A STUDY ON THE SEMIOTIC REPRESENTATIONS AND THE COGNITIVE THEORY OF MULTIMEDIA LEARNING IN MATH CLASSES USING DIGITAL VIDEOS

Valdinei Cezar Cardoso
vccardoso@uem.br

University of Campinas/ University of Maringá

Samuel Rocha de Oliveira
samuel@ime.unicamp.br

University of Campinas

Lilian Akemi Kato
lakato@uem.br

University of Maringá

ABSTRACT

This paper aims to identify, through a field work, the conversions and the treatments in the register of semiotic representations produced by students from their interaction with digital videos. Therefore, we present a categorization of digital videos, according to Mayer's cognitive theory of multimedia learning, seeking possible relations of semiotic representation registers that appear in the videos with those submitted by the students in writing activities. The videos deal with the content of: rule of three, linear equations, polynomial function graph, modular functions, rational function, trigonometric functions, derivative function and integral function. The research subjects were thirteen students beginning undergraduate courses in Physics, Chemistry, Education, Production Engineering, Textile Engineering, Mathematics and Production Engineering with emphasis in Agribusiness. We have noted, from the point of view of mathematical contents, different semiotic representations expressed by the students in activities related to the same digital video. The results show that students do not restrict their representations to the content alone, on what the videos show, but they connect that information with their own ideas.

Keywords: Cognitive Theory; Multimedia Learning; Semiotic; Representations; Mathematics.

RESUMO

Este trabalho visa identificar, por meio de um trabalho de campo, as conversões e tratamentos nos registros de representações semióticas, elaborados pelos estudantes, a partir da interação destes com vídeos digitais. Para tanto apresenta-se uma categorização dos vídeos digitais, segundo a teoria cognitiva de aprendizagem multimídia de Mayer, buscando possíveis relações dos registros de representação semióticas que aparecem nos vídeos com os apresentados pelos estudantes nas atividades escritas. Os vídeos tratam dos conteúdos: regra de três, funções do primeiro grau, gráfico de funções polinomiais, funções modulares, função racional, funções trigonométricas, função derivada e função integral. Os sujeitos da pesquisa foram treze estudantes ingressantes nos cursos de graduação em Física, Química, Pedagogia, Engenharia de Produção, Engenharia Têxtil, Matemática e Engenharia de Produção com ênfase em Agroindústria. Constatamos, sob o ponto de vista dos conteúdos matemáticos, diferentes representações semióticas manifestadas pelos estudantes em atividades relacionadas a um mesmo vídeo digital. Os resultados mostram que os alunos não restringem as suas representações sobre os conteúdos, apenas naquilo que os vídeos apresentam, e sim interligam tais informações com suas próprias concepções.

Palavras-chave: Teoria Cognitiva; Aprendizagem Multimídia; Representações Semióticas; Matemática.

1. Introduction

It is common to find studies in the literature that deal with the production/use of educational videos in teaching and learning situations; among them there are: the study of video production by students, and its implications for the teaching and learning of mathematical concepts, especially the concept of function (MENEGHETTI and REDLING, 2012), the understanding of concepts related to Differential and Integral Calculus (MONTEIRO JÚNIOR, 2007), the study of contributions on the construction of videos, by students, and the subsequent posting on the Internet for the learning of the concept of functions (FREITAS and ROSA, 2010), the use of video as simulators of physical or chemical phenomena (LOPES, 1995), among others.

This article deals with the production of videos by teachers of mathematics aimed at learning concepts related to the study of the concepts of function and rule of three, taught at distance, through the virtual learning environment (VLE) Moodle.

For Meira (1994), the way mathematics is taught in educational environments restricts the production of specialized representational systems by students. Trying to circumvent this problem, in our work we use the idea of reverse classroom[1], presenting at each video a theoretical explanation of the content, followed by the solution of some examples by the teacher and an evaluation activity related to the concepts discussed in the video.

In this context, to produce the videos, we have taken care of providing explanations of the concepts studied, in a balanced way, in our view, between formal aspects and applications. That is, something that should not remain only in the theoretical field or bring excessive contextualization of the concepts taught, which could impair learning (MEIRA, 1994). Furthermore, we aim to overcome the use of the contextualization[2] of mathematical concepts only as a step for the abstraction and cognitive development.

According to Meira (1994), the analysis of mathematical symbolic systems should have its starting point in the influence of some specific activities, without forgetting that the

[1] It is a concept of North America origin and characterized by integrating components of on-site class, such as mediation of the teacher, with elements of distance education, such as the use of video to explain content.
[2] We understand contextualization as the act of including or merging a given subject in a context.

symbolic systems necessary for learning math are continually modified; in our case, we expect changes to occur, motivated by the interaction of students with the videos produced.

Considering our intention to identify conversions and treatments in semiotic representation registers produced by the students from the interaction with digital videos in the solution of the proposed activities, we have applied a written activity for the analysis of the registers obtained after the release of each video in the VLE.

The results show that the treatments and conversions performed by the students do not rely solely on the digital video related to what they studied, opening the way for further research to investigate this issue.

2. Theoretical foundation

2.1. Mayer's cognitive theory of multimedia learning

For Mayer (2009), multimedia learning is a change in knowledge attributed to experience. The learning act is understood as personal and the cognitive changes involve reorganization and integration of knowledge.

Learning under this view is a change that occurs in the learner, and one reason for this change is the acquisition of experiences during the study of a particular subject. In our work, we seek to understand how digital videos can help students to act proactively in building the concept of function.

The cognitive theory of multimedia learning (CTML) takes the information processing system as being composed of two channels: the visual and the auditory ones. Each one has a limited processing capability, and it is primarily through these systems that people learn.

