

## Mathematical modelling when the problem is proposed with digital video: multi-voicedness, multimodality, domestication

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**Abstract:** This article describes research that explored the possibilities of digital video in mathematical modelling practices. It was developed in an online course aimed at in-service teacher education. Its scenario was a modelling practice in which a problem is proposed through a digital video (modelling videoproblem) and the participants are challenged to produce a video as an answer (modelling videoresponse). This is qualitative research based on the theoretical perspectives of the humans-with-media construct, Activity Theory, and Social Semiotics. The results point out that the way of combining semiotic resources in the videoproblem scenes influences the production of meanings and the modelling, and that the underutilization of resources of this media can limit educational possibilities. Furthermore, from the combination of different theoretical approaches, new theorizations emerge to be explored in future investigations.

**Keywords:** Humans-With-Media. Activity Theory. Social Semiotics.

## Modelación matemática cuando el problema se plantea con video digital: multivocalidad, multimodalidad, domesticación

**Resumen:** Este artículo describe una investigación que exploró las posibilidades del video digital en las prácticas de modelación matemática. Fue desarrollado en un curso en línea dirigido a la formación docente en servicio. Tuvo como escenario una práctica de modelación en la que se propone un problema a través de un video digital (videoproblema de modelación) y se reta a los participantes a producir un video como respuesta (videorespuesta de modelación). Se trata de una investigación cualitativa sustentada en los referentes teóricos del constructo ser-humano-con-medios, la teoría de la actividad y la semiótica social. Los resultados apuntan que la forma de combinar los recursos semióticos en las escenas del videoproblema influye en la producción de significados y en la modelación, y que la subutilización de los recursos de este medio puede limitar las posibilidades educativas. Además, de la combinación de diferentes enfoques teóricos surgen nuevas teorizaciones para ser exploradas en futuras investigaciones.

**Palabras clave:** Seres-Humanos-con-Medios. Teoría de la Actividad. Semiótica Social.

## A modelagem matemática quando o problema é proposto com o vídeo digital: multivocalidade, multimodalidade e domesticação

**Resumo:** Este artigo descreve uma pesquisa que explorou as possibilidades do vídeo digital em práticas de modelagem matemática. Foi desenvolvida em um curso online, voltado para a formação de professores em serviço. Teve como cenário uma prática de modelagem em que um

problema é proposto por meio de um vídeo digital (videoproblema de modelagem) e os participantes são desafiados a produzirem um vídeo como resposta (videoresposta de modelagem). Trata-se de uma pesquisa qualitativa, realizada a partir das referências teóricas o construto seres-humanos-com-mídias, a teoria da atividade e a semiótica social. Os resultados apontam que a forma de combinar recursos semióticos nas cenas do videoproblema influencia a produção de significados e a modelagem, e que a subutilização dos recursos desta mídia pode limitar possibilidades educacionais. Além disso, da combinação dos distintos enfoques teóricos surgem novas teorizações a serem exploradas em futuras investigações.

**Palavras-chave:** Seres-Humanos-Com-Mídias. Teoria da Atividade. Semiótica Social.

## 1 Introduction<sup>1</sup>

Mathematical modelling is a pedagogical practice in Mathematics Education, with roots in Applied Mathematics, which consists of approaching problems extrinsic to Mathematics with supports from Mathematics. Within the scope of Mathematics Education, modelling assumes a diversity of conceptions and perspectives that reflect the educational objectives and views of knowledge of those who practice it (Borba & Villarreal, 2005). This teaching practice is associated with a line of research that has been consolidated over 40 years of tradition, in the Brazilian and international scenarios (Araújo, 2010).

The modelling perspective that we assume in this article refers to a process of knowledge production, in which one seeks to respond to a problem, which is not necessarily a mathematical problem. It involves proposing questions (problematizing), mobilizing strategies in order to seek answers (investigating), which includes making use of mathematical ideas, concepts and procedures (mathematizing) (Canedo Junior, 2021). We understand modelling as a teaching practice in synergy with the presence of different technologies, both digital technologies, such as electronic spreadsheets, dynamic geometry software, and digital videos, and non-digital technologies, such as pencil, paper, measuring tape, stopwatch, various measuring instruments, etc. This way of understanding modelling reflects the view that knowledge results from the interrelationships between humans and different technologies, in processes involving humans-with-media thinking collectives (Borba & Villarreal, 2005).

The research results presented and discussed in this article were developed in light of previous perspectives of knowledge and modelling and had an investigative focus on the potential of digital video technology (media) in modelling practices developed by participants of an online course, aimed at the education of in-service teachers. The objectives of this investigation were outlined from the guiding question: How does digital video participate in modelling practices when the problem is proposed with this medium? The research scenario was one of the dynamics developed in the course, which consists of a way of carrying out work with modelling in which a problem is proposed through a digital video (modelling videoproblem). In addition to presenting a theme, bringing some information and posing questions, the video invites participants to produce a response in the form of video (modeling videoresponse).

The objective indicated in this question shows that, although the research was developed in the context of modelling practices that involved the proposition of a problem with the digital video media and the production of another video by the students/teachers of the course, the investigative focus was concentrated on how this media participates in the proposition of the

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problem and on the way in which it influences modelling. The investigation was developed from a qualitative point of view, so that the data were produced in the context of the research itself through interviews, participant observation and study of the materials produced by the participants in their modelling practices. These data were analyzed inductively, emphasizing knowledge production processes rather than results (Bogdan & Biklen, 1994). This analysis was developed from the perspective of knowledge present in the humans-with-media construct (Borba & Villarreal, 2005; Borba, 2009), in combination with the analytical principles of Activity Theory (Engeström, 2001; Engeström & Sannino, 2010), and Social Semiotics (Jewitt, 2005; Kress, 2009; Bezemer & Jewitt, 2010; Jewitt & Kress, 2010).

