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Actor-network theory and mathematics education: materializing the concept of inscription based on mathematical knowledge for teaching

La teoría del actor-red y la educación matemática: traduciendo inscripciones asociadas con conocimientos matemáticos para la enseñanza

Théorie des acteurs-réseau et enseignement des mathématiques : traduire des inscriptions associées à des connaissances mathématiques pour l'enseignement

Teoria ator-rede e educação matemática: traduzindo inscrições associadas ao conhecimento matemático para o ensino

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Abstract

This theoretical piece aims to analyze how actor-network theory (ANT) can contribute to research in the field of mathematics education by harnessing the concept of inscription through mathematical knowledge for teaching (MKT). We are guided by this theory, which was devised by Bruno Latour and his collaborators to discuss relationships between humans and non-humans when it comes to MKT. This term has been discussed to permeate how a teacher uses mathematics in teaching and how differently they act compared to how other professionals use it in their tasks. To initiate the discussion, we mapped the relations between ANT and MKT to highlight the concept of inscription. The conclusion is that humans and non-humans can develop inscription procedures and create parameters that allow the ordering of different mathematical relationships, which aim to stabilize sociotechnical networks and generate an ever-bigger number of heterogeneous allies and aggregates.

Keywords: Mathematics teaching, Inscription procedure, Associations, Teachers, Sociotechnical network.

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Resumen

Este trabajo teórico tiene el objetivo de analizar como la teoría del actor-red (TAR) puede contribuir a las investigaciones en el campo de la educación matemática, conjeturando el concepto de inscripción a través del conocimiento matemático para la enseñanza (CME). Tomamos como referencia esa teoría, desarrollada por Bruno Latour y sus colaboradores a fin de discutir la relación entre los humanos y los no-humanos por el CME, un término que ha sido debatido para orientar la manera por la que un profesor usa las matemáticas en la enseñanza y se diferencia de la manera por la que otros profesionales las usan en sus respectivas tareas. Para promover esa discusión, identificamos las asociaciones entre la TAR y el CME a fin de evidenciar el concepto de inscripción. Concluimos que tanto los humanos como los no-humanos pueden desarrollar procedimientos de inscripción, crear parámetros que permitan ordenar diferentes relaciones matemáticas, que tienen el objeto de estabilizar las redes sociotécnicas y generar un número cada vez mayor de agregados y aliados heterogéneos.

Palabras clave: Enseñanza de las matemáticas, Procedimiento de inscripción, Asociaciones, Profesores, Red sociotécnica.

Résumé

Cet essai théorique vise à analyser comment la théorie de l'acteur-réseau (TAR) peut contribuer à la recherche dans le domaine de l'enseignement des mathématiques, en conjecturant le concept d'inscription à travers les connaissances mathématiques pour l'enseignement (CME). Nous prenons cette théorie comme référence, développée par Bruno Latour et ses collaborateurs, dans le but de discuter de la relation entre humains et non-humains dans le biais CME, un terme qui a été débattu pour imprégner la façon dont un enseignant utilise les mathématiques dans l'enseignement et différencie de la façon dont d'autres professionnels l'utilisent dans leurs tâches respectives. Pour une telle discussion, nous avons cartographié les associations entre ANT et CME, en cherchant à mettre en évidence le concept d'inscription. Nous concluons que les humains et les non-humains peuvent développer des procédures d'inscription, créer des paramètres qui permettent d'ordonner différentes relations mathématiques, des relations qui visent à stabiliser les réseaux sociotechniques, et former un nombre croissant d'agrégats et d'alliés hétérogènes.

Mots-clés : enseignement des mathématiques, Procédure d'inscription, Les associations, Enseignants, Réseau sociotechnique.

Resumo

Este ensaio teórico visa analisar como a teoria ator-rede (TAR) pode contribuir para as pesquisas na área da educação matemática, conjecturando o conceito de inscrição por meio do conhecimento matemático para o ensino (CME). Tomamos como referência a TAR, desenvolvida por Bruno Latour e colaboradores, com o intuito de discutir a relação entre humanos e não humanos no viés do CME. Esse termo que vem sendo debatido para permear como um professor faz uso da matemática no ensino e se diferencia de como outros profissionais a utilizam em suas respectivas tarefas. Para tal discussão, mapeamos as associações entre a TAR e o CME, buscando evidenciar o conceito de inscrição. Concluímos que tanto os humanos quanto os não humanos podem desenvolver procedimentos de inscrição, criar parâmetros que permitam ordenar diferentes relações matemáticas, relações estas que visam à estabilização de redes sociotécnicas, e formar um número cada vez maior de agregados e aliados heterogêneos.

Palavras-chave: Ensino de matemática, Procedimento de inscrição, Associações, Professores, Rede sociotécnica.

Actor-network theory and mathematics education: materializing the concept of inscription based on mathematical knowledge for teaching

This article constitutes a theoretical essay[3] in which we analyze how the actor-network theory (ANT) can contribute to research in mathematics education, conjecturing the concept of inscription associated with mathematical knowledge (MK). Ball, Thames, and Phelps (2008) propose a theoretical model to map the mathematical knowledge necessary to solve tasks in *mathematics education practices*. For the authors, practice requires knowledge that intertwines aspects of teaching-learning[4] with the content. However, inspired by cognitivist theories, principles proposed in the MKT focus only on the subjects. For this study, inspired by a post-human perspective, we will use ANT to confront some arguments and show that objects also act. From this perspective, it is imperative to examine practices and what is associated with them through the redefinition of the social aspect, returning to its roots and enabling the tracking of new associations. This is possible through inscription games resulting from practice, crossing the materialization of knowledge production in terms of stabilization and socialization.