Mayer's CTML (2009) seeks to understand the potential of multimedia to promote learning. According to this theory, learning occurs more deeply if the ideas are expressed through words and images. In a manual activity, touch, smell and taste could be complementary channels for the learning, but the CTML is designed and tested only for the two senses of sight and hearing.

For Mayer (2003), the simple addition of images to narrated texts not always improves learning; for him, multimedia instruction goes beyond the simple verbal transmission of content; it must show step by step the concept being taught, with words that describe each step (printed or narrated) accompanied by illustrations that complement what is explained. Thus, Mayer (2003, p. 4) says that:

> In an environment based on books, the external representations can include printed words and illustrations, both of which initially enter through the eyes. The student must select relevant aspects of the input images for further processing.

The same occurs in the environment based on digital educational videos: if the material is presented only in the visual channel or just the verbal one, the other one is ignored, and learning may be impaired.

This loss occurs because words are more appropriate to present some types of materials, and images are best prescribed for others. Moreover, Mayer (2003) states that an environment of instruction, computer-based, must instruct using spoken words, which are captured by the ears, and animations, which are captured by the eyes, and this favors, by the student, the selection of relevant aspects of the sounds and the images for further processing.

Mayer (2009) argues that technology should be used to expand the cognitive capacity, and it needs to be consistent with the manner of the functioning of the human mind. Thus, the computer emerges as an artifact of reference, which in teaching situations can be used as a means of automation or as a motivator of argument, being the latter advocated as the most effective for learning.

The multimedia learning from the perspective of Clark, Nguyen and Sweller (2006) can occur through the acquisition of information, the strengthening of responses (stimulus-response theory) that are limited, or the construction of knowledge provided by the cognitive aid.

Precisely this last possibility of multimedia learning is the focus of our work, because, as stated by Mayer (2009), when watching a video related to a matter considered to be complex, people do not resort to videos for every unknown word; the tendency is to turn to prior knowledge about what is studied.

The goal of multimedia presentations is not only to provide information but also to guide on: how to process the information presented, how to mentally organize information and how to relate it to prior knowledge. From these goals, in our work, we seek to understand how the videos contribute to the learning of mathematical concepts.

We agreed with Mayer (2009) when he states that the learning goals are to understand and to remember. To evaluate the success rate in this context, transfer tests can be used, which would be the ability to apply a concept or a scheme learned from one context into another or into a close concept, with some similarities, but not identical. The activities proposed to the students in our work are based on this type of test.

When the goal is to analyze what the students recall, retention tests are indicated, which can be about the recognition of information, as in most entrance exams, or about the exact measuring of what was memorized after the study of a certain subject; both are interested in the amount of knowledge retained.

An example of application of these tests is presented by Mayer (2009) in a study performed with three persons. For the first one, it was asked a reading on a subject on which they were not motivated to learn. For the second, who was willing to learn, it was asked a reading of the same text, and finally, for the third subject, who was also motivated to learn, it was presented a multimedia consisting of a text shown on a computer screen which explained some phenomena demonstrated in an animation.

The results of this study show that the first person, who was not motivated to learn, did not understand, nor could explain or apply what was learned in the text. The second person retained more information from the text, but did not know how to apply the knowledge from the text in related problems and had the same failure as the first in the applications of what they had studied. The third person understood the main concepts in the text, was able to generate creative solutions to the problems posed and showed significant knowledge about what they studied.

From these results, Mayer (2009, p. 49) presented some suggestions on the integration between text and images in digital media. The first suggestion is that the text and the images emphasize the key ideas of the subject studied, being concise and without unnecessary detail. The images and texts showed must be relevant, practical and of easy viewing. Both texts and images should be understandable and close to the students' prior knowledge.

Mayer (2009) lists twelve principles, according to which learning, mediated by educational media, can be enhanced or hindered depending on the way that each video is produced.

Thinking about the best organization of these principles, Mayer (2009) organizes them into three groups: the first is called **"principles for reducing extraneous processing"** and includes the principles listed below:

> P01- **Coherence**: people learn better when the use of extraneous words, pictures or sounds is minimized.

For Mayer and Durso (1999), students who read a passage explaining the steps to perform a particular task, in a clear and objective way, reached 50% more useful solutions on a subsequent solution of problems than students who only read some information with additional details included in the material.

> P02- **Signaling**: people learn better when some tips that highlight the main points of the material are added.
> P03 - **Redundancy**: people learn better when media use graphics and narration than when using graphics, narration and written text on the screen, because, in the latter two, the channels (auditory and visual) are used simultaneously to present the same information.
> P04 - **Spatial Contiguity**: People learn better when corresponding words and pictures are displayed next to each other and on the same page.

The great contribution of these principles is that they provide subsidies enabling us to understand that if corresponding figures and words can be processed in the memory at the same time, each being captured by a different channel, the construction of correspondence between their meanings can be fostered. And such fostering directly contributes to conceptual learning.

> P05 - **Temporal Contiguity**: people learn better when corresponding words and pictures are presented simultaneously than when they are presented successively.

Mayer and Durso (1999) showed that students with high spatial ability are able to store the visual image in the working memory, and thus are more likely to benefit from contiguous presentation of words and images.

For them, students, with high or low ability, who have contact with multimedia explanations are more prepared to build two different mental representations - the verbal and visual ones - and establish relationships between them.

The second group of principles presented by Mayer (2009) is entitled "**principles for managing essential processing**":

> P06 - **Segmenting**: people learn better when an online lesson is presented in units than when it is presented in a continuous and uncut way.
> P07 - **Pretraining**: people learn better with a multimedia lesson when they know the names and characteristics of the essential concepts.
> P08 - **Modality**: people learn better from graphics and narration than with written texts and animations on the screen.