The present research was developed in the Grupo de Pesquisa em Informática, Outras Mídias e Educação Matemática (GPIMEM). By thematizing the potentialities of digital video in modelling practices, this study follows GPIMEM's nearly 30-year tradition of understanding the modelling-technologies dialectic. Furthermore, this study brings digital video to modelling research, a technology that has lately become more and more a means of communication and entertainment among people of all ages and from different cultures (Borba & Canedo Junior, 2020). The possibilities of this technology in Mathematics Education have occupied GPIMEM's research agenda, with emphasis on the Festival de Vídeos Digitais e Educação Matemática, an event that takes place annually since 2017. This Festival is an educational action of national and international scope, which constitutes a research scenario (Borba, 2021). By focusing on the possibilities of digital video in modelling practices, this text brings modelling research closer to one of the technologies that mark the transition from the fourth to the fifth phase of digital technologies in Mathematics Education (Borba, 2021; Borba, Souto & Canedo Junior, 2022).

The literature review of research published from 2015 to 2019, dedicated to the potential of digital videos in Mathematics Education, reveals a still incipient scenario, which reflects efforts concentrated in some research groups. In the specific case of modelling, this scenario is reduced to four publications. Alfke (2017) investigated how filming modelling practices, with digital video resources, can support teacher interventions. Orey and Rosa (2018) studied the contributions of virtual environment technologies, including digital video, in modelling work. Paraizo (2018) analyzed the influences of video production on modelling practices, when results are presented through this medium. And Domingues and Borba (2017) thematized the participation of digital videos in modelling projects developed by students, based on themes chosen by themselves. In none of these studies is digital video considered as an actor in proposing modelling problems, which reinforces the relevance of this research.

## 2 Modelling, technologies and Mathematics Education

The research discussed in this article was developed in light of the epistemological perspective present in the Humans-with-Media construct, through which knowledge is produced in a process that involves human actors and the various technologies (media), so that humans-with-media thinking collectives become the unit that produces knowledge (Borba & Villarreal, 2005). From this perspective, knowledge produced with pencil and paper is neither better nor worse, but qualitatively different from that produced with so-called digital technologies: calculators, software and applications, internet, digital videos, among others. This epistemological conception is rooted in the work of Tikhomirov (1981), when he assumes that computational technologies reorganize thought in a similar way, although qualitatively different, to orality and writing. Another source of inspiration for this theoretical construction is the notion of technologies of intelligence, presented by Lévy (1993), in which the advent of a new technology — in the way that happens today with the fast internet, social networks and

digital video — establishes cognitive ecologies distinct from those that figured in historical moments prior to it.

The Humans-with-Media construct leads to the understanding that the emergence of new technologies has the potential to shape Mathematics Education, by allowing new pedagogical practices to be constructed and new research questions to arise (Borba & Penteadó, 2001; Borba & Villarreal, 2005; Borba, 2009; Borba, Scucuglia & Gadanidis, 2014; Borba, 2021; Borba *et al.*, 2022). From this perspective, it makes no sense to talk about good or bad technologies, but about a relationship that can be one of resonance, or of dissonance, between these media and the pedagogical approaches in which they participate.

One of the ways for a medium to become dissonant from the intended objectives of a pedagogical practice is to promote its domesticated use. The domestication of a technology consists of an underutilization of its possibilities, when trying to reproduce with it practices that proved to be resonant with another media (Borba & Penteadó, 2001; Borba *et al.*, 2014). An example is the use of digital video to reproduce an expository class (videoclass), without exploring the audiovisual resources that this media makes possible.

In the case of modelling, Borba and Villarreal (2005) point out that the resonance between this pedagogical approach and the use of technologies depends on the perspectives of modelling and technology assumed. When considering the presence of computational technologies in modelling practices, these authors state that if the computer is seen as a tutor and modelling is reduced to an application exercise, as found in traditional textbooks, it is a relationship of dissonance. “The computer medium becomes domesticated in this case, as it is taking very little advantage of the possibilities of this medium as it tries to reproduce the way written texts are presented” (Borba & Villarreal, 2005, p. 57).

This understanding of the educational role of technologies influences our modelling conceptions. We assume modelling as a knowledge production process that develops from a problem. It includes proposing questions and raising hypotheses (problematizing), mobilizing actions to seek answers and testing hypotheses (investigating), which involves making use of mathematical concepts, ideas and procedures (mathematizing) (Canedo Junior, 2021). This modelling perspective is based on a problem conception, understood as an open situation that arouses interest (subjective dimension), and that presents itself as an obstacle, since there is no immediate solution or directly available means for resolution (objective dimension). Both mentioned dimensions need to be considered in terms of the human and technological actors involved. “What is perceived as an obstacle, and what provokes interest, also depends on the media available” (Borba, 2009, p. 458).

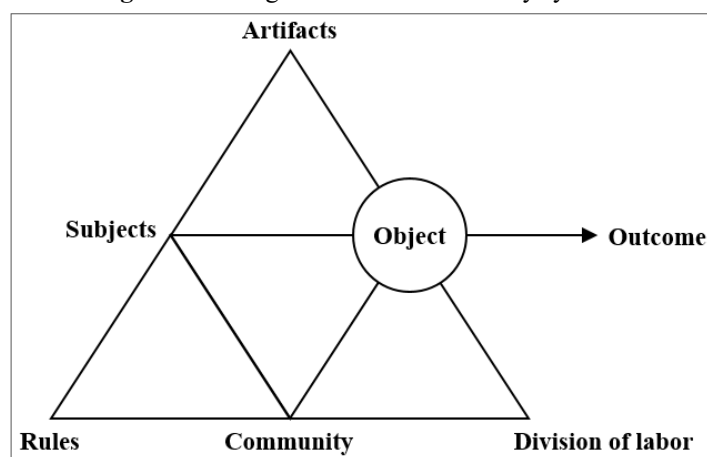
We understand the problem as a triggering element of modelling practices, a starting point, so that new problematizations can arise in the humans-with-media collectives involved. This modelling perspective is resonant with that presented by Borba and Villarreal (2005), who emphasize that modelling is not limited to problem solving, as it includes the possibility of new problems arising from the situation in question. It is a conception of modelling that is resonant with emancipatory, dialogical and problematizing education, proposed by Paulo Freire and a counterpoint to banking education, in which the teacher is the one who thinks and asks, and the student is the thought, who responds passively (Freire, 1987). The notion of problem starts to be understood, in this perspective, as instigating curiosity that becomes the driving force of the production of knowledge that, in the perspective assumed in this research, configures a collective action of humans-with-media (Borba, Canedo Junior & Carvalho, 2022).

