Distance Education: Complex System that can be solved with application of the methodology of Structured Knowledge Maps

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Abstract

This article presents a new tool to be used in distance learning courses: Structured Knowledge Maps. The method is best adapted to what one wants to teach/transmit (explicit/tacit knowledge), personalizing the didactic material to the student and equalizing the necessary knowledge for all the learners in the same class, that is, if the student performed the TAQ and was qualified, when participating in each stage of the course he or she will be in an equal position with the other students to acquire the knowledge. This makes teaching democratic, as educators like to say that this is necessary but fail to do. This tool, applied to Distance Learning or EAD as is it known in Brazil, aims to guarantee the effectiveness of learning, in addition to ensuring the memorization of the acquired knowledge and, consequently, the permanence of the student throughout the course. Based on the Theory of Categories and Theory of Functors, the tool is constituted by a Radius of Knowledge and an Area of Ignorance, which applied, in parallel to the Method of Effective Memorization in the Binary Base 2^n, contributes to the creation of a new model of Distance Learning. In this process, we consider the aspects of the Complex Systems Theory that demonstrate failures in the application of the current Distance Learning model used not only in Brazil, but in the vast majority of Distance Learning courses that exist today all over the world. In this way, considering the dynamicity of learning and the transmission of knowledge, the Structured Knowledge Maps ensure plasticity in the teaching-learning process, allowing the student to go through as many branches of knowledge and concepts as necessary to start a new Ray of Knowledge, prerequisites required to initiate the initial Ray of Knowledge, ensuring that it will only pass to another Ray of Knowledge when all Area of Ignorance is eliminated, in other words, when all questions are cleared. Learning is confirmed when the student undergoes a non-dual evaluation process which ensures that what was taught was effectively learned.

Keywords: Distance Learning; Complex Systems; Education; Structured Knowledge Maps;

1. Introduction

The discussion about the use of teaching methodologies, learning techniques and didactic tools goes back to the time of the ancient philosophers, such as Socrates and Plato. Names like: Piaget, Skinner, Vygostky and Paulo Freire, are classic examples in the study that concerns teaching methods. It is based on the greatest names that new research is developed and improved over the years. This is necessary, given the changes that have taken place in the transmission of knowledge with the advance of technologies, the

internet, the form, dynamism and access to information.

Nowadays, when we talk about teaching, it is almost irrefutable not taking into account Distance Learning and the studies of applications of methodologies in this modality.

According to data from the Brazilian Distant Learning Census, conducted by the Brazilian Distance Education Association (ABED – Associação Brasileira em Educação à Distância), in 2016, 3458 distance education courses were accounted only in Brazil. A not seemingly large number, but compared to 2011, when 179 Distance Learning courses were offered, there was an increase in courses of more than 90% in this modality. The numbers are expressive, and this paper raises questions as to how these Distance Learning Courses have guaranteed concrete learning among its adherents. One of the points of the report that most calls attention to is the necessary care that must be taken with the Distance Learning. At the top of the list of the Census it states that Distance Learning requires innovation in pedagogical approaches, followed by technological innovation, innovation of administrative processes, high infrastructure standards, hiring of trained professionals, continuous training, development of support structure to students and complex administrative structure, in that order. Such questions, which in the current situation can be analyzed at a certain angle, being related to the parasitism observed for the first time by Samosata (1905) in the book The Parasite, and later appropriated to biology and also in Complex Systems (GOODMAN, 2012).

It is not intended here to question the qualifications of the most varied Distance Learning courses and institutions in Brazil, but rather present possible solutions to the primary question of Distance Learning: Do students effectively attain enough knowledge to guarantee a place in the market or institutions and not pose any threats whether to themselves or to society? How can this be assured? Making sure that students do not drop out? Getting a diploma or certificate? It is known that having a degree is not a guarantee of learning, just follow television news to see grotesque errors of doctors in operating rooms.

