive load theory: Effects of modality and cueing. British Journal of Educational Psychology, 74, 71-81.

[65]. - Tarmizi, R. A., & Sweller, J. (1988) Guidance during mathematical problem solving. Journal of Educational Psychology, 80, 424-436.

[66]. - Tindall-Ford, S., Chandler, P., & Sweller, J. (1997). When two sensory modes are better than one. Journal of Experimental Psychology: Applied, 3, 257-287.

[67]. - van Merrie¨nboer, J. J. G., & Ayres, P. (2005). Research on cognitive load theory and its design implications for e-learning. Educational Technology Research & Development, 53, 5–13.

[68]. - van Merriënboer, J. J. G. (1990). Strategies for programming instruction in high school: Program completion and program generation. Journal of Educational Computing Research, 6, 265-287).

[69]. - Van Merriënboer, J. J. G. (2007). Alternate models of instructional design: Holistic design approaches and complex learning. In R. A. Reiser, & J. V. Dempsey (Eds.), Trends and issues in instructional design and

technology (pp. 72–81). Upper Saddle River, NJ: Pearson/Merrill Prentice Hall.

[70]. - van Merriënboer, J. J. G., & de Croock, M. B. M. (1992). Strategies for computer-based programming instruction: Program completion vs. program generation. Journal of Educational Computing Research, 8, 365-394.

[71]. - Van Merriënboer, J. J. G., & Kester, L. (2005). The four-component instructional design model:Multimedia principles in environments for complex learning. In R. E. Mayer (Ed.), The Cambridge handbook of multimedia learning (pp. 71-93). New York: Cambridge University Press.

[72]. - Van Merriënboer, J. J. G., & Kester, L. (2007). Whole-task models in education. In J. M. Spector, M. D.Merrill, J. J. G. van Merriënboer, & M. P. Driscoll (Eds.), Handbook of research on educational communications and technology, (pp. 441–456, 3rd ed.). Mahwah, NJ: Erlbaum/Routledge.

[73]. - Van Merriënboer, J. J. G., & Kirschner, P. A. (2007). Ten steps to complex learning. Mahwah, NJ: Erlbaum/ Routledge.

[74]. - Van Merriënboer, J. J. G., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. Educational Psychology Review, 17, 147–177.

[75]. - Van Merriënboer, J. J. G., Kirschner, P. A., & Kester, L. (2003). Taking the load of a learners' mind: Instructional design for complex learning. Educational sychologist, 38, 5–13.

[76]. - Wittrock, M. C. (1989). Generative processes of comprehension. Educational Psychologist, 24, 345–376.

[77]. - Yeung, A. S., Jin, P., & Sweller, J. (1998). Cognitive load and learner expertise: Split attention and redundancy effect in reading with explanatory notes. Contemporary Educational Psychology, 23(1), 1-21.

2/21/2022