For Sweller (2005), the processing of knowledge by students requires great cognitive effort; if such requirement is too great, the student may not be able to turn their attention to the selection, organization and integration of what has been studied. The result is the low retention, poor performance and the inability to transfer the concept studied to other situations, which, in the school environment, can result in low academic performance and superficial understanding of what is studied.

The third group of principles suggested by Mayer (2009) comprises the "**principles for fostering generative processing**", presented below:

> P09 - **Multimedia**: people learn better from words and pictures than from words alone.
> P10 - **Personalization**: people learn better from a multimedia lesson when words are in a conversational style rather than in a formal style.
> P11- **Voice**: People learn better when the narration in a multimedia lesson is spoken by a friendly human voice rather than a machine voice.
> P12 - **Image**: people do not necessarily learn better from a multimedia lesson when voice on images is added to the screen.

The central idea advocated in these principles is that human learning is optimized when the teaching material presents information that can be captured by different senses, e.g. hearing and vision, simultaneously. Affective factors must also be taken into account when preparing an instructional material, since the personalization of the material approximates the student from what is taught.

The next section provides a brief overview of Duval’s (2003, 2009, 2011) semiotic representation theory, which we will use to analyze the data collected during our work.

2.2. Semiotic representation registers, some considerations

For Duval (2011), learning is related to the simultaneous coordination of different registers related to the same concept; in this context, learning means to communicate through different semiotic representations.

For this author, the construction of mathematical concepts does not follow the same path of the everyday life concepts. Instead, the formation of a mathematical concept depends on: past experiences that have something in common, the use of different representations of a mathematical system and requires the ability to convert between different registers of representation.

Considering this, we have assumed that one of the difficulties for learning mathematical concepts is the implicit mobilization of several registers whenever the person needs to present an idea explicitly.
We are looking for possible relationships between treatments and conversions used by the videos authors and those used by the students through written productions related to videos.

According to Duval (2011, p. 106), in Mathematics, we rarely think about a single register, but on several registers at the same time, even though the productions favor a single register.

Thus, to analyze the learning of Mathematics, it is necessary to consider all registers, mobilized in mathematical activities, used to develop a particular task, specifically the conversions between them, which are implied, but which should be more or less spontaneous.

For example, during the solution to a problem, not only the form of the resolution that the teacher considers correct should be taken into account, but also all the paths followed by the students. But, how do we analyze all registers of representation used in a mathematical activity?

For Duval (2011, p.117), a way would be to evaluate the "cognitive distance that separates the representations of two different registers", and for this, the author classifies the registers in:

- discursive (using natural language or mathematical language) or non-discursive (based on diagrams, graphics, pictures);
- multifunctional (where treatments cannot be turned into algorithms) or monofunctional (transformations of expressions can be turned into algorithms).

The monofunctional registers are the most frequent in the construction of mathematical knowledge. Even so, in the teaching of mathematics, educators first use, in most cases, the multifunctional registers to express the mathematical knowledge, which is monofunctional, which can compromise learning, if not taken into account the associations of registers that will be used for the teaching/learning of the concept studied (DUVAL, 2011, p. 117).

The reason is that there are considerable differences between what we write on the board or on the computer and the way we explain it, at the very moment we're writing and not later.

It must be taken into account that a student who knows how to do a conversion of a discursive register to a non-discursive register does not necessarily know the inverse operation.

About this, Duval (2011, p.118) states that "direct and inverse conversions are two different cognitive tasks such as climbing and descending a steep mountain." He further states that the origin of these difficulties lies in the understanding of additive problems[3]. Moreover, in both situations of multi-representations and mono-representations, it is always the same cognitive process that is requested, and it is precisely the variation of congruence and non-congruence where the major causes of difficulties or errors of students are.

In order to overcome such difficulties, Duval (2011) proposes attention to two ideas widely disseminated in educational environments: the first is that multi-representations (parallel presentation of statements, figures and graphics) facilitate understanding. Actually, in mathematics, it may create more difficulties. Mayer (2009) also agrees that it is not every multi-representation that contributes to the construction of knowledge, but he says that if they are presented in a coordinated way, the narrations and images can contribute to the learning process.

The second idea is that mathematical problems should not be shown from statements made by mono-representation, but through concrete materials. However, Duval (2011, p.121) states that changing the materials that comprise the statement of a problem only causes the displacement of cognitive difficulties to other fields, but does not solve the problem because "the variations of congruence and non-congruence are between the material and the semiotic register mobilized."

Given this, Duval (2011, p.124) states that "there is no isomorphism between the representations of the same mathematical object and a register and its possible representations in other registers" because the conversions of representations are cognitive operations that cannot be reversed.

Thus, trying to propose a basis for analyzing the cognitive functioning of the mathematical thinking, Duval (2011, p.124) proposes the following observations:

> - there is a specific semiotic functioning for each representation register.
> - the passage from one register to another requires that we begin to develop a synergistic coordination between at least two registers. This development requires specific activities and tasks, different from those privileged to acquire "concepts".

[3] These problems are the ones in which the statements describe everyday situations and whose solution requires the use of only the operations of addition or subtraction.

> - the understanding of "mathematical concepts", unlike the understanding of concepts in other disciplines, requires the synergistic coordination of at least two representation registers.

For Duval (2003), there is a conversion of congruent registers when there are transformations of representations, with changes in the systems of registers, keeping the mathematical object studied. For cases where the mathematical object is not maintained, after changing the register systems, it is said that the conversions are non-congruent.

Based on this theoretical framework, we sought to identify, in the students' written productions, the conversions (congruent or non-congruent) and treatments manifested from digital videos related to the concept of function.