### 3 Theoretical references and methodological design

In addition to the vision of knowledge underlying the Humans-with-Media construct, the theoretical references of this research include principles of Activity Theory (Engeström, 2001; Engeström & Sannino, 2010), and Multimodal Analysis, the latter from the perspective of Social Semiotics (Jewitt, 2005; Kress, 2009; Bezemer & Jewitt, 2010; Jewitt & Kress, 2010). Based on these theoretical approaches, we pursue the objective, pointed out by the guiding question, of understanding how digital video participates in modelling, when the problem is presented with this medium.

Activity theory is based on the concept of activity system, represented in the triangular structure of Figure 1. The subjects are those who share the object of the activity, to which the actions turn. This object reflects individual and collective motives and is associated with a product in which the subjects envision transforming it through their actions. The mediating artifacts are the technical and psychological tools (signs), which mediate the subject's actions on the object. The community represents those individuals who participate in the activity systems, mediating the interrelationships between subjects and the object, but who do not directly share the object. Between the subjects, the community and the object, rules are interposed, which can be explicitly (laws, contracts, subject programs, school curricula etc.) or implicitly established, in addition to a division of labor, which can reflect historical power relations, or configure a division of tasks emerging from the dynamics of the systems itself (Engeström, 2001; Engeström & Sannino, 2010).

**Figura 1:** Triangular structure of activity systems



Source: Based in Engeström (2001)

In addition to the notions referring to this triangular structure, Activity Theory assumes five analytical principles. The first one refers precisely to the assumption of the activity system as the basic unit of analysis. The second concerns multi-voicedness, which implies considering the different voices that make themselves heard in the dynamics of the system, so as not to neglect those that, for various reasons, may become less prominent. The third principle highlights the historicity of these systems, so that significant changes take place over relatively long time intervals. The fourth principle contemplates the role of contradictions, which are seen as conflicts that may reflect discontent, but which include possibilities for change. The fifth consists of expansive transformations, which are reconfigurations that take place in activity systems in order to overcome contradictions and explore new possibilities (Engeström, 2001).

The research described in Souto (2013) was based on analytical possibilities that emerge from the combination of the principles of Activity Theory with the vision of knowledge

underlying the Humans-with-Media construct. From this theoretical dialogue, the construct Systems-Human-with-Media (S S-h-c-m) emerges, which consists of an expansion of the activity systems (Figure 1), in the sense of considering the possibility of the media acting, not only as mediating artifacts, of the way that Activity Theory originally envisages, but also at other positions in the triangular framework. This theoretical dialogue is based on the common root that these two theories have in the work of Oleg Tikhomirov (Tikhomirov, 1981). This author's contributions, which form one of the pillars of the Humans-with-Media construct, are based on the ideas of Lev Vygotsky, who is considered the father of Activity Theory by authors such as Engeström (2001) and Engeström & Sannino (2010).

In proposing this emerging theorization, Souto (2013) also considered the analysis of empirical data produced in his research, which was developed in the context of an online course aimed at continuing education for teachers, in which properties of conics were explored with the Geogebra and internet media. The author observed episodes in which the construction on the Geogebra screen ceased to be a mediating artifact of the subjects' actions and became the very object of the activity, as well as faced situations in which the internet acted as a non-human member of the observed activity systems community.

When considering this participation of internet media in the communities of the observed systems, Souto and Borba (2018, p. 16) pointed out that

while researching the internet's role of community, we realized a multivocality expansion of the system that encompassed not just the individuals who were part of it, but the multiple voices of those who were external but somehow related to it as well. The building of a website is permeated with different values, stories, conventions, placements, i.e., different experiences of its creators, and, when used as a source of research, it transmits all these variables into the system.

This multivocal expansion, to which the cited authors Souto and Borba (2018) refer, reconfigures the principle of multi-voicedness, in the sense of including the voices of the media, more specifically of the so-called digital technologies, such as the internet. These non-human voices are now considered with the potential to echo in the various vertices of the systems, not only as artifacts, but also as an object, community, and even as subjects, making these human collectives, human-with-media collectives (Souto & Borba, 2018). This presence of media voices reinforces the conception, defended by Borba (2021) and Borba et al. (2022), that the media have agency, which harmonizes with the view of technological artifacts “as the historical, social, and cultural factors in the collective that produces knowledge. It stresses a view that knowledge is produced [...] by humans-with-artifacts” (Borba, 2021, p. 391).

In dialogue with the previously discussed theoretical references, the methodological design of this research includes considering modelling practices as activity systems, in which the voice of the digital video echoes among the multiple voices present there. The analysis of these voices will take into account their multimodal properties. From the perspective of Social Semiotics, multimodality implies considering not only what voices communicate, but also the way in which semiotic resources (images, footage, animations, writing, orality, different sounds etc.) are organized in the modes present in this communication (Jewitt, 2005 & Kress, 2009; Bezemer & Jewitt, 2010; Jewitt & Kress, 2010).

Social Semiotics proposes the transposition of an analysis focused on written and spoken language signs towards an approach that includes semiotic resources such as colors, gestures, sounds, animations etc., which are combined in the processes of communication and production and meanings (Kress, 2009). Jewitt and Kress (2010) emphasize that Social

Semiotics has, as its central construct, the notion of mode, which refers to an organized set of semiotic resources to give meaning (image, gesture, writing, for example). The mode constitutes the analytical unit of the production of meanings. From this perspective, a speech accompanied by the gesture of pointing to a mathematical expression written on the blackboard is different from when that same speech is associated, for example, with a moving image on a software screen.

[...] social semiotics assumes that representation and communication always draw on a multiplicity of modes, all of which contribute to meaning. [...] different modes shape the meanings to be realized in mode-specific ways, so that meanings are in turn differently realized in different modes (Bezemer & Jewitt, 2010, p. 183).