Thus, it is based on the discussions that permeate Distance Learning, regarding the methodology and the effectiveness of learning, which, in this text, will address issues such as Complex Systems (SIMON, 1962), cognitive overload (SWELLER, 2003), (BURNS, 2000), cognitive degradation (RAZ, 2002), based on Structured Knowledge Maps (COSM, 2005), based on the Theories of Categories and Theory of Functors (ASPERTI; LONGO, 1991) of Memorization the Method of Effective Memorization in the Binary Base 2n (MMEEBB – Método de Memorização Exponencial Efetiva na Base Binária in Portuguese) (DIAS, 2008).

Thus the primary question that surrounds the purpose of this article is: Distance Education, as it is modeled today, guarantees the effectiveness of learning? From this question, which permeated the studies of this research, in such a way that the answer was the emergence of other questions: how does a Distance Learning course model the particularities of each student? Do the disciplines require or specify conceptual or knowledge prerequisites to start the course? Do the evaluations guarantee, without a doubt, that there has been an effective learning of the transmitted knowledge or only guarantees that the students do not drop out?

In the search for answers, it was observed that Distance Learning has a system which does not know the structure of the problem, that is, one does not go through the difficulties and individual needs of the students and there is no deep mapping regarding learning. So how can these courses attend the demands of each

student if they do not consider the contents and prerequisites of concepts and knowledge of each one of them, nor the places to which they belong (since distance implies questions of values , ethic and moral) ? They can't. After all, how is it possible to measure these distances? Not knowing the structure of the problem is its failure. And, precisely, because it does not know the structure of the problem and the variables that belong to it, in this research, Distance Learning is considered to be a Complex System. Considering that every Complex System can not be copied, precisely because the structures of the problem are not known (SIMON, 1962) how is it possible that many Distance Learning courses based and / or copied from other institutions, some even foreign, guarantee knowledge effectiveness without measuring these variables?

In this context, the Structured Knowledge Maps establish, through a functor, the mapping between the agents involved, in this case student and teacher, later considered categories, of knowledge and concepts, or morphisms and objects, as it is named in the Theory of Functors, among the categories, having as parameter the mapping of the teacher category in relation to the student category. This process is done through the Qualitative Assessment Table (TAQ – Tabela de Avaliação Qualitativa in Portuguese) that identifies the concepts and knowledge that the student category must possess so that it can initialize a Ray of Knowledge. In this way, it is possible to determine what each student will need as a prerequisite to start the same Knowledge Radius, since the Structure Knowledge Maps (MCE – Mapa de Conhecimento Estruturado in Portuguese) performs the necessary mapping. This guarantees that the same course with an Initial Radius of Knowledge will have different starting points for each student, since the MCE ensures autonomy and personalization of the Areas of Ignorance of each student, enabling them to have the necessary conditions to follow a Ray of Knowledge at a time eliminating the entire Area of Ignorance from its respective radius, because "satisfaction is not the excess of knowledge, but rather the lack of ignorance" (COSTA, 2005). After the acquisition of knowledge, it is necessary that this knowledge be memorized, after all knowledge that is not memorized is useless (LIMA, 2013). Notice that at this point Distance Learning is no longer a Complex System because we now have a view of the structure of the problem. Being able to solve it is another matter, which will be discussed later in this material. What is necessary to emphasize is that solutions can only be proposed, when the structure of the problem is understood, if not, all else will be invalid.

2. Development

2.1 The question of EAD terminology

Nowadays in Brazil, the concept of EAD (Educação à Distância in Portuguese or Distance Learning in English) is far from the objectives that such an acronym is proposed to achieve. Distance Learning, from what it can be seen worldwide, is far from an Education process. In order to understand this statement in a simple way, observe some fundamental concepts:

• Information: the process of acquiring knowledge.

• Teaching: the aggregated information to a methodology and an efficient non-dual mechanism of learning assessment.

• Education: teaching added to moral, ethical, social, religious and legal values.