3. Methodology

This study was performed with thirteen first year students at a public university in the state of Paraná, who participated in a online course on Basic Mathematics, taught at distance, during the study of the concept of function (first degree, modular, trigonometric, differential and integral) as well as simple and composed rule of three.

These students were invited to watch eight digital videos, then solve a sequence of activities related to the content displayed in the videos and send the resolutions to the VLE.

Considering our intention to identify conversions and treatments in semiotic representation registers produced by the students, from the interaction with digital videos, in the solution of the proposed activities, we have applied a written activity for the analysis of the registers obtained.

According to Duval (2003), there is no mathematical knowledge that can be mobilized without the aid of a representation. However, Duval (2011, p.116) states that, unlike other areas of knowledge, "from the mathematical point of view, a single register is sufficient to perform a mathematical path;" in this case it is important to study the treatment given to this register "directly in relation to the objects represented, and not indirectly in relation to a second register we would need to mobilize" (DUVAL, 2011, p.116). In our work, we sought to know which and how the elements of the mathematical concepts involved were manifested in the semiotic representation registers.

In this way, our study is classified as quasi-experimental, from the perspective of Campbell and Stanley (1979), since we had no absolute control over the experimental stimuli provided by the videos or from the interaction between student-student and student-professors, the latter made through forums and messages in the VLE.

The videos were designed to give students freedom of choice in relation to the best resolution strategies that could be used for the solution of activities, and they could seek assistance whenever necessary from the professors through the VLE.

In order to give details of the tasks proposed, we will describe, in the next section, some characteristics about the digital videos used and the procedures adopted in the course of the activities developed.

We will also analyze the registers built by the students to solve the activities proposed, to infer on the possible contributions of videos to the conversion of semiotic representation registers of mathematical concepts related to the study of functions.

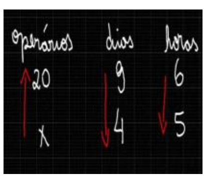
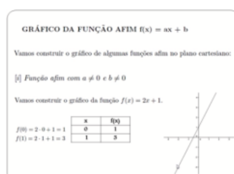
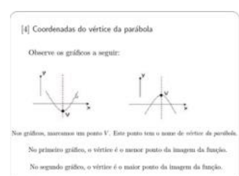
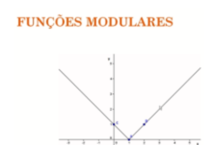
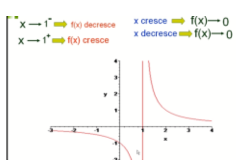
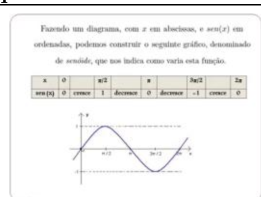
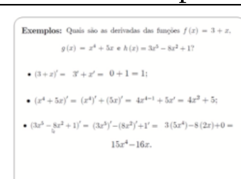
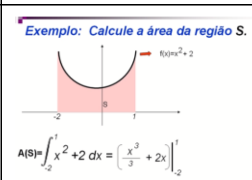
4. Analysis of the digital videos used

In this section, we categorize the videos used in our work according to the principles proposed by Mayer (2009); the aim of this categorization is to know whether the videos used in the course were produced according to what the cognitive theory of multimedia learning sees as more effective for the teaching and learning process mediated by multimedia.

Moreover, we want to know if the videos that serve a greater number of principles proposed by Mayer (2009) were also those that motivated a greater success in solving activities related to them.

In Chart 01, we have enumerated the videos used and the essential concepts discussed in each one.

Chart 01: Videos and their concepts[4]

			
V01: Rule of three	**V02:** First degree equations	**V03:** Polynomial Function Graph	**V04:** Modular Functions
			
V05: Rational Functions	**V06:** Trigonometric Functions	**V07:** Derivative Function	**V08:** Integral Function

Source: research data collected

In Chart 02, we see which principles proposed by Mayer (2009) were included in the digital videos, mentioned above. To this end, we have organized the following caption:

