Sociedade Brasileira de Educação Matemática

RIPEM

# Multimodality and the expression of mathematical ideas through videos by Mathematics undergraduates

**Liliane Xavier Neves**
Universidade Estadual de Santa Cruz
Ilhéus, BA — Brasil
lxneves@uesc.br
0000-0001-8535-0779



2238-0345

10.37001/ripem.v13i3.3573

Received • 28/02/2023
Approved • 26/05/2023
Published • 10/09/2023

Editor • Gilberto Januario

***Abstract:*** The research reported in this article sought to understand how Mathematics undergraduates in Distance Education combine semiotic resources when using videos to express mathematical ideas. Adopting the qualitative methodology, the research was developed with students of the Analytical Geometry discipline and the participant observation in forums of the virtual learning environment was used in the monitoring of the video productions by the participants. Functional Systemic — Multimodal Discourse Analysis supported the analysis of the strategies used in the combinations of semiotic resources in the produced videos. In this article, the analysis of one of the videos produced in the research is discussed. As a result, it was found that the multimodal nature of the video encourages the use of contextualization in the construction of digital mathematical discourse. However, the concepts are formalized from a recontextualization referring to the classroom, which shows the influence of the experience in this environment in the construction of the mathematical discourse shared in the online environment in the context of this research.

***Keywords:*** Video Production. Semantic Expansion. Analytical Geometry. Distance Education.

## Multimodalidad y la expresión de ideas matemáticas a través de videos de estudiantes de Matemáticas

***Resumen:*** La investigación relatada en este artículo buscó comprender cómo los estudiantes de grado en Matemáticas en Educación a Distancia combinan recursos semióticos al utilizar videos para expresar ideas matemáticas. Adoptando la metodología cualitativa, la investigación fue desarrollada con estudiantes de la disciplina Geometría Analítica y la observación participante en foros del ambiente virtual de aprendizaje fue utilizada en el seguimiento de las producciones de video por parte de los participantes. El Análisis Funcional Sistémico — Multimodal del Discurso apoyó el análisis de las estrategias utilizadas en las combinaciones de recursos semióticos en los videos producidos. En este artículo se discute el análisis de uno de los videos producidos en la investigación. Como resultado, se encontró que la naturaleza multimodal del video incentiva el uso de la contextualización en la construcción del discurso matemático digital. Sin embargo, los conceptos se formalizan a partir de una recontextualización referente al aula, lo que muestra la influencia de la experiencia en este entorno en la construcción del discurso matemático compartido en el entorno en línea en el contexto de esta investigación.

***Palabras clave:*** Producción de Vídeo. Expansión Semántica. Geometría Analítica. Educación a Distancia

## Multimodalidade e a expressão de ideias matemáticas por meio de vídeos por licenciandos em Matemática

***Resumo:*** A pesquisa relatada neste artigo buscou compreender como licenciandos em Matemática da Educação a Distância combinam recursos semióticos ao utilizarem vídeos para expressar ideias matemáticas. Adotando a metodologia qualitativa, a pesquisa foi desenvolvida com alunos da disciplina Geometria Analítica e a observação participante em fóruns do ambiente virtual de aprendizagem foi utilizada no acompanhamento das produções de vídeos pelos participantes. O Sistêmico-Funcional — Análise do Discurso Multimodal fundamentou a análise das estratégias utilizadas nas combinações dos recursos semióticos nos vídeos produzidos. Neste artigo, discute-se a análise de um dos vídeos produzidos na pesquisa. Como resultado, constatou-se que a natureza multimodal do vídeo estimula o uso da contextualização na construção do discurso matemático digital. Entretanto, os conceitos são formalizados a partir de uma recontextualização remetendo à sala de aula, o que mostra a influência da experiência nesse ambiente na construção do discurso matemático compartilhado no meio online no contexto desta investigação.

***Palavras-chave:*** Produção de Vídeos. Expansão Semântica. Geometria Analítica. Educação a Distância.

## 1 Introduction

The aim of the research[1], presented in this article, was to understand how mathematics undergraduates in distance education combine semiotic resources when using digital videos to express mathematical ideas. According to Jewitt, Bezemer and O'Halloran (2016), semiotic resources are a set of tools formed over time by culturally and socially organized societies for the production of meanings. These resources are materialized in visual, auditory or somatic mode, which characterizes them as a multimodal phenomenon - one that involves multiple semiotic resources materialized in two or three modes (O'Halloran, 2022). In this sense, it is understood that the video has a multimodal character, as it allows different semiotic resources, manifested in visual and auditory form, to be combined for the production of meanings as a communicational phenomenon.

The Internet has revolutionized communication, contributing significantly to the information society and shaping new forms of social interactions. Videos are elements that stand out in this scenario for their potential with regard to multimodality. Castells (1999) emphasizes the potential of what he calls the new communication system, which is based on network integration and whose main feature is the ability to include and encompass all cultural expressions, the author adds that

> it is precisely because of its diversification, multimodality and versatility that the new communication system is able to embrace and integrate all forms of expression, as well as the diversity of interests, values and imaginations, including the expression of social conflicts. (Castells, 1999, p. 461).

In fact, digital media assume a formative role, transmitting ideas and values (Setton, 2015) and influencing educational institutions, which try to align their actions with social and cultural practices in order to prepare students for the exercise of citizenship and for work. According to Gino, Mill and Nagem (2013), in a context of accelerated development of information and communication technologies, they transform the notions of educating, learning and managing education. These authors point out that, for this civilization of the image, it would be neither easy nor correct to separate the use of computers and films in school, since the implications brought by innovations must be reversed in contributions to education. In general,

[1] This article is the excerpt of a doctoral thesis defended in the Programa de Pós-Graduação em Educação Matemática da Universidade Estadual Paulista, Rio Claro campus, written by the first author and supervised by the second author.

technologies cause internal transformations in human beings, influencing cognitive development and the construction of knowledge (Lévy, 1993). In the case of videos, these choices and ways of combining semiotic resources intervene qualitatively in the constructed message, in particular, in the mathematical discourse, enabling the production of meanings in mathematical learning (Borba, O'Halloran & Neves, 2021). Thus, analyzing the potential of videos for the production of meanings is an important point for teaching mathematics, considering the social and cultural scenario in which audiovisual communication plays a prominent role in the formation of individuals.

The production of meaning is an important factor for the construction of mathematical knowledge. According to Andrade and Sartori (2018), working with technologies in the digital age involves recreating senses and meanings for the construction of knowledge and the storage of new data, such as relevant information, happens when they are articulated to other information that appears in the individual's miscellany of meanings and emotions. For these authors, knowledge is a knowledge that expresses meaningful relationships between information in the form of an idea, being built in a process of internalization, experimentation on the world, mediated by the other and the social context, which involves a deep search for motivation and that can be mobilized through a movement of contextualization, followed by generalization and transfer to other contexts.