2.1.1 Understanding the concepts

As far as the word **distance** is concerned, it can be said that distance will always exist, whether it is social, ethical, moral, emotional, religious or even just physical (which is the type of distance chosen to compose the acronym EAD - in Portuguese). Thus, it may be that a teacher is in a separate room from the student by a few millimeters or it may be that another teacher is in the same room as the student separated by several meters between them. In this case, the physical distance of the teacher who is not physically present at the student's site will be less than the distance of the teacher present in the same room. In this way, should the concept of distance be applied by whether or not the teacher is seeing it? Again, one can see the teacher who is hundreds of miles on a 100-inch high-definition screen, with the student standing close to the screen, more so than, for example, a teacher in the same room. It can be said, therefore, that the distance, whatever the chosen parameter, will always exist. The big problem is to define the higher goal of Distance Learning, which is Education.

As for the word Education, it is necessary to extend the concept that differentiates Education, Teaching and Information, concepts that define and explain one of the biggest problems that teaching and education currently have.

• Information: is any knowledge obtained by reading a text or acquired by some sound / visual media. Being aware of something does not imply that the person who holds it can do something with it. An example of means of information is an encyclopedia. Reading about how airplanes are built does not imply that the reader, after acquiring this information, will be able to build one.

• Teaching: it is a process where information is added to a methodology to transmit the knowledge, in a didactic way, being necessary a system of evaluation of learning to be able to effect the teaching. There is no teaching if it is not proven that the student has learned exactly what was intented. There is no teaching without learning. There is no teaching without an efficient, non-dual mechanism to assess whether what was taught was actually learned. In this case, multiple choice tests can be considered as selection mechanisms, in which students either know the answers or get them right by luck. Nothing guarantees that the student will really know what he has marked as the right answer. An evaluation mechanism that confirms learning is the practical realization of what has been learned, and thus it is reaffirmed the need for laboratories where the student can repeat what has been learned, so it’s possible to evaluate and prove that the teaching was made effective.

• Education: it is teaching added to moral, religious, ethical, legal and social values. Thus, not every teaching process can be considered education. To educate someone, it is necessary to know the individual, to know the legislation under which he or she is protected, his or her moral, legal, social, ethical and religious standards. It is concluded, therefore, that for teaching to be considered as education, it’s necessary to know the person or group that will be taught. In this case, to be able to educate one has to know the distance, with all the concepts previously observed.

Delimiting and clarifying these concepts may at first seem dull and unnecessary, but contrary to what it seems, these concepts are still often misused. First, it is necessary to recognize that: "knowledge that is not learned is information and knowledge if not memorized is useless" (LIMA, 2013). To illustrate these two

sentences, imagine, for example, a scenario where, in a surgical room, a doctor during a brain surgery, needs to do a procedure in which he scored the highest grade at college and did residency in that area, but does not remember correctly how to proceed. If he has not kept what he learned in his memory, he will not have the time to remember it and save the life of the patient, and therefore the learning he obtained from scoring the highest grade is useless. The same occurs in the most different and varied areas such as aviation in which the pilot has to do emergency maneuvers, a skater performing a complex maneuver, etc. Although classical and alternative teaching methods and models exist today, if the knowledge being conveyed is not memorized by the learner, it will be useless when needed in the future. Thus: "knowledge that is not learned is impossible to be memorized" (FERREIRA, 2014), or the dual form of "the process of memorizing and reinforcing learning only begins when it is ensured that it was correctly acquired" (FERREIRA, 2014). Thus, the relevant question arises: currently, what guarantees that professionals and apprentices in training are truly qualified and prepared to act and that will effectively learn and retain the learning so that they are able to use the acquired knowledge when required? This is a matter of the utmost concern to companies, such as large hospitals, to accept in their medical staff only those who demonstrate knowledge, skills and competences that are consolidated and retained in the memory for immediate use, as it is done by the preliminary examinations of the United States Medical Licensing Examination (USMLE) in training and physician selection. The process is so serious that even the matching process algorithm for linking hospital professionals to hospitals was awarded a Nobel Prize in Economics in October 2012 by Dr. Alvin E. Roth and Lloyd S. Shapley. Therefore, it is essential that the memorization process proceeds to each acquired knowledge and evaluated. The memory recall process is only started after the validated guarantee of what has been learned. Therefore, the process of teaching must be always accompanied by a process of non-dual evaluation in which what was taught was actually learned. Teaching without evaluation is not teaching, it is information. In this process of teaching, it is important to contextualize, so that it be different from the Information and Education processes, related themes, but with conceptual differences and different application goals.