[4] www.youtube.com/v13dinei

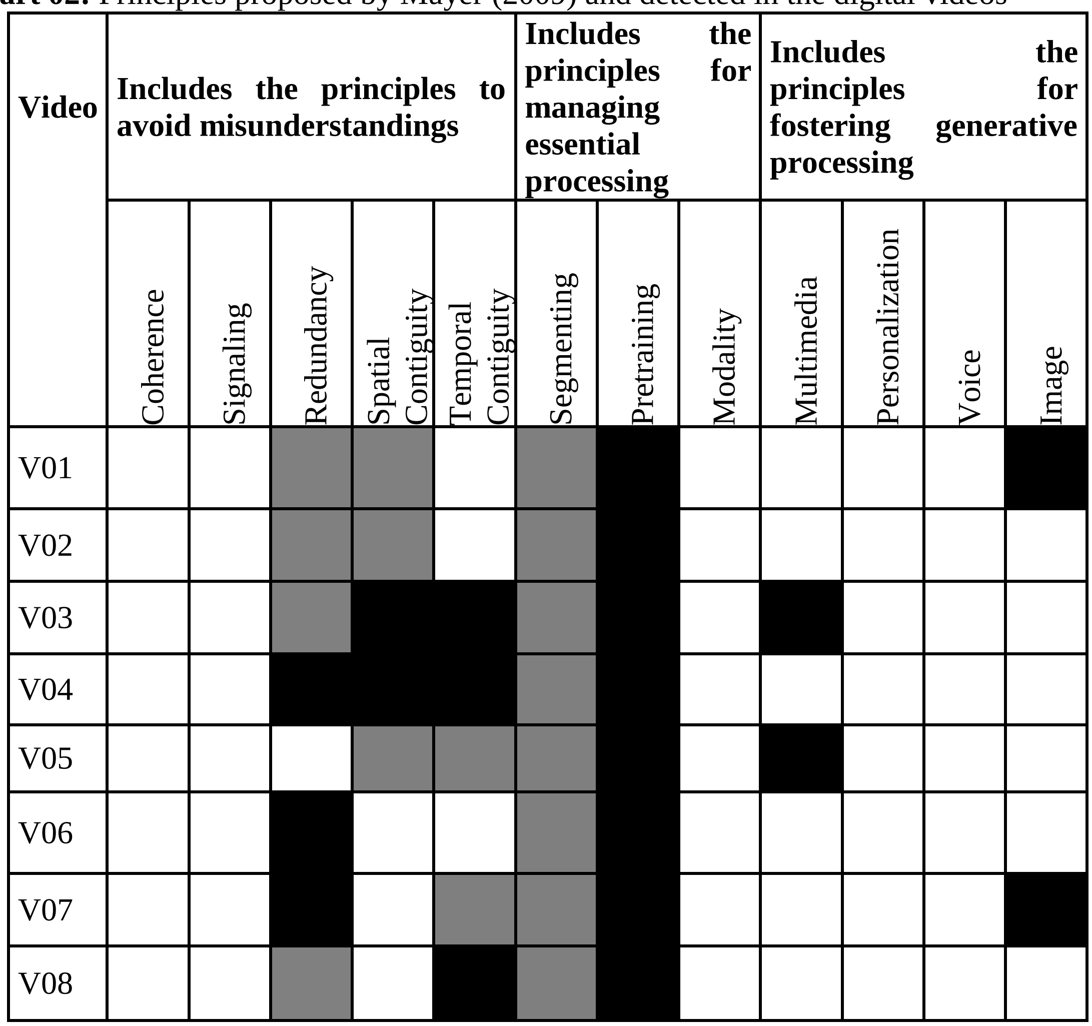
Completely fulfilled	
Partially fulfilled	
Failed to fulfill	

The principles that were completely fulfilled were marked in white, the principles that have been partially fulfilled were marked in gray and the principles that failed to fulfill were marked in black.

We believe that a video completely fulfilled one of Mayer's (2009) principles when it meets the characteristics proposed by the principle in more than 50% of the length of the video, partially fulfilled one of the principles when it features scenes which are characterized according to the principle analyzed and failed to fulfill one of the principles if no part thereof has what is stated in the beginning.

It's worth noting that these videos were produced by professors of mathematics who had no advanced knowledge about video editing and who also did not know about CTML.

Chart 02: Principles proposed by Mayer (2009) and detected in the digital videos



Source: research data.

We can see in Chart 02 that the pretraining principle was not used in any of the videos; this is because the videos were prepared in order to explain certain mathematical concepts. Not to review all the concepts involved in the video, otherwise the media would be very long and tiresome to be watched, which could reduce students' attention to the most important points covered in the explanation.

For Mayer (2009, p. 189), “People learn more deeply from a multimedia message when they know the names and characteristics of the main concepts.” These videos did not assume that students would know in advance the names of the concepts involved, or remember key features of what was taught.

We can also observe that the segmenting principle, in which Mayer (2009, p. 175) says that “People learn better when a multimedia message is presented in user-paced segments rather than as a continuous unit”, was not fully followed in any of the videos, since each video consists of a single teaching unit on a given subject.

Videos V03 and V04 did not meet the spatial and temporal contiguity principles, neither the principles of multimedia, for V03, and redundancy, for V04. However, we can note that the students had a higher performance in the activities related to these videos than the performance obtained in the activities related to the videos V01 and V06, which did not fulfill two of Mayer’s (2009) principles, and V02, which did not fulfill one of Mayer’s (2009) principles.

Given this, we did not observe a direct correspondence between the performance of students in the activities related to the videos and how such videos complied with the Mayer’s (2009) principles.

In the next section, we will review the videos and also the written productions of the students using as background the Duval’s (2009) semiotic representation theory, trying to build a bridge between this theory and Mayer’s (2009) CTML.

5. Semiotic representations that emerged from the interaction with videos

For Duval (2011), the congruence phenomena are more common than the non-congruence ones. Therefore, even if they are more difficult to study, as they are unpredictable and numerous, they must be studied case by case in each of the activities we suggest.

The access to mathematical objects is made through the use of different semiotic representation of registers. Such records may allow the use of certain treatments or conversions (DUVAL, 2011). Considering that, we made a preliminary study to know some possible treatments or used conversions in each one of the mathematical concepts in this research. The results give us some knowledge about the conversions or treatments used during the teacher’s video production or in the activities of the student’s resolutions.

Thinking about this, we have selected, in each of the videos, the congruent conversions and treatments made to the explanation of the concepts. Then, we sought in the students’ activities the conversions (congruent or non-congruent) and treatments performed.

The next step was to analyze the possible differences between treatments and conversions present in the videos and the written productions presented by the students, and discuss the possible causes of the non-congruent conversions that may be related to: the role of natural language in addressing the problem by the video, the understanding of the statements of the problems proposed, and the need for auxiliary representations of transition and problems between the cognitive articulation, natural language and other registers.

In Table 01, in the column completely or partially "fulfilled Mayer's principles", we have calculated the percentage of this author's principles fulfilled in each of the videos; for example, in video V01, the 71% percentage was obtained by dividing the 8.5 principles (eight principles completely fulfilled and one principle partially fulfilled) fulfilled by this video (Table 01) by the total of principles enunciated by Mayer (2009), twelve.