Ferrés (1995) explains that, through video, ideas can be communicated through emotions and states that "The optimization of the teaching and learning process desired by educational technology cannot be achieved, within the framework of what is considered the civilization of the image, without the incorporation of audiovisual" (Ferrés, 1995, p. 127). As a technology that stimulates the senses in the production of knowledge, the video unites hearing, sight and emotions from the combination of images, sounds, music, scenarios, body expressions and other semiotic resources specific to audiovisual language (Neves & Borba, 2020), in order to arouse sensations, such as surprise, astonishment, amazement, enthusiasm, joy and wonder, with the simulation of situations involving mathematical concepts. It is in this sense that Moran (2013) talks about the creative use of video, which motivates and sensitizes students when used to illustrate, tell, show and make complicated topics closer. Thus, the digital mathematical discourse (Borba, O'Halloran & Neves, 2021) enables contextualization and interdisciplinarity, articulated so that concepts are developed from strategies that have direct reference to events anchored in the real world. For Andrade and Sartori (2018), contextualization is a facilitator of teaching and the first step towards the active construction of knowledge, in which the meaning, purpose and objective of learning must be intertwined with the socially constructed meanings of knowledge accumulated over time.

In order to express a mathematical idea in a video, the producer mobilizes the resources available in this technology in a process of thinking for the audiovisual format. This raises the question of how mathematical knowledge, traditionally enunciated from the resources of language, symbolism and graphic images, can be transformed into a discourse expressed in video (Neves & Borba, 2020). According to Silva and Rosa (2020), thinking-with-digital-technologies occurs when the being is-with-digital-technologies. Thus, experiences with the use and production of videos, experienced by students outside the classroom, can significantly influence the construction of digital mathematical discourse, enabling the reorganization of thinking (Engelbrecht, Llinares & Borba, 2020). Souto and Borba (2018) explain that different types of media have affected the production of knowledge throughout history and that, in the interaction with the media, the human being reorganizes thought according to the multiple possibilities and limitations that the media offer. Thus, video has been intervening in the production of knowledge, acting significantly in the collective formed by human beings and media.

Systemic-Functional Multimodal Discourse Analysis (SF-MDA) is a theoretical approach that aims to understand and describe the functions of semiotic resources as meaning systems, as well as to analyze the meanings that arrive when semiotic choices are made for the combination of these resources (Jewitt, Bezemer & O'Halloran, 2016). In the research reported in this article, the combinations of semiotic resources for the expression of mathematical ideas in digital videos by undergraduate mathematics students were analyzed. These combinations result in possibilities for the production of meanings, conditioned to the choices of resources and the technology used, in this case, the video.

The research presented here reflects the interest in the choice and combination of semiotic resources, such as verbal language, mathematical symbolism, images, body language, music and sounds, in order to produce meanings in mathematical discourse. This inquiry was developed with students in the disciplines of Analytical Geometry and Informatics in Mathematics Education of the undergraduate course in Mathematics in Distance Education. Its implementation was based on the proposal of a video production activity involving the contents of these disciplines. Five videos produced by the participants were analyzed and the discussion forums available in the virtual environment of the course were fundamental for monitoring the participants' productions. The videos analyzed addressed different contents and their semantic potential was analyzed considering the functionalities of the resources, from the Systemic-Functional - Multimodal Discourse Analysis. In the following sections, the theoretical assumptions of Systemic-Functional - Multimodal Discourse Analysis used in the research, the methodology and procedures adopted will be discussed and, finally, a section of the analysis of one of the videos produced for the research will be presented, namely, the video entitled "Civil Construction" that deals with the concept of Distance between points (or vector module).

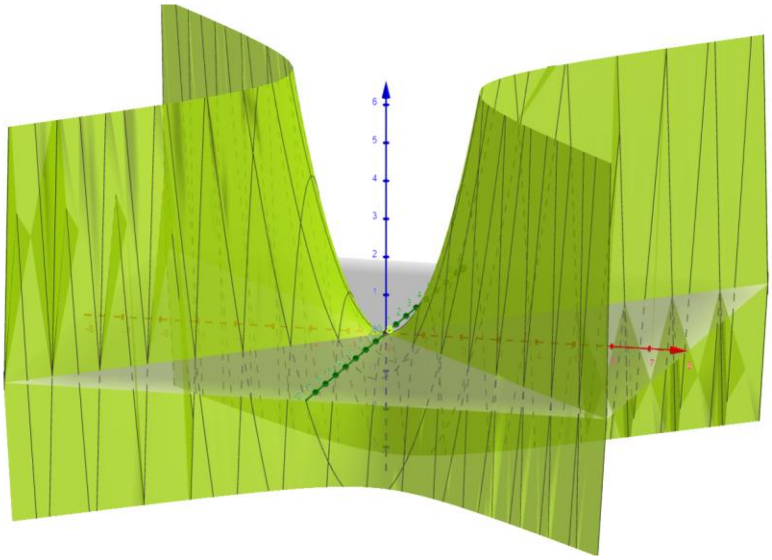
## 2 Theoretical framework

Systemic-Functional Multimodal Discourse Analysis (SF-MDA) is an approach that deals with understanding and describing the functions of semiotic resources as meaning systems in communicational phenomena. This description enables the analysis of meanings resulting from semiotic combinations (Jewitt, Bezemer & O'Halloran, 2016). Semiotic resource is the key concept of this approach and, according to Van Leeuwen (2005), it is formed by actions, materials and artefacts used for communicative purposes, which can be produced physiologically or technologically, together with the ways in which these resources can be organized. Also according to Van Leeuwen (2005), semiotic resources have a meaning potential based on their past uses and a set of 'affordances' based on their possible uses, which are updated in concrete social contexts. Jewitt, Bezemer and O'Halloran (2016) explain that semiotic resources are used to construct human experiences, logically connect events, establish social relations, organize and compose a message. These are strands of meaning known as metafunctions of semiotic resources.

Language, gestures, facial expressions, music, sound, graphic images, photographs, paintings, mathematical symbolism, colors, three-dimensional objects, lighting, clothing, setting, framing, camera movement and space are examples of semiotic resources. In communication, semiotic resources are chosen considering the situational context and combined to produce meanings. In a conversation, the message is understood from the observation of oral verbal language and its various nuances, facial expressions, posture and gestures, for example. At first glance, verbal language can be considered the most important resource in discourse in a situation where all those involved in the communicational phenomenon are listeners, however, the understanding of the message happens considering the integration of other semiotic resources. In SF – ADM, it is assumed that no resource is more important than another in a communicational phenomenon, even if some, such as verbal language, have been structured better over time than others.