3. Complex Systems

Before taking any action to solve the question of how to ensure the effectiveness of learning. We must first understand the structure of the problem of the question to be analyzed. In this case the Distance Learning. Therefore it is necessary to first understand what is referred to in this work as Complex System. So, to understand the complexity of the Distance Learning system it is first necessary to understand what a Complex System is. For Simon (1962), Complex Systems are:

> Composed of a large number of parts that interact in a non-simple manner. In such systems, the whole is more than the sum of the parts, not in a metaphysical ultimate sense, but in the pragmatic important sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole . (SIMON 1962: 468)

Another important factor related to Complex Systems are the hierarchies:

> The design of a complex technological system has been shown to encompass a hierarchy of design decisions (Marples, 1961, Alexander, 1964, Clark, 1985). Decisions made at higher levels of the hierarchy set the agenda (or technical trajectory) for problems that must be solved at lower levels of the hierarchy (Dosi, 1982). These decisions influence many subsequent design choices, so they are referred to as concepts. (BALDWIN et al., 2010, p. 3)

Note that Complex Systems are those that can not be copied and can not be learned alone. So when the system is complex it is no use buying a book to learn, learning will not be accomplished. This is not to say that you do not learn from books, you do not learn complex things from books. A classic example is to study all the components of a cell in a book and want to produce human life after understanding and knowing the smaller parts of the cell.

> Complex systems can't be copied. Suppose I said to you: "Let's look around the world, find the economy that seems to work the best, and then replace our own system by copying the one we like better." If you have any sense, you would respond by saying, "Goodman, that is a really dumb idea; don't you know that complex systems by definition can't be copied?" (GOODMAN, 2012, p 41)

Another lesson of Goodman (2012) is to avoid command the system from the top, but from the bottom up.

> If we are dealing with a complex system and we don't have a reliable model to predict how it will respond to simple parameter changes, it is more important than ever to avoid trying to solve problems with top-down commands. Instead, we need to begin the process of liberation by working from the bottom up" (GOODMAN, 2012, p 40)

Names mentioned in the theme, mentioned above, affirm that Complex Systems are insoluble systems. Contrary to what is believed, Complex Systems can be solved, but for this it is necessary to know the whole structure of the problem, even if one does not have the skill and the competence to solve it, it is paramount to know the structure and the fundamentals of the problem. A skill is having a specific quality to accomplish a certain task. You can be a good carpenter. Competence is to do this task correctly without harming or ruining anything. These are two very different things. Consequently the System ceases to be complex, quite different from saying that every Complex System is insoluble. In addition, what the study proposes is that the Complexity of the System may depend on who is analyzing the system. An example of this case can be given by proving mathematical theorems. For some people to prove mathematical theorems will be considered complex systems while for others who are deeply familiar with this content the proof of theorem will not be a Complex System.

3.1 Distance Learning as Complex Systems

When referring to Distance Learning, taking as reference the current models, they don't consider the prerequisites for each student. The student starts the course and the teacher has no idea about what the

student knows or does not know. How to determine the knowledge of the student ensuring that he does not need any prerequisites to start the discipline? You must determine the Area of Ignorance for that student. But each student, even at the same level of knowledge, may have different Areas of Ignorance. Providing a Distance Learning course without measuring what each student knows is not knowing the problem. Not knowing the basis of the structures and foundations of the student's problem makes Distance Learning a Complex System. How to replicate the same Distance Learning course if the structure of the problem is not well understood? Trying to do this is synonymous with incompetence, since it can cause damage in the teaching-learning process, such as cognitive overload (SWELLEN, 2005) and, consequently, cognitive distortions (BURNS, 2000), which leads to evasion or worse , students are formed who have not learned but only have information about the subject. Ignorant students, considering that ignorance is lack of knowledge. And this is not the purpose. The ultimate goal is to ensure that students truly learn. With this, one can guarantee the competence of what the student has learned, since competence is to know how to do things in the right way, without causing any harm to himself or to others. But do some people actually learn in the current model of Distance Learning? Yes. Only 5%. The Gauss Curve explains this number, in which 5% would not learn in any way, either by withdrawal, lack of money to pay for the course or simply because they lack the cognitive conditions for the study. 90% of them will take the course, but they will not learn. They conclude, but they will be incompetent because, as they have not learned, they can do some damage when they try to put into practice the knowledge they should have learned. Only the remaining 5% will actually have learned. Why? Because Distance Learning is a Complex System, since it does not know the whole structure of the problem. Therefore, the Gaussian Curve, in this case, presents this interpretation.