Considering the participation of the voice of digital video in the activity systems under study, from a perspective of Social Semiotics, can be seen as a step forward in expanding the principle of multi-voicedness, presented by Souto and Borba (2018). It consists of an analytical proposal that promotes an approximation between the analytical principles of the Activity Theory, the vision of knowledge present in the human-with-media construct and the assumptions of Social Semiotics.

This theoretical combination is considered by Jewitt (2005), when he stated that

Understanding the social context is crucial to thinking about the sign maker's interest. Bringing together multimodality with activity theory offers a way of thinking more clearly about meaning making and discourse as situated within a social activity system that extends 'beyond' the individual (Jewitt, 2005, p. 313, author's emphasis).

In this research, the analyzed data, according to the mentioned theoretical perspectives, were produced in the context of an online course aimed at the continuing education of teachers. The investigation is qualitative in nature, so that the data, produced in the online environment of the course, were analyzed inductively, highlighting the processes more than the results (Bogdan & Biklen, 1994). The course had synchronous classes held in a Facebook group; with the writing of individual logbooks, referring to each of the classes, in text documents shared on Google Drive; and with asynchronous interactions in the Facebook group itself.

The focus of the analysis was the modelling work developed within the scope of a dynamic in which a problem is proposed through a digital video (modelling videoproblem), which also challenges students to produce another video in the form of a response (modelling videoresponse). Four videoproblems were presented to the students, who were divided into pairs, so that each one chose one of the videos from which they developed their work.

The objectives of this text highlight the production of one of these pairs (Ari/Vera), who chose the videoproblem *Água: por um consumo consciente* (Water: for conscious consumption), which can be accessed from its link on YouTube (<https://www.youtube.com/watch?v=0SrALIKgVh4>). The data considered in the analysis were produced by the first author of this text, who acted as a member of the teaching team of the aforementioned course, within the scope of the online environment in which the modelling practices were developed. The procedures listed in this production included participant observation in classes and in other instances of the course; reading the logbooks; multimodal reading of videoproblems and video answers; and interviews with the duo, through WhatsApp.

Consistent with the assumed theoretical perspectives and with the objective pointed out in the guideline question, the analysis of these data sought to show how the multimodality of

the voice of the videoproblem shape the production of meanings and the actions developed within the scope of modelling practices, the latter being considered in the scope of systems activity. The results produced from this analysis are discussed in the following sections.

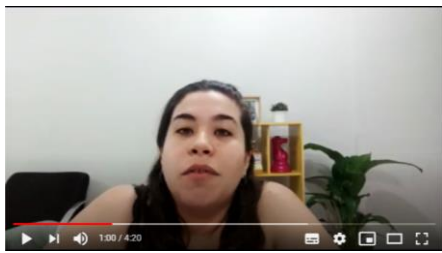
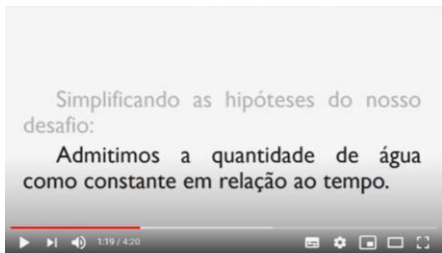
#### 4 Between the problematization and the game of questions and answers

The meanings produced by the duo Ari/Vera point to a tendency to interpret what is proposed in the videoproblem *Water: for conscious consumption* as a kind of questionnaire. This production of meanings was reflected in the work developed by this pair, so that the modeling process of these participants was permeated by a kind of game of questions and answers.

This tendency emerged from the way in which some questions, which are presented throughout the scenes of the videoproblem in order to provoke reflections, were understood by the pair, who considered them as if it were a questionnaire, that is, a list of questions to be answered, one by one. These questions appear in the video in number of three: (1) According to the Ministério do Meio Ambiente (Ministry of the Environment)<sup>2</sup>, a shower spends, on average, 150 liters every 10 minutes. Are our measurements compatible with this average? (2) And your shower, how much do you use every 10 minutes? (3) The World Health Organization suggests that 40 liters of water are enough to meet our daily needs. Does the water you consume per day comply with these 40 liters?

The presence of this game of questions and answers can be observed in the videoresponse produced by Ari and Vera, which can be watched from the link (<https://youtu.be/X8L-U0WHXyc>). Frame 1 below seeks to portray an excerpt from this video production (between 1min 0sec and 3min 34sec), by providing the images of the scenes side by side with their corresponding transcription of talk between Ari and Vera.


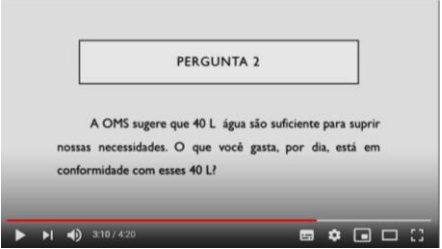
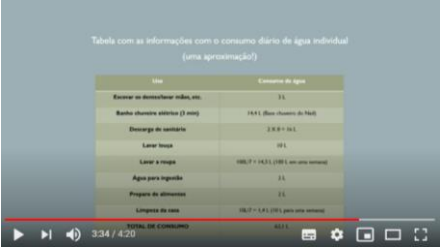
**Frame 1:** Excerpt from the videoresponse by the duo Ari and Vera based on the videoproblem *Water: for conscious consumption* — 1min 0sec to 3min 34sec (images and transcription of talk).

	Images of the scenes	Transcription of talk
1		<p>Responding to the first challenge made by Neil's video, which, according to the World Health Organization, a shower consumes, on average, 150 liters of water every 10 minutes. Are these measures represented in the video compatible with this average?</p>
2	 <p><b>Image translation (text):</b> Simplifying the hypotheses of our challenge: We assume the amount of water as constant with respect to time.</p>	<p>To simplify the hypotheses of this situation, we will assume the amount of water as a constant, with respect to time,</p>

<sup>2</sup> The Ministério do Meio Ambiente (Ministry of the Environment) is an agency of the Brazilian government.