In mathematical discourse, traditionally, the main semiotic resources used are verbal language (oral or written), mathematical symbolism and mathematical images, especially graphic images (O'Halloran, 2022). According to O'Halloran (2018), mathematical symbolism developed from verbal language, being structured as a system in order to make mathematical writing universal. Thus, in mathematical discourse, symbols assume predefined meanings, used in order to visually organize, through writing, mathematical thinking in a logical sequence, based on theorems and properties, in order to show the validity of results in a generalized way. Mathematical images help in the description and interpretation of problems, a necessary preliminary step for their resolution. Over time, a system of meanings for graphic images has been developed, which sets a standard for the graphical representation of mathematical objects. For example, the use of dashed lines to indicate the parts of a surface that is overlapped by another part, as illustrated in Figure 1.

**Figure 1:** System of Meanings of Graphic Images



**Source:** Own elaboration

Figure 1 illustrates a representation of a hyperbolic paraboloid whose symbolic representation is $f(x, y) = x^2 - y^2$. The intersection of this surface with $x = k$ planes are the parabolic curves represented with black lines. The parts of these curves that are in the background of the image are dotted. This is a rule used to indicate the position of parts of the image in three-dimensional space. Other elements that are part of the system of meanings of graphic images are colors, scale, the position of the object in the plane or in three-dimensional space and the orientation of the coordinate axes.

According to O'Halloran (2018), semiotic resources are materialized through the visual, auditory or somatic modality, which refers to the way people have access to these resources to produce meaning. Music and sound, for example, are materialized by the auditory modality. A gesture or a graph of a function, by the visual modality. In the somatic modality, people access semiotic resources through touch, smell or taste, producing meaning from physical sensation. In mathematics, the somatic modality can be activated when performing activities with concrete materials (Neves & Borba, 2020). A communicational phenomenon is multisemiotic and multimodal when it involves two or more semiotic resources and modalities, respectively. It is worth mentioning that semiotic resources do not meet the metafunctions in a uniform way, since they have different levels of structure for representation. As Jewitt, Bezemer and O'Halloran (2016) exemplify, images do not structure the world in the same way as language.

In mathematical discourse, language, mathematical symbolism and mathematical imagery have specific functions, structured over time. In fact, Friedlander and Tabach (2001) state that mathematical language is used to carry out analyses of mathematical results or in the contextualization of problems; mathematical symbolism establishes relationships between mathematical concepts and operations, serving to generalize results and standardize scientific language. Images are presented as resources that allow the visualization of the relationships established between variables and mathematical operations, making it possible to visualize the mathematical phenomenon as a whole and its parts. The combination of these semiotic resources is considered central to the effective understanding of mathematical concepts (Wilkie, 2016) and is a natural action in the context of mathematical teaching and learning.

In a multisemiotic and multimodal phenomenon, the production of meaning comes from the combination of the different metafunctional competencies of the semiotic resources involved. This combination of resources results in a new meaning, different from the sum of the individual meanings. Lemke (2010) refers to this property as multiplier meaning which refers to the notion that a text means more when juxtaposed with a picture, and vice versa.

The notions of intersemiosis, recontextualization, resemiotization and semantic expansion are also important in SF – ADM. Intersemioses are the processes by which semiotic choices interact and combine to produce meaning, considering the context surrounding the multimodal phenomenon. According to O'Halloran (2018), the process of recontextualization points to the fact that meaning is not fixed, being modified according to the situation and the cultural context in which they appear. Resemiotization refers to the reconstruction of semiotic choices within and across multimodal phenomena, being a possible outcome of the recontextualization process, which enables semantic expansions in mathematics, such as equations that arise from concrete mathematical activities. Finally, semantic expansions are the contextualized meanings resulting from intersemiosis. The SF – ADM theoretical approach proposes the analysis of intersemiosis processes, in which semiotic choices interact and combine for the production of meanings. With videos, mathematical discourse involves the traditional semiotic resources of mathematical discourse, namely language, mathematical symbolism and images, as well as other resources specific to video, gestures, facial expressions, movement, scenery, music and sounds.

Features of cinematographic language are studied in film theories and have pre-established meanings. For example, the general plan, when the camera shows the entire environment where the object of the action is, according to Moletta (2009), suggests loneliness or isolation; the Zoom effect, serves to draw attention to a specific object of the image; the plongê plan, in which the camera is positioned from top to bottom, conveys to the viewer the feeling of oppression and inferiority of the character, who places himself as powerless before the universe. These elements, when combined with sounds, music, scene objects, costumes and lighting, produce meanings and arouse sensations in the viewer. Body language is a form of non-verbal communication in which the individual expresses himself through signs such as gaze, facial expressions, gestures and body positions. According to Mortimer and Quadros (2018), body language is loaded with meanings that are evaluated together.

Body language is also present in the classroom and contributes to the communication of mathematical ideas by intersemiosis with the usual semiotic resources of this discipline, with verbal language, symbolism and images enhancing mathematical discourse. Facial expressions, as resources that are part of body language, include tensions in the muscles of the face, such as frowning, as well as variations in the look and smile. This set of resources can emphasize, confirm or deny points mentioned in the speech. Jewitt, Bezemer and O'Halloran (2016) describe the influence of facial expressions on the conclusions of a multimodal analysis of a job interview. The authors found that looking, raising eyebrows, smiling or frowning provided additional information beyond the answers given in verbal speech. Gestures reinforce statements, adding visual elements to multimodal discourse. An integral part of mathematical thinking, gestures constitute a mode of communication in the mathematics classroom that, according to this author, serves as a window through which students think and talk about mathematics. McNeill (1992) ratifies this idea by stating that gestures articulate the relevant features in the context of speech and are not forced to include features just to meet the standards of form because they are not constrained by rule systems.

Alibali *et al.* (2013) present two types of evidence of the incorporation of mathematical cognition by gestures. They are: deictic gestures, which establish a referential from the foundation of mathematical thinking in the physical environment, and representational gestures, which reflect simulations of actions and perceptual states. For the case of deictic gestures, the authors exemplify by saying that "if a teacher points to the 3 in x3 while saying the word exponent, a student who is not sure what an exponent is can better understand the teacher's utterance" (Alibali *et al.*, 2013, p. 437, our translation). In turn, representational gestures, according to these authors, can be seen when, for example, the teacher uses his hands to portray characteristics of a cube that he had in mind and thus helps students to visualize this cube.

Music and sound do not have clearly structured metafunctions, however when they are combined with other semiotic resources, such as language and images, they result in the production of logical, experiential and interpersonal meanings (O'Halloran, 2018). The intersemioses obtained by the combinations of music, sound, image and verbal language contribute with their potential to elicit emotions through memory. Thus, Moletta (2009) states that music is responsible for the manifestation of emotions in audiovisuals. In an action scene, music with sound impact, strong beats and grandiose chords arouses adrenaline in those who watch. Likewise, a melancholic song provokes sadness. The sound effects, the author adds, bring the audiovisual closer to reality, when in a movie, for example, you can see the door closing, but the certainty that it really closed is only with the sound effect.