As complex systems can not be copied, because in order to do so, you have to understand the structure of the problem, how is it possible that Distance Learning courses still exist and are replicated in every corner of the world? It is generating a legion of people who do not have effectively acquired knowledge in certain areas.

To better visualize this process imagine that a student has knowledge in Mechanical and Electrical Engineering, but needs to learn the vocabulary and terms of Computer Engineering. The student explains to the teacher that he does not understand anything about the subject and asks if the subject requires prerequisites. The teacher says no and the explanation begins. In the first explanation the student already faces a term that he does not know. To explain it the teacher uses three more terms, also unknown to the student. You see, the student who in this case is not ignorant because he acknowledged not having the knowledge in the area, is completely lost since, instead, of advancing a Ray of Knowledge at one time the teacher advanced four. This student can not keep up with the class. But is it his fault? No. The teacher said he did not need prerequisites. He (the teacher) had no competence, and competence is to know how to do something right without causing any damage, to explain. The student gives up. He was doing the discipline because he did not know the terms and the teacher said he did not need prerequisites. This is what happens in Distance Learning. The need to know the prerequisites of the students is not considered. Note that, prerequisites does not mean having completed a certain course or graduation to start the Distance Learning. What is considered a prerequisite is the determination of what the student really knows so that he can begin the course without any doubt. It is to empty the Area of Ignorance that the student had added the necessary

concepts and knowledge so that he can begin the course and then guarantee the advance of one Ray of Knowledge at a time so that there is no overload (SWELLEN, 2005) or cognitive distortions (BURNS, 2000). This is what we call Structured Knowledge Maps.

4. MCE and MMEEBB added to technology to guarantee learning

Trying to get all the context-dependent constants (the hidden variables), dynamically changeable during various phases of the learner's life, at once, is an impossible task, and by designing a system for copying or replicating it, as the theory of Complex Systems asserts.

The Structured Knowledge Maps (MCE) and the Effective Exponential Memorization Method in the Binary Base (MMEEBB) ensure that the individual, who wants to learn, advances one ray of knowledge at a time and only goes ahead when, in the evaluation, it is proven that he or she really learned. Otherwise, other lines of knowledge are introduced to remedy deficiencies and only advance in new knowledge. The personalization of the knowledge valuing the pre-knowledge that the student has and the adaptability identifying if each student has the concepts and knowledge necessary to start each module, each class, without any doubt. The methodology assures that there will be no cognitive overload (SWELLEN, 2005) avoiding distortions (BURNS, 2000), which guarantees satisfaction in learning, since satisfaction is not excess of knowledge, but lack of ignorance. In this way, non-invasive, since those who discover and use the constants is the apprentice itself, the complex system is reconstructed from nano systems.

Based on the Theory of Categories and the Theory of Functors, MCE maps from one category to another, from teacher to student, in this way learning will only begin when the student category has all the objects / concepts and morphisms / knowledge needed so that the Functor, that is, the realization of knowledge is established. If the individual or category does not have any of the objects or morphisms, to begin the course, the method allows the degradation of knowledge or concepts so that the student can learn about the subject. This branching extends to a certain degree which defines the minimum knowledge that the individual must have in order to begin the course. These ramifications, called TAQram, work together to ensure that there are no cognitive distortions (BURNS, 2000), and that there are no feelings of failure or thoughts of incapacity, which could lead to dropping out.