<p>3</p>	<p><b>Image translation (text):</b> QUESTION 1 According to the World Health Organization, a shower spends, on average, 150 L of water every 10 minutes. Are the measures represented in the video compatible with this average?</p>	<p>... that is, maintaining the standard, this opening of the shower valve, including to maintain a constant temperature.</p>
<p>4</p>	<p><b>Image translation (text):</b> In the experiment done by Neil in the challenge video: In 10 s ----- 800 ml Then, we have: In 20 s ----- 1600 ml In 30 s ----- 2400 ml . . In (t)s ----- (v) ml  function of the type <math>y = ax+b</math>, that is, <math>v(t) = at+b</math>, where we will have <math>v(t) = 80t</math>, with <math>t</math> in seconds.</p>	<p>In the experiment done by Neil, in the video challenge [referring to the videoproblem 'Water: for conscious consumption'], we saw that, in 10 seconds, we have 800 ml of water. So for 20 seconds, 1600 ml, 30 seconds, 2400 ml. As we assume, then, a function of the type <math>y=ax+b</math>, that is, a linear function, we will have, then, a flow of 80 times <math>t</math>, of water, in <math>t</math> seconds. So, for 10 minutes, we will have, then, that there will be a flow of 48000 ml in 600 seconds, since 10 minutes is equivalent to 600 seconds. Thus, in 600 seconds there will be a flow of 48 liters of water.</p>
<p>5</p>		<p>In the experiment carried out by me (Vera), in 1 minute there was a flow of 3200 ml ...</p>
<p>6</p>	<p><b>Image translation (text):</b> In Vera's experiment: In 1min ----- 3200 ml In 2min ----- 6400 ml .</p>	<p>... in 2 minutes, 6400 ml. Therefore, as we assume a linear function of the type <math>y=ax+b</math>, we will soon have, in this case, that there will be a flow 3200 times <math>t</math>, in <math>t</math> minutes. Therefore, for 10 minutes, we will have a flow of 32000 ml, that is, 32 liters of water, in 10 minutes.</p>

	<p>.</p> <p>In (t)min ----- (v) ml</p> <p>Linear function of type <math>y = ax + b</math></p> <p>where we will have in this case that:</p> <p><math>v(t) = 3200t</math>, with t in minutes.</p> <p>Then, for 10 minutes, we will have:</p> <p><math>V(10) = 3200 \cdot 10 = 32000</math> ml</p> <p><math>v(10) = 32</math> L</p>	
7		<p>Thus, both experiments, both by Neil and the one performed by me (Vera), are below the average provided by the World Health Organization, which was 150 liters of water in 10 minutes.</p>
8	 <p><b>Image translation (text):</b> QUESTION 2 WHO suggests that 40 L of water is enough to meet our needs. What do you spend per day in line with those 40 L?</p>	<p>Let's go to question two. The World Health Organization suggests that 40 liters of water are enough to meet our needs. What do you spend per day in line with those 40 liters?</p>
9	 <p><b>Image translation (title text)</b> Table with information about the daily individual consumption of water, per person. (approximated values!)</p> <p><b>Image translation (table information):</b> Brushing teeth, washing hands, etc.: 3 L Electric shower bath (3 min): 14.4 L (based on Neil's shower) Flushing the toilet: <math>2 \times 8 = 16</math> L Wash the dishes: 10 L Clothes wash: <math>100 \text{ L} / 7 = 14.3</math> L (100 L in a week) Water to drink: 2 L Food preparation: 2 L House cleaning: <math>10 \text{ L} / 7 = 1.4</math> L (10L in a week) Total consumption: 63.1 L</p>	<p>According to the simulation made in the table, from the approximate consumption that we do in our daily lives, we can assume a daily expenditure of at least 63 liters of water.</p>

**Source:** Research Data

Frame 1 shows that the questions presented in the videoproblem are mentioned in the videoresponse scenes produced by Ari and Vera. The analysis of this excerpt from the duo's

video production indicates that the denomination QUESTION 1 (lines 1, 2 and 3 of the chart) refers to the first two questions presented in the videoproblem: (1) According to the Ministry of the Environment, a shower consumes, on average, 150 liters every 10 minutes. Are our measurements compatible with this average? and (2) And your shower, how much do you spend every 10 minutes?

The scenes referring to line 4 present an answer to question 1. By means of direct proportion and some concepts of linear function, the pair showed that the 800 ml in 10 s, obtained in an experiment presented in the videoproblem, correspond to 48 liters of water every 10 minutes. While question (2) — And your shower, how much do you spend every 10 minutes? — is answered throughout the scenes corresponding to lines 5 and 6 of Frame 1, which show the experiment carried out by the pair (line 5) with Vera's shower, and the calculations (line 6) by which the answer of 32 liters was obtained of water every 10 minutes. In the scenes corresponding to line 7, the pair synthesize the answers they obtained for questions (1) and (2) of the videoproblem, by informing that both in the experiment shown in the videoproblem (which refers to question (1)) and in the one carried out by double (corresponding to question (2)) water consumption is below the 150 liters every 10 minutes, informed in the videoproblem, based on data from the World Health Organization<sup>3</sup>.

The question announced in the videoresponse as QUESTION 2, as shown in line 8 of Frame 1, refers to the third question that the videoproblem presents: (3) The World Health Organization suggests that 40 liters of water are enough to meet our daily needs. Does the water you consume per day comply with these 40 liters? Line 9 shows that the Ari/Vera duo made estimates of the water consumed by themselves in some day-to-day activities, which led to the result that a person consumes, on average, a minimum daily value of 63 liters, which exceeds the 40 liters suggested by the WHO.

The question presented by Vera, in one of her logbooks, reaffirms that the pair interpreted the questions presented in the videoproblem as a list of questions to be answered, one by one. This production of meanings favored a game of questions and answers to permeate the modeling of these participants.