In addition to language, symbolism, mathematical images, gestures, facial expressions, music and sound, other semiotic resources can compose the digital mathematical discourse, considering the possibilities of video. Borba, Scucuglia and Gadanidis (2018) argue that video should be taken to the classroom because it is the way in which the new generation communicates, in addition to allowing mathematical discourse, specifically, to be presented in an aesthetic that would be impossible using only verbal language. For O'Halloran (2022), the technological and social configuration resulting from the popularization of technological resources stimulates a new pattern of discourse, characterized by the construction of meanings through the combination of different resources, influencing the modes of communication by linguistic and cultural diversity.

## 3 Methodology and procedures

The question proposed in the research reported in this article was: "How do mathematics undergraduates in Distance Education combine semiotic resources when using videos to express mathematical ideas?", which suggests an interest in "how it is done", proposing a more descriptive answer based on the actions of the subjects, which also defines the procedures to be adopted, leading the research design. This question induces a mapping of the semiotic resources used by mathematics undergraduates participating in the research for the construction of mathematical discourse through video. From this question, we aimed to investigate the potential of the combinations between the semiotic resources present in the videos to produce meanings. This question involves an analysis of the nature of the relationships between the usual mathematical representations, namely language, symbolism and mathematical images, with other semiotic resources present in the videos produced by the subjects when they express mathematical knowledge and bring out other dimensions inherent in the theme being researched.

In the search for interpretations around the formulated question, importance was given to subjective factors related to the subjects and that emerged during the production of research data. The natural environment, in this case the online environment, was constituted as a direct source of data by providing space for the storage of records of interactions carried out during the development of the research. The data resulting from these interactions bring elements of the process to compose the interpretations around the question. These aspects characterize the qualitative approach of the research (Creswell, 2014).

The natural locus of this investigation was the virtual environment of a public university, in which the researcher made use of participant observation in forums of a degree course in Mathematics of the distance modality, in a way that guided the process of production of the videos of the participants of the research. The data production was carried out in two moments. Initially, it was done with a class of students in the discipline Analytical Geometry II, between the months of July and November 2016; the following year, a new data production was carried out, now in the subject Informatics Applied to Mathematics Education, between the months of March and June 2017. Eighty-five students of the distance learning Mathematics degree course of this university, distributed in six centers, participated in the research.

The procedures adopted resulted in three types of data to be confronted in the analysis, namely, thirty videos with mathematical content, records of students' posts in the forums on video production, scripts and reports describing the decisions made regarding the production of videos by the groups. Among the advantages offered by data in video format, Powell and Silva (2015) point out the possibility for researchers to visualize the recorded events as often as necessary, in addition to considering varied image formats for this observation, which makes them viable in analyzes of multimodal phenomena. The detailed analysis of video images also makes it possible to perform interpretations from multiple perspectives.

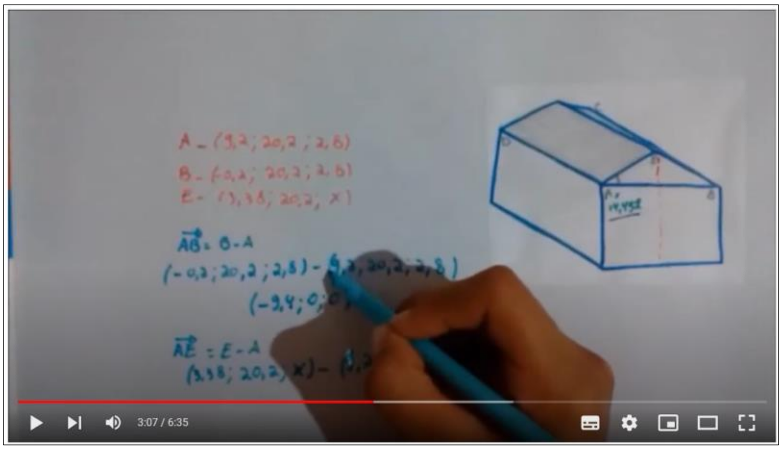
An initial analysis of the videos was performed with the thirty videos produced and followed some of the steps of the video analysis model described by Powell and Silva (2015): (a) visualization and description; (b) coding; (c) critical events; (d) transcription of critical events. The different semiotic resources involved in the multimodal phenomenon and the way they were combined were the two main criteria for choosing the videos that would be analyzed under the light of SF – ADM, but other factors led some videos not to be considered in the in-depth analysis, such as poor visibility, sound interference and long video duration.

The repeated viewing of the videos acted as a magnifying glass that raised expectations regarding the semantic potential of combinations of resources, however further analysis was required, based on SF – ADM, to confirm or not these assumptions. The videos that stood out, according to the initial analysis, were five: *Practical application of Analytical Geometry, Displacement made on a wheel, Construction, Sine and Cosine Functions in GeoGebra and Rosacea.* According to Marshall (1996), this is an intentional sample, in which the researcher selects the most productive sample to answer the research question. The five selected videos were analyzed considering the functions of Mathematical Language, Mathematical Symbolism, Mathematical Images and other resources used in them, as well as their interactions carried out in order to produce meanings. The analyses were carried out around the ways in which these resources were integrated, based on the functions they performed in the specific contexts of the videos. In this article, we will present a section of the analysis of the video *Civil Construction*.

## 4 Analysis of the video "Civil Construction"

The video *Civil Construction* (link: https://youtu.be/2wjTnFpv3oM) presents the content Distance between points from a problem that involves calculating the height of the vertex of a roof in relation to the slab line, considering the triangular shape of the roof. This video was produced by five students of the third semester of the undergraduate course in Mathematics of the Distance Education modality, participants of the research. In the script, notions of vectors were used to determine this height. The preliminary analysis of this video revealed the use of oral and written verbal language, mathematical symbolism, numerical representation, images, moving images, deictic gestures and music in the construction of the discourse.

**Figure 2:** Image from the Civil Construction video




**Source:** Neves (2020, p. 239)

The video mixes images of a construction and slide transitions in the introduction, as well as a cell phone recording of solving the problem about distance between points. The recording of the construction was used in the introduction of the video, in which a musical background was added. Some images in drawing format make references to the areas in which the content of Analytical Geometry can be applied, and then the recording of the broadcaster's hands enunciating and developing the resolution of the problem on a sheet of paper containing the drawing of a house with a triangular roof is presented, as illustrated in Figure 2.