In this way, guaranteeing satisfaction not by excess of knowledge, but by lack of ignorance (LIMA, 2013), ensures contentment and enthusiasm motivating and arousing interest. The person realizes that he / she can do it, that he / she understands and wants to move on, to continue step by step. In addition, it guarantees different individuals a personalized, adaptive and democratized Distance Education course.

Parallel to the learning process, the MMEEBB will ensure the memorization of what has been learned. Based on the use of the Learning Reinforcement Interval (IRA - Intervalo de Reforço de Aprendizagem in Portuguese) equal to 2^n, the method ensures that with each review there is a 20% decrease in the cognitive effort to relearn. If at first there is a cognitive effort of 100%, in a first review there will be an effort of only 80%, in a third review there will be a decrease of 20% of the effort over 80%. Thus, after several tests, analysis with control groups and analysis of the equations, the IRA rate was reached so that the memories kept 100% of memorization (effective memorization) from Reinforcement Learning Intervals (IRA) of 2^n, with $n = 6$, which determines the Memorization Curve.

Based on the Curve of Forgetfulness (EBBINHAUS, 1886) and the Learning Curve presented in 1936 by Theodore Paul Wright, the Effective Memorization Curve (CME) comprises the Learning Reinforcement Interval applied to the exponential base 2^n, a method which was proven and applied for more than a decade in Pedagogy, Music, Arts, Engineering, Letters, Physical Education and Administration (LIMA, 2013) and in a study with elderly people (FERREIRA, 2014). In the case of Distance Learning, the mapping of the smallest ray of knowledge is done by the Qualitative Assessment Table (TAQ – Tabela de Avaliação Qualitativa in Portuguese) that verifies the smallest subcategory free from doubts. This means that, if within this Ray of Knowledge, there is any question concerning the concept or knowledge pertinent to the current Ray, being a concept, that is, that which is possible to define, the student is directed to visualize the concept. If one of these doubts is a new knowledge, a new TAQ, now called ramified TAQ (TAQram – Tabela de Avaliação Qualitativa Ramificada in Portuguese), will be opened, which will generate a new area of ignorance.

To retain information, each new knowledge learned is reinforced through the MMEEBB, which reminds the new knowledge one day after receiving it, then in two days, four days and so on following the IRA = 2^n. The parallel of the Effective Memorization Curve with the Oblivion Curve, can be seen just below:

It is important to emphasize that the process of memorization begins only after the learning process is established and can be done by passive memories, through summaries or active memories, with the use of quizzes, discussions, among other forms. However, cognitive overload should be avoided whenever possible (SWELLER, 2005). It is known that the brain is not multitasking (MEDINA, 2007), that is, the human being is only able to process cognitively a knowledge at a time. When one has more than one knowledge to be processed, the efficiency, that is, the capacity for learning is divided by the number of simultaneous knowledge. On the other hand, if something is already memorized in a consolidated way, it is no longer necessary for cognition only reinforcement in the memory of knowledge. Once the recall process has been completed, it is advisable to avoid cognitive overload. For this, it should be remembered that intervals of 2^n are maximum time intervals between memories, but nonetheless, not as a norm, but based on studies, even using permanent memory (already consolidated knowledge) and not short-term memory It is advisable not to have more than 7 (+/- 2) chunks (MILLER, 1956) of knowledge to be remembered in one day.

5. Conclusion

In order for Distant Education ceasing to be a Complex System, it is necessary to know the basis and fundamentals of the problem that makes it so. This is what the Structured Knowledge Maps propose. Among the agents involved in the system, it is possible to degrade concepts and actions, at least as relevant as possible, using TAQ to minimize complexity. Locally eliminates the complexity of the system by focusing on a context. That is, the TAQ degrade the actions and concepts of the agents to the minimum area of ignorance, so that all variables can be determined, which at the beginning of the process could not determine because the agents involved in the system were not known. The TAQ degrades the system, transforming the Complex System into nano systems in such a way that it is possible to identify the existing variables in each agent (variables that can be different from agent to another) in order to be able to add a