*I have [...] questions regarding this activity. [...] — IS IT FOR US TO ANSWER THROUGH A VIDEO HOW MUCH WE SPEND ON WATER IN OUR SHOWER EVERY 10 MINUTES? IF THE WATER WE USE IS IN COMPLIANCE WITH THE WHO OF 40 LITERS PER DAY? OR CAN WE PRODUCE A VIDEO WITH THE THEME CONSCIOUS CONSUMPTION OF WATER WITH A FREE THEME? (Vera — Writing from the logbook)*

Vera's question points to a dilemma between the duo's intentions to work on the issue of free water consumption and the need to answer the questions in the video. Vera mentioned question (2) and (3), respectively, when asking, first, if it is for the pair to answer through a video how much water they spend in their showers every 10 minutes and, then, if the water they spend complies with the WHO of 40 liters per day. The answer given by Vera, in one of the interviews, reinforces this dilemma.

*Vera: We are still very attached to the environmental issue. [...] For example, Ari, he talked about showing the resort and the water supply in his region. Here in Ribeirão [Referring to the city of Ribeirão Preto, São Paulo, Brazil], we use water from the Guarani Aquifer and, as there is also a source, there is a lot of talk about the issue of capitation and conscious consumption, because here the capitation of water is*

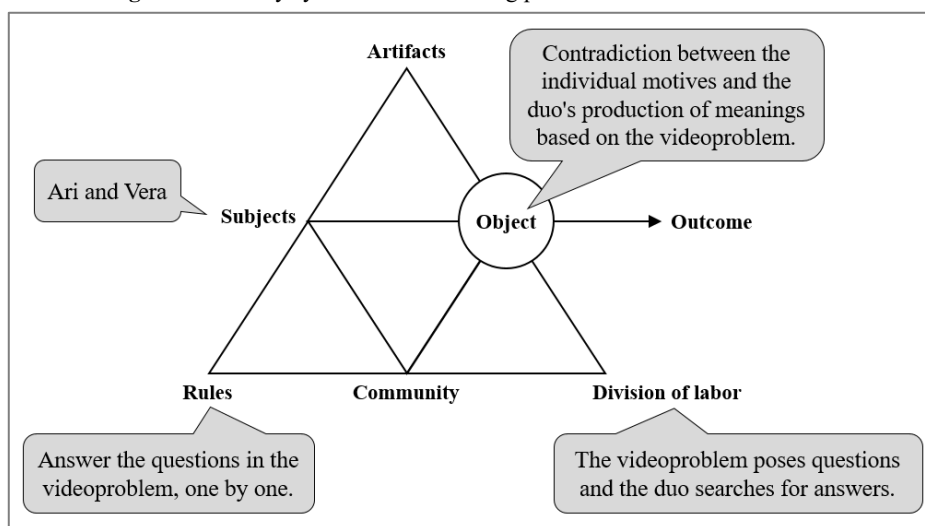
<sup>3</sup> These data are attributed to the WHO and were obtained from a document from the Ministry of the Environment (Brazil).

*less and less. [...]Anyway, this is information that we want to highlight in our video, in addition to the answer, that's why I asked there on Drive, in the logbook [Referring to the logbook, which the course students filled in on Google Drive], if it was merely for us to answer the question, or if we could be talking a little more regarding the importance of this video, and all that. (Vera — Interview via WhatsApp — audio transcript)*

Vera's response reveals that the duo's intentions are to address the topic related to water consumption, considering situations related to the social contexts of each one. However, the way they gave meaning to the videoproblem leads to simply answering the questions presented.

Considering Ari and Vera's modelling practices as an activity system (Figure 2), the aforementioned dilemma can be interpreted as a contradiction between the duo's motives, related to expanding their actions towards new problematizations that turn to environmental issues concerning to their social contexts, and to the way they understood the purpose of the videoproblem, which refers to answering the questions as if it were a questionnaire. The object of this system now includes, on the one hand, the duo's motives for addressing environmental issues more broadly and, on the other hand, the tacit obligation to answer the questions of the videoproblem, the latter being an unfolding of the production of meanings by these participants, through the digital text of this medium. In short, there is a conflict between problematization and the game of questions and answers, which reflects the dilemma between the motives of the pair and the way they gave meaning to the videoproblem. This contradiction gave rise to an implicit rule in this system to answer the video questions one by one, and a division of labor through which the videoproblem poses questions and the double search for answers.

**Figura 2:** Activity system of the modeling practices of the duo Ari and Vera



**Source:** Elaboration of the authors from the research data

In terms of the perspectives of modelling and knowledge that we assume in this research, the presence of this game of questions and answers in the duo's actions can be seen as a degeneration of the modelling process. The way in which the rules and division of work were established in the activity systems under study configure fragments of a pedagogical practice in which the digital video media takes on the teaching role of posing questions and students limit themselves to answering what is proposed to them. It is as if the banking education questioned by Freire (1987) was present in the duo's modeling practices, with the videoproblem taking on the teaching role of proposing questions, and the students/teachers taking on the role of passively answering them.

On the other hand, we add that the presence of the game of questions and answers permeated, but did not reduce to this game, the duo's process of modelling. Issues related to conscious water consumption were raised and addressed, through estimates and comparisons, leading to attitudes that corroborate conscious water consumption. In fact, as can be seen in Canedo Junior (2021), the duo ends their videoresponse by proposing a problem, which leads to a reflection on equity related to the distribution of this vital good, by comparing the amount of water that a person uses per day with that needed to fill a swimming pool.

## 5 The domestication of a multimodal perspective

An analysis of the modelling process of the duo Ari/Vera, from a perspective of Social Semiotics (Jewitt, 2005; Kress, 2009; Bezemer & Jewitt, 2010; Jewitt & Kress, 2010), allows us to deepen understandings about the influences of the video digital media in the duo's production of meanings, more precisely in the occurrence of the mentioned game of questions and answers. This implies considering this production of meanings considering not only what is communicated, but also the modes involved in this communication and, in line with the objectives of this investigation, seeking to understand how these meanings influence actions within the scope of the activity systems under study.

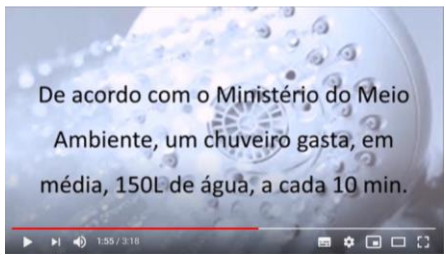
Let's take the answer given by Ari in one of the interviews, as a starting point for this discussion.