The second column shows the treatments performed by the authors of the videos within the same register of semiotic representation. For example, in the video V01, the 2AW code means that during this video, in two stages, treatments were performed using the writing algebraic. The third column refers to treatments used by the students during the performance of written activities relating to videos. In the fourth column, the conversions between different registers of semiotic representation are shown - presented by the authors of the videos.

For example, the video V01, 3(WL,T) indicates that in three moments the author made a conversion of the written language for representation by means of a table. In the fifth column the misleading conversions used by students during the course of the written activities related to the videos are presented.

Table 01: Treatments, conversions and mistakes made

	Fulfilled Mayer's principles	**Treatments presented in the videos**	**Treatments presented by the students**	**Conversions presented in the videos**	**Conversion errors committed by the students**
V01	71%	2AW, 3ML, 3T, 3WL	14AW,12T	3(WL,T), 3(T,ML), 3(ML,AW)	1(WL,T)
V02	79%	13AW, 2G, 9ML, 4T, 3WL	29AW, 14T, 7ML, 22G	4(WL,T), 1(T,ML), 13(ML,AW)	2(AW,G), 1(ML,AW)
V03	58%	8AW, 14G, 8ML, 7WL	47AW, 10T, 2 ML, 20G	4(AW,G), 3(T,ML), 11(ML,G) 2(G,AW)	10AW, 1(AW,G)
V04	63%	9AW, 4G, 1ML, 5T, 5WL	38AW, 35T, 33G	3(AW,G), 6(ML,AW)	3AW, 1(AW,G), 1(AW,T), 1(T,G)
V05	71%	9AW, 4G, 1ML, 5T, 5WL	7AW, 27T, 12ML, 29G	2(AW,G), 4(AW,T), 4(T,G)	-

V06	79%	6AW, 6G, 5ML, 4T	10T, 18ML, 18G	3(AW,G), 2(AW,T), 2(T,G),4(G,AW), 1(G,T)	2(ML,G), 1(AW,G), 2(AW,G)
V07	67%	12AW,12ML, 1WL	59AW, 1ML, 7N	12(ML,AW)	21AW, 6N
V08	75%	11AW, 9G, 9ML, 1WL	39AW, 37ML	7(G,AW)	-

AW- Algebraic writing, G- graphics, WL- oral or written language, T- table, N – numerical treatment, ML – mathematical language.
Source: research data.

Although it is not possible to solely say that the treatments presented by students in the activities developed were influenced by the videos, Table 01 allows us to observe the following aspects: the most common treatment used in the videos is AW (70 treatments), ML comes in second place with a total of 54 treatments, then we can observe that treatment G appears 37 times, followed by treatment WL in 20 cases, treatment T appears 16 times and finally treating N shows up in only two occasions.

The most used conversion in the videos is (ML,AW), being used 34 times; then, we can see that: conversion (G,AW) was used 13 times; conversion (AW,G), 12 times; conversion (ML,G), 11 times; conversions (T,ML) and (AW,T), 7 times; conversion (T,G) 6 times; and conversion (G,T), only once.

The treatment most used by the students was AW (233 times), then we have: treatment G was used 122 times; treatment T, 108 times; treatment ML, 65 times; and treatment N, 7 times.

These data are consistent with what happens to students before a mathematical task. They are used to solve (math) problems using algebraic writing, even if it is not needed. This also explains the fact that treatment T appear less frequently.

This finding is also detected in the work of Kato *et al.* (2013), in which college students use algebraic language even in arithmetic problems, in which the use of algebra is not necessary.

This makes us think that despite the videos, these students bring a baggage of previous knowledge related to solving mathematical problems, which is very strong and that inhibits the search or assimilation of other treatments to address them. Thus, they get stuck in some conceptions of problem solving, and the strongest one detected in this group was algebraic writing.

Observing the treatments applied in the videos and in the students' written activities, we can observe that treatment AW is the most used one; treatment ML is more used in videos than in the students' written activities, which may be related to the greater ease of professors, who made the videos, in dealing with such language when compared with students.

Treatment G was widely used in both videos and the students' activities; the same goes for treatments T and N, which were rarely used in both videos and the students' activities.

The presence of treatment G in the videos is justified by the choice of the mathematical concept being treated, functions, considering that the videos focused on the close relationship between the algebraic and graphical representation of a function.

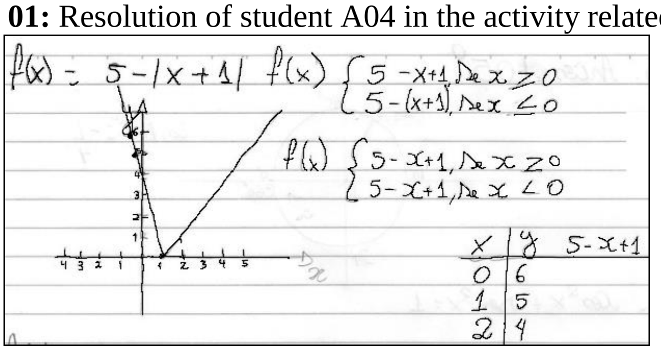
The strong presence of treatment G in the students' activities may not have been solely influenced by the videos, as other studies (CLARK, MAYER, 2011) found that even for students in the first year of high school, who are having formal contact with the concept of function for the first time, there is this a strong relationship between the concept of function and the graphical representation.

Moreover, no student used treatment ML in the activities related to videos V01 and V04, which had this treatment. Video V01 addresses the concept of the rule of three, which is quite familiar to those students, and hence the activities were developed without mathematical language, using only arithmetic operations, from algebraic equations, which are the starting point for the solution of a problem involving the rule of three.

In video V04, which discusses the concept of modular function, with a definition strictly in mathematical language, $|x| = x \text{ if } x \geq 0 \text{ and } -x \text{ if } x \leq 0$, this understanding by students occurs through algebraic writing.