In the introduction, the students cite aeronautics, computer game graphic design, mechanics and construction as areas in which Analytic Geometry is applied and explain that the video will focus on its application in construction. To introduce the topic, the authors use music, verbal language, images (drawings) and moving image (showing the scene of a house under construction). When filming a construction of a real house, organizing the sequence of images: first the image of a closed door, followed by the door opening, the construction and ending with the slab without the roof, there is a concern to establish an association between mathematics and a real problem, attributing meaning to the content that will be treated in the video.

A piece of music accompanies the moving image and appears at the beginning at a low volume, as a musical background for the interlocutor's speech about the areas in which Analytic Geometry can be applied. From 22 seconds, the music continues at a higher volume, as a musical background for the moving images that show the house under construction. It is an instrumental song with a sound impact highlighted by strong beats, a rhythm marked mainly by a drum that involves those who watch in an urgent and dynamic atmosphere. The scenario proposed by the video is thus immersed in an informal, relaxed environment and in this place the mathematical discourse is introduced.

The semiotic resources used in the introduction were combined in order to establish a relationship between mathematics and construction, which would serve as a motivating factor for the interlocutors. An excerpt from the introduction is presented in the following transcript.

> *Hello everyone, how do you know what Analytic Geometry is used for? It is used in aeronautics, computer game graphics, gravitation, mechanics and construction. In this video we will see the application of Analytic Geometry in civil construction. Come and see! (0s to 22s).*

The video starts a conversation with the interlocutor inviting him to see how mathematics is connected to everyday life. The problem is presented from the calculation of the distance between two points and, for the resolution, the resources of verbal language, mathematical symbolism, image and deictic gestures were articulated. Deictic gestures were used intensively in the resolution, combined with mathematical symbolism, which described the logical sequence until reaching the result, and the image that represented the house with the triangular roof. Vertices, angles and sides of the triangle are not defined, but identified by the use of deictic gestures with the support of the image and oral verbal language.

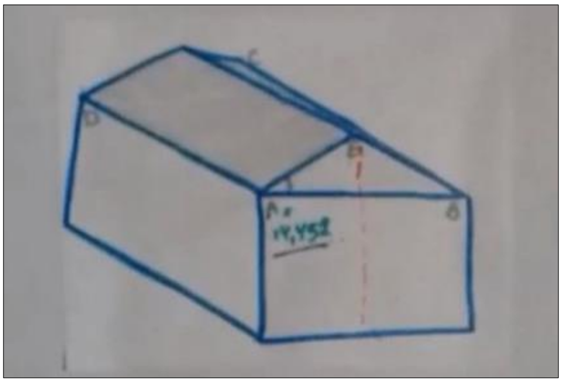
The production uses a model that is quite popular on the internet, whose technique consists of developing the resolution of a problem, with the camera frame limited to the paper, pencil and hands of the issuer. In this scenario, the oral verbal language is articulated with the development of calculations (mathematical symbolism), organized in an understandable logical sequence and with the image that represents the situation proposed in the problem statement.

The verbal language metafunction is evident in the discourse with the contextualization and enunciation of the problem, in the justification of operations and in the description of the relationships between variables. In the following transcript, the student presents the necessary steps to determine the mathematical relationships that will lead to the development of the resolution, based on the data informed in the problem statement. It is observed that parts of the process are implicit in the explanation, which is typical of verbal language according to O'Halloran (2018). This characteristic reinforces the difficulty in understanding mathematical concepts and can be observed in the following excerpt from the transcript.

> *We are going to calculate what the height of point E is in relation to the slab, but initially we will need to calculate what the height of point E is in relation to the ground. Knowing that angle A measures 14.452 degrees approximately, we will need to determine what the coordinates of points A, B and E are, point A, B and E. The coordinates of point A are nine point two, twenty point two, and two point eight. The coordinates of point B are negative zero point two, twenty point two and two point eight. The coordinates of point E are three point thirty eight, twenty point two and x, which is the height we are looking for. (29s to 1min30s).*

The explanation of the problem solving is carried out combining verbal language and mathematical image and deictic gestures, the latter essential in the understanding of mathematical relations and in the definition of subliminal concepts. In the excerpt above, the student considers a roof whose front part has a triangular shape with vertices A, E and B (Figure 3).

**Figure 3:** Visualization of the roof height problem



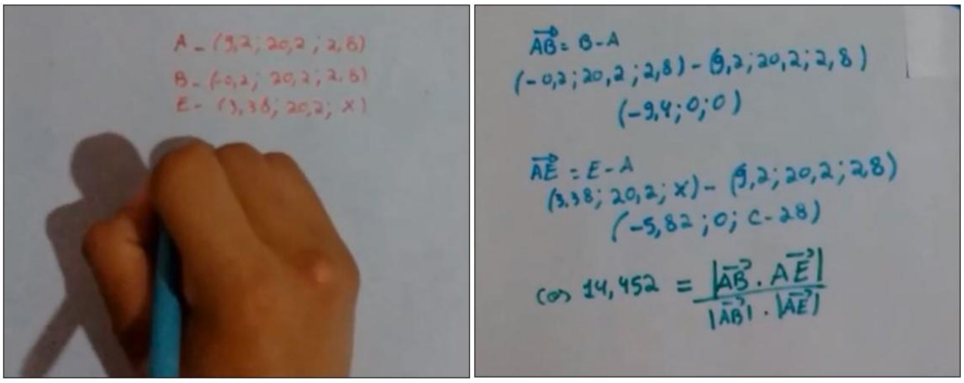

**Source:** Neves (2020, p. 235)

The student explains that determining the coordinates of the vertices of this triangle is necessary to calculate the height of point E in relation to the slab, however this calculation is not presented in the video and the student only presents the coordinates of the points in three-dimensional space. The discourse continues with the presentation of the coordinates of the points. Thus, there is a logical organization in the discourse that exposes a sequence based on the organization of mathematical thinking, but the chains of implicit reasoning, characteristic of verbal language, stand out. This does not invalidate the constitution of the logical meaning, referring to the metafunction of language, in the discourse.

In the video *Civil construction*, verbal language presents mathematics as a necessary science for the development of society, due to its connections with essential areas, such as those mentioned in the introduction of this audiovisual; on the other hand, a technicist mathematics takes place in the statement and development of the problem. In solving the problem, there is little discussion around the theme of civil construction, and the cosine formula is presented without justification.

The cosine formula referred to by the student is the Law of cosines, which introduces mathematical symbolism in the video, which, together with the numerical representation, is responsible for complementing the mathematical discourse in the gaps left by the language, which does not clarify all the steps of the logical reasoning that involves solving the proposed problem. In any case, when using symbolism, students also skip steps in the process. As an example of this, the coordinates of the vertices of the triangular roof are represented by points in three-dimensional space in a way disconnected from the statement. Figure 4 illustrates the coordinates of each of the points $A$, $B$ and $E$, where E is the non-collinear vertex of the triangle, with its last coordinate, which defines the height $x$.