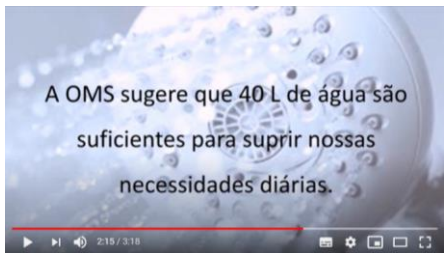
*Ari: The way in which that video was recorded [...] makes some questions clear. [...] I think it influences in that sense. [...] As much as we give an environmental direction, the very structure in which the video was recorded led us to answer certain questions that are fixed, punctual. (Ari — Interview via WhatsApp — audio transcript)*

Ari shows, first, that the way the videoproblem was produced highlights the aforementioned questions that gave rise to the game of questions and answers. This became clear when he stated that: “the way that video was recorded [...] makes some issues clear”. Further on, he mentions how the structure of that video directed them to answer those questions, one by one, when he says: “the very structure in which the video was recorded led us to answer certain questions that are fixed, punctual”.

In view of Ari's considerations, we will direct a multimodal view at the structure of the videoproblem, more specifically, at the modes that make up the scenes of the excerpt (1min 45sec to 2min 27sec) in which the referred questions are presented. Frame 2 seeks to portray this multimodality, by displaying, side by side, the images of the scenes and the transcription referring to them.

**Frame 2:** Excerpt from the videoproblem ‘Water: for conscious consumption’ - 1min 45seg to 2min 27seg (images and transcription of talk).

	Images of the scenes	Transcription of talk
1		<p>According to the Ministry of the Environment, a shower consumes, on average, 150 liters every 10 minutes.</p>

	<p><b>Image translation (text):</b> According to the Ministry of the Environment, a shower consumes, on average, 150 L of water every 10 minutes.</p>	
2	 <p><b>Image translation (text):</b> Are our measurements compatible with this average?</p>	Are our measurements compatible with this average?
3	 <p><b>Image translation (text):</b> And your shower, how much water do you use every 10 minutes?</p>	And your shower, how much do you spend every 10 minutes?
4	 <p><b>Image translation (text):</b> WHO suggests that 40 L of water are enough to meet our daily needs.</p>	The World Health Organization suggests that 40 liters of water are enough to meet our daily needs.
5	 <p><b>Image translation (text):</b> Does the water you use per day comply with these 40 L?</p>	Does the water you consume per day comply with these 40 liters?

Fonte: Research Data

Frame 2 shows that the communicative resources present in the modes of the scenes in which such questions are presented are reduced to the written and static text, accompanied by a narration that repeats, almost in its entirety, what is written. The considerations presented by Ari in the interview excerpt presented above, combined with the multimodal view that Frame

2 favors, suggest that the game of questions and answers may have been influenced by the way in which the modes were organized in the videoproblem scenes, in which the aforementioned questions are presented. This result is consistent with the assumptions of Multimodal Analysis, in the perspective assumed in this research, since Social Semiotics assumes that “different modes shape the meanings to be realized in mode-specific ways” (Bezemer & Jewitt, 2010, p. 183).

But what are the specificities of the modes present in the scenes in which the questions are exposed in the videoproblem? Orality, with the written and static text, constitute communicative resources that refer to the specific modes of the tradition of the classroom, in which the blackboard and chalk are media that have predominated for at least 200 years, as shown by Villarreal and Borba (2010). This reduction of the multimodal possibilities of digital video to static text combined with orality can be seen as a domestication of this media, which consists of an attempt to repeat practices and results specific to other media.

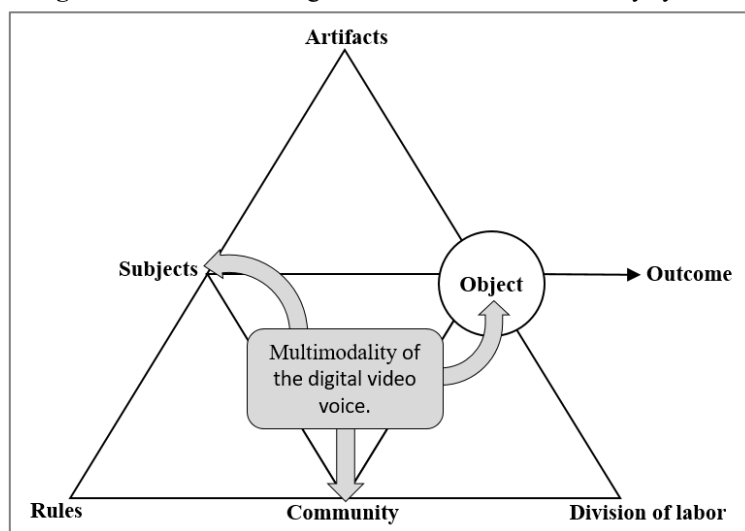
When discussing the notion of domestication, authors such as Borba and Penteado (2001) and Borba et al. (2014) consider, on the one hand, the underutilization of the potential of a media and, on the other, the attempt to reproduce with a new medium consecrated practices and results achieved with another, which predominated in another historical moment of knowledge production. The way in which the communicative resources were mobilized in the videoproblem scenes in which the questions are presented refers both to underutilization, by limiting the audiovisual resources that digital video allows to static text and orality, as well as to reproduction, by keeping resources in this media specific to blackboard and chalk.

In view of the above, we understand that the analysis of the empirical data of this investigation allows advancing the understanding of the notion of domestication when considering it from a multimodal point of view. From this perspective, domesticating a medium implies limiting the communicative resources it allows, promoting a domestication of its modes (underutilization of multimodalities). This domestication can be seen as an attempt to repeat in one medium the specific modes of another (multimodality reproduction). The reduction of the modes of the videoproblem to those specific to the blackboard and chalk refers to this domestication of multimodalities.