For example, to plot the graph of the function $5 - |x + 1|$, the student A04 did not use the mathematical language to represent the module function, instead relied on algebraic writing. We can see in Figure 01 that student A04 did not understand the definition of module and therefore could not extend it to a function that has a different law of formation from $|x|$.

Figure 01: Resolution of student A04 in the activity related to video V04.



Source: research data collected

Note that the student did not use the definition of module for this function because if x is greater than zero, A04 does not consider that the function would take the form *"f(x) = 5 - x – 1 = 4 – x"*. Instead, he writes *"f(x) = 5 – x + 1 = 6 – x"*. One possible cause of this misconception is the fact that the student has not understood the module concept for different algebraic expressions involving the variable " x " since, for the student, the algebraic expression representing the function is the same for both $x \geq 0$ or $x \leq 0$.

In video V07, it was not shown treatment N; however, students used such treatment in seven opportunities. We assume that the use of treatments that are not in the video is due to previous school experiences of students, who gave them more certainty to use one type of treatment over another.

The type of treatment used is also related to the level of mathematical knowledge of the subject; for example, it is easier for a mathematician to use treatment ML than for a student.

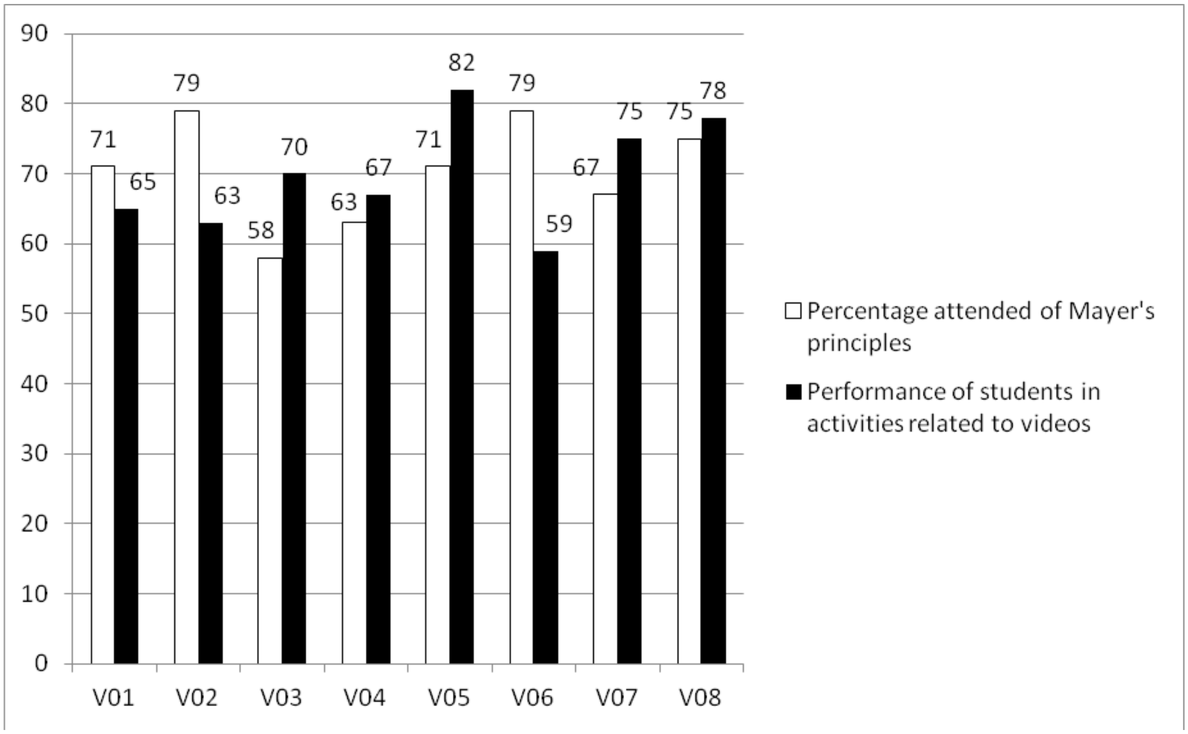
Many of errors in treatment or conversions were made using procedures that had not been presented in the videos, e.g., in video V02 no conversion was given (AW, G), however the student A01 used this conversion improperly on two occasions, during the resolution of the activities related to this video.

The same occurred in the activities of video V06, which showed two conversion errors (MM, G), even if not such conversion was presented in the video. We could also observe, in the activities related to video V07, seven errors in treatment N, even though this treatment was not used in the video.

According to Mayer (2009), student performance on transfer tests, such as those used in our study, is related to the willingness of students to learn and how the multimedia presented in the teaching situations meet the twelve principles proposed by him.

In our case, we believe that the students who voluntarily enrolled for the course were predisposed to learn, and that the videos used during the course attended most of the principles proposed by Mayer (2009). Thus, we decided to build Graph 01, which compares the students' performance in the activities related to each video and how each one fulfilled the principles proposed by Mayer (2009).

Graph 01: Students' performance compared with how the videos met Mayer's (2009) principles



Source: research data.

Graph 01 shows that the videos analyzed fulfilled over 50% of Mayer's (2009) principles, and that the students' performance, in all written activities, was greater than 50%.

This allows us to affirm that, despite the complexity of the components involved in the learning process, a further study concerning the role of videos in this process is necessary; for example, video V03 fulfilled less than 60% of Mayer's (2009) principles, however the students' success in the activities related to this video was 70%, higher than the performance shown by the students in video V06, which fulfilled almost 80% of Mayer's (2009) principles, but which had students with a performance below 60% in the resolution of the activities related to this video.