**Figure 4:** Elements present in the formula for the angle between vectors

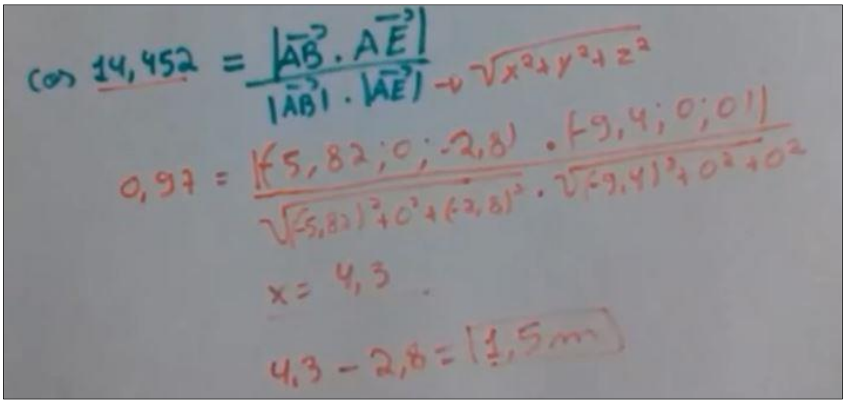


**Source:** Neves (2020, pp. 238-239)

What should be noted, with respect to the coordinates, is that, since point E is the vertex of the roof, the last coordinate of this point in three-dimensional space refers to its height, i.e. the height of point E relative to the ground, which is to be determined. The formula of the angle between vectors is established as a viable method for solving the proposed problem due to the data provided in the problem, which were the coordinates of the points $A$, $E$, $B$, vertices of a triangle formed by the roof of the house in which we want to calculate the height in relation to the slab, where the point $E$ is the non-collinear point of the triangle and the Â angle is made up of the vectors $\overrightarrow{AE}$ and $\overrightarrow{AB}$.

The mathematical relations that justify the value of the norm of a vector, which is associated with the idea of calculating the distance from the point that determines the endpoint of the vector to the origin, are used for a vector with coordinates $x, y$ and $z$e presented as an additional information, without clear explanation (formula application). The expression representing the formula of the cosine of the angle between vectors was differentiated by colors; the formula was written in blue and the numerical calculation in red, as illustrated in Figure 5.

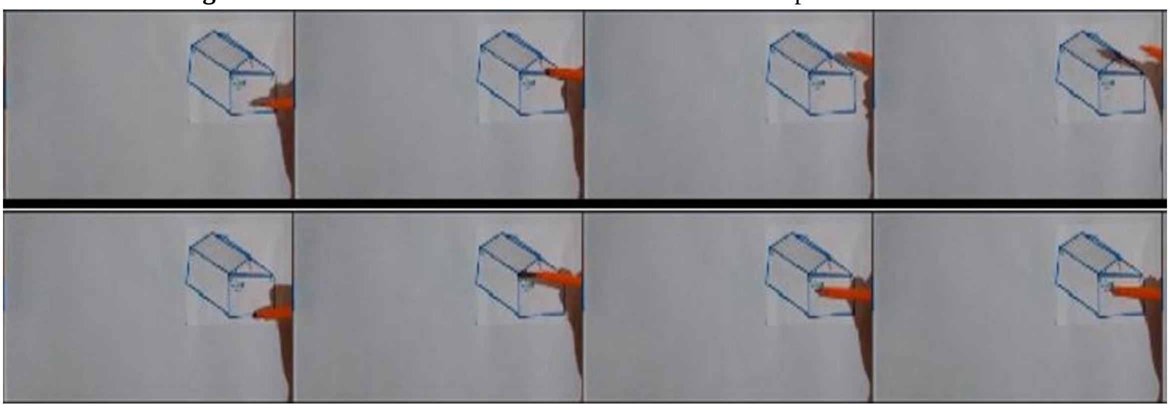
**Figure 5:** Numerical resolution of the roof vertex height problem



**Source:** Neves (2020, p. 239)

The arrangement of the calculation shows the sophistication of the mathematical symbolism that is complemented by other semiotic resources during the explanation, which fill the gaps left in the step-by-step record until the final solution. The image plays a central role in the discussion by presenting the scenario in which the problem proposed in the video develops. Students use deictic gestures to contextualize the problem being stated, illustrating in the mathematical image which are the main elements that make up the mathematical concept. The students state the problem while indicating with the deictic gestures which elements of the mathematical image are related to the idea expressed in the discourse, as shown in Figure 6.

**Figure 6:** Presentation of the elements that constitute the problem statement



**Source:** Neves (2020, p. 238)

The main question that drives the problem presented in the video, namely, "what is the height of point E, vertex of the roof of the house, in relation to the slab?" was materialized by the use of deictic gestures. Moreover, additional information present in the statement was embodied when the student used the gestures to indicate the angle formed by the side of the roof and the line of the slab, as well as the segments for which they should calculate the measure. The visualization provided by the interaction of gestures with verbal language and mathematical symbolism brings a complete idea of solving the problem. The mathematical operations developed were introduced into the discourse with the contribution of the deictic gestures. The subtraction operation between vectors was highlighted in the discourse and the deictic gestures complemented what was being expressed by oral language, reinforcing the ideas presented with the association of the visual elements present in the numerical representation. The differences performed, coordinate by coordinate, was illustrated by the sequence of movements performed by the deictic gestures, indicating the members of the operations, considering each vector.

## 5 Discussion

In the *Civil Construction* video, the content of Distance between points (or the module of a vector) is inserted in a context that involves the height of a roof in relation to the slab of a house. This insertion is done in an introductory way, at the beginning of the video when, using oral verbal language, the problem is stated and has the purpose of establishing a relationship between Mathematics and everyday life, from a common action linked to construction. Moran (2013) states that the video can be used to arouse the curiosity and motivation of students for new themes and this potentiality was taken advantage of by the research participants in this video.

The introduction of the video has a well-defined objective, namely to invite the interlocutors to watch and perceive mathematics closer to people. In order to achieve this goal, the resources of verbal oral language, still images, moving images and music were used. The language resources and images used in the introduction have different characteristics from those used in the second part of the video. The verbal language is relaxed, less formal and the images illustrate references to the specific areas in which mathematics is applied to produce goods for society. These semiotic choices were made so that the functionalities of the resources would bring out the interest in the applicability of mathematics and, in this case, the music and the images, in movement of a construction, draw attention to the video, making clear the theme that will be worked on in the script. The resources were used in a way that complemented each other in the introductory multimodal discourse, each with a specific function: verbal language - to introduce the theme and present the objective of the video; images - to illustrate the applicability of Mathematics in the areas enunciated from the language; music and moving images - to introduce emotion making the environment formed for the mathematical discourse more inviting, by using instrumental music that harmonizes with the verbal language in an informal tone. The suspense provoked by the door that opens and the image of a slab without the roof shows that there is a real problem that can be solved with the manipulation of concepts of Analytical Geometry.