## 6 Emerging theorizing

The influence of the videoproblem on the production of meanings shaped the dynamics of the actions of the duo Ari and Vera and the structure of the activity system under study (Figure 3). The echoes of the multimodality of the voice of this media may have been decisive for the occurrence of the rule and the division of labor inherent in the game of questions and answers that permeated the actions of Ari and Vera, configuring the presence of this voice in the system's community. As previously discussed, the analysis of the subjects' modelling practices shows the presence of this voice in the object's configuration itself (see Figure 2), since this construct experienced a conflict between the pair's motives and the way they understood (they heard the voice of) the videoproblem. Furthermore, the influences of the multimodality of this voice in the production of meanings by Ari and Vera suggest its presence among the subjects of the activity system under analysis.

**Figura 3:** The voice of digital video media in the activity system.



**Fonte:** Elaboration of the authors from the research data.

The presence of media at vertices of the triangular structure of activity systems that, in the original scope of the Activity Theory, were restricted to humans was previously discussed by Souto (2013) and Souto and Borba (2018), when observing the presence of the voice of the internet in the community and that of Geogebra as an object in the activity systems considered by them. The present research seeks to advance this discussion by considering the action of the multimodalities of the digital video voice in these systems. The influence of these multimodalities in the production of meanings of the subjects and, consequently, in their actions, is in line with the possibility of the media assuming roles previously restricted to humans in the activity systems.

This possibility reinforces the conjecture raised by Souto and Borba (2018, p. 20) who, when observing the presence of internet media in vertices such as the community and, mainly, as a constitutive part of the object of the activity systems they observed, state that: “[...] a similar argument can be made to place the internet in the subject vertex, as well”. The results of Souto's research (2013) and the considerations presented by Souto and Borba (2018), regarding the participation of internet media in the systems they analyzed, in combination with observations of the presence of digital video media in the actions of the duo Ari and Vera, presented in this article, contribute to support the premise that the media have power of action (agency), as advocated by Borba (2021) and Borba et al. (2022). The view of knowledge as a product of the interrelationships in between humans and media, associated with the findings of these studies, corroborate the theoretical perspective through which it does not make sense to consider the vertices of the triangular structure of activity systems as positions that determine either humans, or artifacts, or object, but as multivocal instances populated by thinking collectives humans-with-media.

In addition, it is worth mentioning that the results presented in this article point to the presence of the multimodality of digital video as a constituent part of the agency of this medium. This presence of multimodal properties allows us to consider that the agency of the digital video media, observed in the present study, assumes a different status from that manifested by the internet media, as seen by Souto (2013) and Borba and Souto (2018). This difference in status in the power of action of the media refers to Borba (2021, p. 391), when he considers that: “Agency, therefore, should not be seen as binary, as either present or absent, but having different levels. I see this notion of agency as a ‘fuzzy’ one, as in fuzzy mathematics, in which



we may have degrees of agency”. In this perspective, it makes sense to say that the agency of the digital video media observed in the present study is in a degree that differs, qualitatively, from that assumed by the internet in the studies by Souto (2013) and Borba and Souto (2018). It is important to emphasize, however, that both the presence of multimodality in the media's power of action and the different degrees of possible agency are still incipient theoretical notions that require further studies.

## 7 Final considerations

In this article, we present an investigation that explored the potential of digital video in the development of modelling work, in a pedagogical practice in which a problem is proposed and answered with this medium, which was carried out within the scope of an online course aimed at the education of in-service teachers. More specifically, we seek to understand how video can shape modelling when the problem is proposed with this medium. This analysis was carried out in the light of the vision of knowledge underlying the Human-with-Media construct and the Activity Theory.

The investigation took on a qualitative approach, so that the data, produced in the online research environment itself, were analyzed inductively, focusing more on the processes than on the results. This analysis was carried out in the light of the vision of knowledge underlying the Human-with-Media construct and the Activity Theory. In addition, principles of Social Semiotics were mobilized, such as the mode notion, in order to highlight the participation of digital videos in the modeling practices under study, based on the multimodal potential of this media.

The results obtained point to a tendency to interpret the proposed problem with digital video (videoproblem) — more specifically the questions that this media presents, with the intention of provoking reflections — as if it were a questionnaire to be fully answered, in which the modelling practices degenerate into a game of questions and answers. A multimodal look at the filmic text of the videoproblem, combined with the analysis of the subjects' production of meanings, suggests that this trend is influenced by a limitation of the multimodalities that the video makes possible, since, in the scenes in which the questions appear, the communicative resources are reduced to the static text accompanied by orality that repeats it in its entirety.

From the perspective of knowledge assumed, this limitation of the multimodal potential of digital video to orality and static text configures a domestication of this media, as it consists of an underutilization of its audiovisual resources, in addition to referring to a reproduction of the modes that characterize the blackboard and the chalk, media that mark the tradition of school Mathematics Education. We add that this result, in addition to allowing a multimodal approach to the notion of domestication, brings contributions to the design of future pedagogical practices in which digital video is present, in order to avoid limiting its multimodal potential.

We understand that the present research, when analyzing the empirical data from the lens of the Human-with-Media construct, in combination with analytical principles of Activity Theory and Social Semiotics, reveals analytical possibilities that can be explored in future research. It consists of a step forward in GPIMEM's investigative effort, in the sense of understanding the roles played by the media in the dynamics of these systems, which converges to the understanding of the triangular structure as an instance populated by collective human-with-media, in all its vertices, which reinforces the argument that not only humans, but also the media, have power of action (agency).

We reiterate that this research advances understandings about the modeling-with-technologies dialectic, which has been the subject of research and educational actions

throughout the three decades of GPIMEM's history. When returning to our research question, we see that digital video has the potential to bring to modelling the multimodal potential of a media that is becoming increasingly present in the most diverse social contexts, including educational ones. The participation of digital video in proposing the problem brings possibilities that are neither better nor worse, but qualitatively different from those offered by media such as, for example, pencil and paper. However, we emphasize the importance of not limiting — or domesticating — the multimodal potential of the videoproblem to those that pencil, paper, blackboard, textbook, among others that occupy the school tradition already offer us. The multimodal domestication of video can “stop” multivocal, dialogic and educational transformations, not favoring the problematizing and emancipating education defended by Paulo Freire.

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