new Ray of Knowledge. This is possible through a transfer functor (Theory of Categories and Theory of Functors) that represents the agent to be represented. This means that with the use of Structured Knowledge Maps, a model of Distance Learning can be created, which allows, through the agents involved (student-teacher), to first map all the knowledge and concepts that the teacher has and the student does not, using the TAQs that will identify the necessary prerequisites of each student, which may be different from agent to agent. This means that each student's Ray of Knowledge may be different, but it will always be one Ray at a time. The Ray of Knowledge is a constant variant because it can vary from agent to agent, in a constant of one knowledge at a time. This model guarantees reaching the same result, the effectiveness of the knowledge at the end of the course, since the variants of each agent within the system have been respected, making learning possible.

6 - References

ASPERTI, A.; LONGO, G. *Categories types and structures: an introduction to category theory for the working computer scientist. Massachusetts: Foundations of Computing Series*, MIT, 1991.

BALDWIN, C.; MACCORMAC, A.; RUSNAK, J.. *The Architecture of Complex Systems: Do Core-periphery Structures Dominate?*, MIT Sloan School of Management Working Paper Number 4770-10, draft Version 4.0. Havard, Business School, pp 3, 2010.

BURNS, D.. *Feeling Good: The New Mood Therapy*. Quill. 2000.

CAMARGO J. H.; LIMA, L. V. ; LIMA, S. F.; PEREIRA, A. A.; PINHEIRO, A. P.. *A Method for Preparing Experts in Computer Engineering Subjects* - WCCSETE'2006, Santos, 2006.

COWAN, N.. *The magical number 4 in short-term memory: a reconsideration of mental storage capacity.* Behavioral and Brain Sciences, 2001.

DIAS, D. C; COSTA, N. da S.; LIMA, L. V. *Projeto e implementação de recursos didáticos multimídia interativos para melhoria do ensino de disciplinas de engenharia de computação*. ICECE 2009, IEEE Buenos Aires: COPEC, 2009.

EBBINGHAUS, H. (1885). Über das Gedchtnis. Untersuchungen zur experimentellen Psychologie. Leipzig: Duncker & Humblot; the English edition is Ebbinghaus, H. (1913). *Memory: A Contribution to Experimental Psychology.* New York: Teachers College, Columbia University. Reprinted Bristol: Thoemmes Press, 1999

GOODMAN, J. C. *Priceless: Curing the Healthcare Crisis (Independent Studies in Political Economy).*The Independent Institute, 2012.

LIMA, S. F. de O.; BARBOSA F. R.; LIMA, L. V. CAMARGO J. H. *Mapas de Conhecimento: uma ferramenta de aprendizagem por meio de Card Informativo como instrumento de ensino*. Revista Unopar Científica Ciências Humanas e Educação. v. 14, n. 1, 2013.

MAYER, R.; MORENO, R... *Nine ways to reduce cognitive load in multimedia learning.* Educational Psychologist, 2003: pp 43-52.

MEDINA, J.. *Linguagem.* São Paulo: Artmed, 2007.

MILLER, G.. *The magical number seven, plus or minus two: some limits on our capacity for processing information*. Psychological Review, 1956: pp 81-97.

RAZ, A.; FAN, J.; McCandliss, B. D.; SOMMER, T.; POSNER, M.. *Testing the Efficiency and Independence of Attentional Networks. Journal of Cognitive Neuroscience.* Volume 14, Issue 3, April 1, 2002. Pp 340-347.

SIMON, H. A.. *The Architecture of Complexity, Proceedings of the American Philosophical Society* 106: 467-482, reprinted in idem. (1981) The Sciences of the Artificial, 2nd ed. MIT Press, Cambridge, MA, pp 193-229.

SWELLER, J.; MERRIENBOER, J. *Cognitive Load Theory and Complex earning: Recent Developments and Future Directions.* Educational Psychology Review, V.17, N.2, June 2005

SWELLER, J. *Evolution of human cognitive architechture***.** In: The Psychology of Learning and Motivation , by B. Ross, vol. 43, pp. 215-266. San Diego: Academic Press., 2003.