6. Final Considerations

For Mayer (2009), other factors, such as the interest of students and the way the situations were proposed, may influence the teaching and learning process. In this context, the videos fostered several situations that mobilized the use of different treatments with the potential to lead to learning concepts. The focus of this work is on the treatments and conversions of semiotic representation registers present in the videos and the students' resolutions.

Overall, Table 01 shows that treatments and conversions were recurrent both in videos and in the students' resolutions, which shows that students were not totally oblivious to what was presented in the videos.

However, some treatments are presented by students independent of the emphasis on the use of this treatment in the video, according to Mayer (2009, p. 67), “These active cognitive processes include paying attention, organizing incoming information, and integrating incoming information with other knowledge.”

This happens because students have had contact with these types of treatments even though in other concepts, and this repeated contact reinforces the certainty of the students to use them in new situations. The same argument applies to students who had treatments that were not in the video.

The conversions shown in the videos, in general, did not influence the mistakes or successes of conversions made by students. This is because the conversion does not depend solely on the treatment, it depends also very strongly on the situations in which they occur. Vergnaud (2009) states that it is the situations that give meaning to the concept, hence the need for various situations to formalize a concept.

The results show that students do not restrict their representations to the content alone, on what the videos show, but they connect that information with their own ideas. Therefore, more research studies are needed to investigate the relationship between the use of digital videos and the construction of congruent semiotic representations.

7. Acknowledgements

We thank our research group PECIMAT and Prof. Rubia B. Amaral for fruitful discussions. VCC acknowledges partial support by the Coordination for the Improvement of Higher Education Personnel (Capes) and University of Maringá.

8. References:

CAMPBELL, D. T.; STANLEY, J. C..(1979). *Delineamentos experimentais e quase-experimentais de pesquisa.* São Paulo: EPU/EDUSP.

CLARK, R. C.; NGUYEN, F. ;SWELLER, J. (2006). *Efficiency in learning: Evidence-based guidelines to manage cognitive load.* San Francisco: Pfeiffer.

CLARK, R. C.; MAYER, R. E.. *E-Learning and the Science of Instruction: proven guidelines for consumers and designers of Multimedia Learning*. San Francisco: Pfeiffer, 2011.

DUVAL, R. (2003). *Registros de representações semióticas e funcionamento cognitivo da compreensão em matemática*. In: ALCÂNTARA, Sílvia Dias (org.) – Aprendizagem em Matemática: registros de representação semiótica. Campinas, Papirus Editora.

DUVAL, R. (2009). *Semiósis e pensamento humano: Registros semióticos e aprendizagens intelectuais* (Fascículo). Tradução de Lênio Fernandes Levy e Marisa Rosâni Abreu da Silveira. São Paulo: Livraria da Física.

DUVAL, R. (2011). *Ver e ensinar a matemática de outra forma:* entrar no modo matemático de pensar os registros de representações semióticas. Organização Tânia M.M. Campos. Tradução Marlene Alves Dias. São Paulo: PROEM.

FREITAS, D. S.; ROSA, M. (2010). Vídeos Matemáticos Construídos com o Youtube: contribuições para a educação matemática. *Anais do XV EBRAPEM*. Fortaleza. Available in: www.portalrealize.com.br/revista/revistas/ebrapem. Accessed in Feb. 03 2013.

KATO, L. A. et al. (2013). Estratégias de resolução em problemas do Campo Conceitual Aditivo: um estudo com alunos ingressantes nos Cursos de Ciências Exatas. *Boletim GEPEM*. nº 62 jan/jun 2013. Rio de Janeiro: UFRJ.

LOPES, J. J. (1995). *Leituras do vídeo didático de física: estudo de alguns episódios*. 152p. Dissertação. Universidade de São Paulo - Instituto de Física e Faculdade de Educação. São Paulo.

LUZ, S. V. da. (2010). *Aprendizagem significativa de Função do 1º Grau: uma investigação por meio da modelagem matemática e dos mapas conceituais.* 172 f. Dissertação (Mestrado em Educação para a Ciência e o Ensino de Matemática) - Universidade Estadual de Maringá, Maringá.

MAYER, R. E. ;DURSO, F. T. (1999). *Instructional technology. Handbook of applied cognition*. (pp. 551-569). New York, NY, US: John Wiley & Sons Ltd, xxii, 881 pp.

MAYER, R. E. (2003) Elements of a science of E-learning. *J. Educational Computing Research*, Vol. 29(3), p. 297-313. Nova York: Baywood Publishing Co., Inc.

MAYER, R. E. (2009). *Multimedia Learning*. Nova Iorque: Cambridge University Press.

MEIRA, L. (1994). *Análise microgenética e videografia: ferramentas de pesquisa em psicologia cognitiva*. Recife: editora UFPE.

MENEGHETTI, R. C. G.; REDLING, J. P. (2012). Tarefas Alternativas para o Ensino e a Aprendizagem de Funções: análise de uma intervenção no Ensino Médio. *Bolema*, Rio Claro, (SP), v. 26, n. 42ª, p. 193-229.

MONTEIRO JÚNIOR, F. N. (2010). Somando Funções Trigonométricas: uma reconstrução didática do conceito de timbre a partir de duas experiências pedagógicas. *Bolema*, Rio Claro (SP), v. 23, nº 36, p. 597-624.

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.

VALENTE, J. A. *et al.* (1999). *O computador na sociedade do conhecimento.* Coleção Informática para a mudança na educação. Campinas: UNICAMP/Nied.

VERGNAUD, G. (2009). *A Criança, a Matemática e a Realidade: Problemas do Ensino da Matemática na Escolar Elementar*. Tradução de Maria Lucia Faria Moro; Revisão técnica Maria Tereza Carneiro Soares. Curitiba: Editora da UFPR.