In the second part of the video, verbal language, mathematical symbolism, numerical representation and mathematical image had their semantic potential optimized when used in conjunction with deictic gestures. The students, producers of the video, carried out a recontextualization, in which they left an environment built to distance themselves from the classroom (in the introduction of the video) and began to involve the interlocutor in a formal setting where the resolution of the problem that was proposed at the beginning of the video is developed. The usual functions of verbal language, mathematical symbolism, numerical representation and mathematical image were used as described in the theoretical assumptions (O'Halloran, 2022). In fact, oral verbal language was used for the presentation of the data of the proposed mathematical problem and for the explanation of the solving process. The image of the house represents the scenario in which the problem is immersed and contains the measurements of angles and nomenclature of points (ends of segments), important for the organization of strategies and for the development of the resolution. The numerical representation was prioritized in solving the problem, providing the data that would serve for the calculations necessary to reach the solution. These calculations, in turn, were initiated from the formula of the angle between vectors (mathematical symbolism). The combination of deictic gestures with the aforementioned semiotic resources in this interaction was fundamental in clarifying the step-by-step problem solving, complementing elements absent in the mathematical discourse.

The deictic gestures promoted the visualization of the notions of vectors, operations and the modulus of a vector. The intersemiosis resulting from the combination of oral verbal language with images, mathematical symbolism and gestures helped to concretize mathematical ideas, enabling semantic expansion for the calculation of the modulus of a vector. In the video, there is an effort to show the practical utility of the angle formula between vectors. The music invites the viewer to this experience, in which a relationship is established between mathematics and construction, suggesting that it is something motivating. Based on what was presented in the video, we have Chart 1, as follows.

**Chart 1:** Functions of the semiotic resources identified in the video

| Moments from the Video | Semiotic Resources | Function | Modality |
|---|---|---|---|
| Introduction | Oral verbal language | Introduce the topic of the video. | Auditory with an informal tone. |
| | Written verbal language | Introduce information that complements the introduction of the theme of the video and the context in which its production takes place. | Visual, with different colors and fonts according to the informal theme of the stage. |
| | Images | Introduce visual information according to the data entered by oral verbal language. | Visual, cartoon drawings, colorful elements, according to the informal theme of the stage. |
| | Moving image | Introduce real visual elements that exemplify the context in which the problem is embedded. | Visual, real images recorded with the cell phone. |
| | Music | Introduce emotions into speech. | Auditory, rhythm that refers to urgency and dynamism. |
| Resolving the problem | Oral verbal language | Introduce the problem statement and resolution. | Auditory, with a formal tone, according to the rules of the usual scientific language. |
| | Image | Introduce visual elements from the problem data. | Visual, with elements (data) of the problem. |
| | Mathematical symbolism | Introduce the equation that will lead to solving the problem. | Visual, formula for calculating the angle between vectors. |
| | Deictic gestures | Highlight elements expressed by | Visual. |

| | | | |
|---|---|---|---|
| | | oral verbal language and presentation of objects contained in the image but not formally defined. | |

**Source:** Research Data

In the *Civil Construction* video, two intersemioses are performed separated by recontextualization, forming two moments of the video. Thus, the video was divided into two parts, which represent two different contexts, by recontextualization. In each context, the semiotic resources do not differ significantly, but are used in different ways (informal and formal). In the first context, the mathematical content is introduced in a format that refers to an invitation to the viewer, in which the central idea is to arouse motivation and interest, presenting situations in which mathematics is close to people, being part of everyday life, as in the construction of a roof to cover the slab of the house.

In the first context, the theme of the video is introduced with the presentation of the problem and cinematographic resources are used more intensively with well-defined functionalities: music and scenery introduce elements that make the discourse truthful, i.e., closer to something real; the moving image validates the context in which the mathematical problem is inserted; the verbal oral language makes explicit the relationship of Mathematics with the created context; music inserts the emotion element in the multimodal phenomenon, enabling associations to be built between the mathematical content and the emotions suggested by the musical elements, such as rhythm.

The second context, which is formed from the recontextualization, assumes a formal design and is close to what is done in mathematics classrooms. Here, the mathematical content is explained in all its formality and the semiotic resources used in this part of the video are essentially verbal language, mathematical images, mathematical symbolism and deictic gestures. This reconstruction of semiotic choices based on recontextualization implies the realization of resemiotization. The intersemioses, made from the semiotic choices in the first and second contexts presented in Chart 1, result in the production of meanings that constitute the message expressed in the video.

## 6 Concluding Remarks

In the research reported in this article, patterns were identified in the organization of the mathematical discourse produced by the students and by the statements through the videos, which were grouped into two categories defined from the assumptions of Systemic-Functional Multimodal Discourse Analysis. In the analysis of the *Civil Construction* video presented here, it was observed that the content of the video was divided into two moments, each integrated into a specific context. Firstly, an informal context was presented, in which the audience was invited to see how mathematics is close by helping to solve everyday problems. The semiotic resources were not significantly altered, considering the multimodal capacity of the video: verbal language and images were present in both moments of the discourse, but in different ways. The less formal verbal language and the more relaxed and colorful images remained in the introduction. In the second part of the video, both the verbal language and the image used have more formal characteristics, following the protocols of the usual scientific language.

The functions of the semiotic resources of verbal language, mathematical symbolism and mathematical images, constituted over time, were reaffirmed in the digital mathematical discourse constructed by the students participating in the research. Regarding the characteristics of the semiotic resources described by O'Halloran (2022), which make mathematics distant and make it difficult to understand, some were maintained in the production of the video, such as the lack of clarification in passages of the development of the problem solving in which there were interconnected definitions and implicit reasoning. In this case, the image and deictic gestures helped by introducing additional information into the discourse. The combination of semiotic resources, in the two moments of the video, enables semantic expansion regarding the understanding of the concepts involved in solving the problem. On the other hand, the participants used the video technology to reproduce classroom practices, especially in the second part of the video, in which no resources were used to maintain the association of the mathematical content with the context created to show its application.

From the analysis of the video, it can be conjectured that, considering the cut of the research in which the participants assumed to have little technical knowledge regarding video production, the level of contact with the video production process influences how the multimodality of the video will be used and, consequently, the potential of the video as part of the collective that produces knowledge, human beings-with-media. Effectively, as discussed earlier, this is connected with thinking-with-digital-technologies.

This research includes in the theoretical framework of research on digital technologies in Mathematics Education, in particular, on the use and production of videos in Mathematics Education in the Systemic-Functional theoretical approach - Multimodal Discourse Analysis. With this theoretical lens, there is the opportunity to analyze the potential for the production of meanings, from the expression of mathematical ideas in videos, which is directly related to being-with-technologies (Silva & Rosa, 2020) and, consequently, to mathematical learning (Wilkie, 2016; Mortimer & Quadros, 2018; O'Halloran, 2022). The results obtained in this research bring reflections that point to new questions, namely: How do primary and secondary school students use their technological knowledge to express mathematical ideas through videos? How are the different types of knowledge (technological, pedagogical and content) mobilized by teachers for the construction of mathematical discourse through videos? How is prior knowledge and/or conceptual images used in the expression of mathematical ideas through videos? By proposing these new questions, we envision new theoretical contributions composing the framework of research involving the use and production of videos in Mathematics Education.

It is worth mentioning that the data in this research were collected in 2016 and 2017. In view of this, it should be considered that changes have occurred in the Distance Education scenario, especially after the Covid-19 pandemic, which, in addition to taking thousands of lives, transformed the country's educational system, if not, brought to light the existing abyss regarding the use of technologies in public education in the country.

## References


Alibali, M. W.; Nathan, M. J.; Church, R. B.; Wolfgram, M. S.; Kim, S. & Knuth, E. (2013). Teachers' gestures and speech in Mathematics lessons: forging commom ground by resolving trouble spots. *ZDM Mathematics Education*, 45, 425-440.

Andrade, J. P & Sartori, J. (2018). O professor autor e experiências significativas na educação do século XXI: estratégias ativas baseadas na metodologia de contextualização da aprendizagem. In: L. Bacich & J. Moran (Org.). *Metodologias ativas para uma educação inovadora: uma abordagem teórico-prática.* (pp. 175-198). Porto Alegre, RS: Penso Editora.

Borba, M. C.; O'Halloran, K. L. & Neves, L. X. (2021). Multimodality, Systemic Functional-Multimodal Discourse Analysis and Production of Videos in Mathematics Education. In: M. Danesi (Ed.). *Handbook of Cognitive Mathematics.* (pp. 1-30). Switzerland: Springer

Nature.

Borba, M. C.; Scucuglia, R. & Gadanidis, G. (2018). *Fases das tecnologias digitais em Educação Matemática: sala de aula e internet em movimento.* 2.ed. Belo Horizonte, MG: Autêntica.

Castells, M. (1999). *A sociedade em rede.* São Paulo, SP: Paz e Terra.

Creswell, J. W. (2014). *Investigação qualitativa e projeto de pesquisa: escolhendo entre cinco abordagens.* (3a ed.). Porto Alegre, RS: Penso.

Engelbrecht, J.; Llinares, S. & Borba, M. C. (2020). Transformation of the mathematics classroom with the internet. *ZDM Mathematics Education*, 52, 825-841.

Ferrés, J. (1995). *Vídeo e educação*. (2a ed.) Porto Alegre, RS: Artes Médicas.

Friedlander, A. & Tabach, M. (2001). Promoting multiple representations in algebra. In: A. A. Cuoco & F. R. Curcio (Org.). *The roles of representation in schools Mathematics* (pp. 173-185). Yearbook 2001. Reston, WV: NCTM.

G., M. S.; Mill, D. & Nagem, R. L. (2013). Sobre metáforas e animação cinematográfica em processos educacionais: riquezas e cuidados pedagógicos no uso do vídeo na educação. *In*: Mill, D. (Org). *Escritos sobre Educação: desafios e possibilidades para ensinar e aprender com as tecnologias emergentes* (pp. 295-323). São Paulo, SP: Paulus.

Jewitt, C.; Bezemer, J. & O'Halloran, K. L. (2016). *Introducing Multimodality*. New York, WA: Routledge.

Lemke, J. L. (2010). Letramento metamidiático: transformando significados e mídias. *Trabalhos em Linguística Aplicada*, *49*(2), 455-479.

Lévy, P. (1993). *As tecnologias da inteligência: o futuro do pensamento na era da informática.* Rio de Janeiro, RJ: Editora 34.

Marshall, M. N. (1996). Sampling for qualitative research. *Family Practice*, *13*(6), 522-525.

McNeill, D. (1992). *Hand and mind: what gestures reveal about thought.* Chicago, IL: University of Chicago Press.

Moletta, A. (2009). *Criação de curta-metragem em vídeo digital: uma proposta para produções de baixo custo*. (2. ed.). São Paulo, SP: Summus.

Moran, J. M. (2013). Ensino e aprendizagem inovadores com apoio de tecnologias. *In:* J. M. Moran; M. T. Masetto & M. A. Behrens. *Novas tecnologias e mediação pedagógica* (21. ed. pp. 11-7221). Campinas, SP: Papirus.

Mortimer, E. F. & Quadros, A. L. (Org.). (2018). *Multimodalidade no Ensino Superior*. Ijuí, RS: Editora Unijuí.

Neves, L. X. (2020). *Intersemioses em vídeos produzidos por licenciandos em Matemática da UAB*. 2020. 304f. Tese (Doutorado em Educação Matemática). Universidade Estadual Paulista. Rio Claro, SP.

Neves, L. X. & Borba, M. C. (2020). Vídeos em Educação Matemática sob a luz da Sistêmico Funcional — Análise do Discurso Multimodal. *Unión — Revista Iberoamericana de Educación Matematica, 16*(59), 159-179.

O'Halloran, K. L. (2018). A multimodal approach for theorising and analysing mathematics textbooks. [Proceedings]. In: *Second International Conference on Mathematics Textbook*

*Research and Development*. Rio de Janeiro, RJ.

O'Halloran, K. L. (2022). Matter, meaning and semiotics. *Visual Communication*, *22*(1), 174-201.

Powell, A. B. & Silva, W. Q. (2015). O vídeo na pesquisa qualitativa em Educação Matemática: investigando pensamentos matemáticos de alunos. In: A. B. Powell(Org.). *Métodos de pesquisa em Educação Matemática: usando escrita, vídeo e internet*. (pp. 15-60). Campinas, SP: Mercado de Letras.

Setton, M. G. (2015). *Mídia e educação.* São Paulo, SP: Contexto.

Silva, C. A. & Rosa, M. (2020). Corpo, videogame e constituição de conhecimento matemático: um estudo com Xbox Kinect. *Revista Internacional de Pesquisa em Educação Matemática*, *10*(3), 45-69.

Souto, D. L. P. & Borba, M. C. (2018). Humans–with–internet or internet–with–humans: a role reversal? *Revista Internacional de Pesquisa em Educação Matemática*, *8*(3), 2-23.

Van Leeuwen, T. (2005). *Introducing social semiotics.* New York, WA: Taylor & Francis E-Library.

Wilkie, K. J. (2016). Student's use of variables and multiple representations in generalizing functional relationships prior to secundar school. *Educational Studies in Mathematics: na International Journal*, *93*(3), 333-361.