From this perspective, we understand that the concept of inscription serves to materialize something studied (e.g., graphs, maps, photographs, diagrams, tables, documents, software, codes, rules, standards, laws) and implemented through different types of resources (Latour; Woolgar, 1997). Inscription is a semiotic-material process whose social production traverses language itself. In it, humans and non-humans symbolically produce "other" ("new") actors[5] in networks and associations in and with the material world –intermediated or mediated by other networks of actors, such as history, subjectivity, culture, technology, and society. For Latour (2012), sociotechnical networks are performed by associations between the various *actants*.[6] They are defined by their actions and characterized by their connections, convergences, and divergences, promoting transformations, deviations, and continuities. For the ANT, the association is a relationship between actions promoted by distinct *actants* who temporarily come together when acting (Latour, 2012). Traditionally, from a classical anthropological and sociological perspective, the former is linked to culture and the latter to

[3] A theoretical essay is based on logical, rigorous, coherent, and critical argumentation on a given topic so that dialogue with the literature on the object of study supports the construction of this argument (Barbosa, 2018).
[4] We write teaching-learning with a hyphen because we understand it is a continuous process.
[5] According to Latour (2012), *an agent* can make other agents do something, behave in an unforeseen way, and behave on their own terms: the *one who makes doing.*
6 For Latour (2012), the *actant* is everything that promotes an action, produces movement and difference, mediates, transforms, translates, distorts, or modifies the meaning of what it supposedly carries. The actant is analyzed with the same degree of importance, regardless of whether it is human or non-human.

nature. Trying to bring us closer to the context of the COVID-19 pandemic, we present the following example and invite you, the reader, to connect with the following campaign.

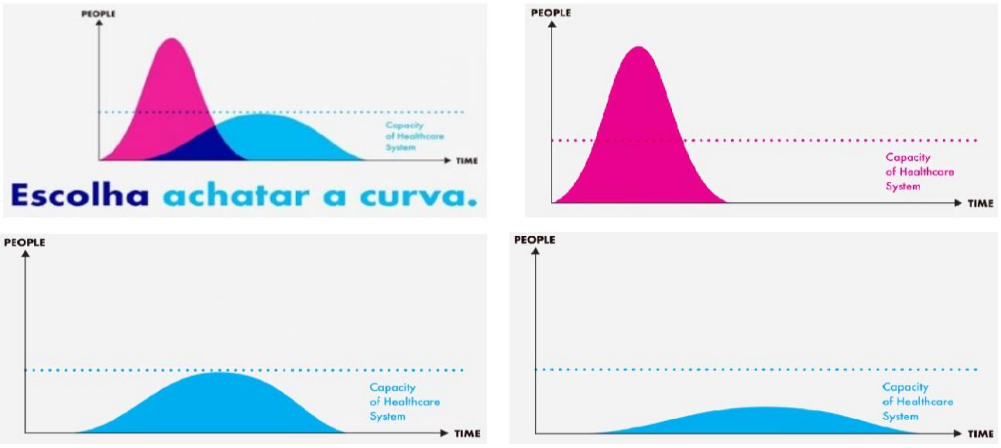


Figure 1

Choose to flatten the curve (Taken from Covid19Município, 2020).

The expression "flatten the curve" has become common when discussing the COVID-19 pandemic. In this context, many humans have been affected by the Sars-CoV-2 virus. It was considered highly contagious, and as it spread, its upward curve quickly overwhelmed the healthcare system. In other words, hospitals did not accommodate many infected people simultaneously. Mathematically speaking, graphs with statistical data to indicate the projection of the contamination rate represented in the domains (time) and in the images (contaminated people) were mobilized. Therefore, this campaign performed in Berlin by art director Luter Filho became global, seeking to explain the importance of preventing mass contamination (many people infected in a short interval) through measures such as social isolation. In this way, people would be contaminated at different times, and the health system would not be overloaded, guaranteeing the availability of more spaces and beds in intensive care units (ICU) in hospitals if necessary. This example narrates the materialization of facts through two curve options on the graph: above the dotted line, outside the limits of the health system (hospital overload), or below the dotted line, within the limits (available beds).

This materialization constitutes an inscription procedure[7]. According to the theoretical bases proposed by Lemos (2013), an inscription is a form of transformation developed due to writing on different elements such as a machine, a law, a map, or a graph, among others, which

7 In this research, we use the term *inscription procedure* to highlight the agency of non-humans in the constitution of the sociotechnical network and explain the actions developed in the study.

may be human or not. Considering inscription as a form of agency of non-humans to transform, explain, or materialize an action, the dominant idea that humans control actions and are above the plane of nature, social formations, and collectives is dismissed (Latour, 2019). The ANT, by bringing non-humans to the center of the debate and considering them as *actants*, advocating both an empirical and theoretical approach, is used in different simple and complex and micro or macro contexts in the national and international scenario (Cavalcante et al., 2017).

Analyzing national research, we can find the contributions of the ANT in different areas of knowledge: administration (Camillis et al., 2016; Camillis et al., 2020; Carreto & Domenico, 2015), communication (Leal & Vargas, 2011; Salgado, 2018), art (Figueiredo & Almeida, 2018; Praude, 2015), psychology (Melo, 2006), architecture (Sbarra, 2021), anthropology (Sá et al., 2011), education (Gomes & Thomé, 2020; Lima et al., 2018; Oliveira & Porto, 2016; Santos, 2016; Silva et al., 2020) and health (Bastos et al., 2021; Cavalcante et al., 2017; Malvezzi & Nascimento, 2020). In health, specifically, the Caixa Preta Research Group of the Multicampi School of Medical Sciences of the Federal University of Rio Grande do Norte (EMCM/UFRN) develops actions, such as courses and colloquia entitled Bruno Latour no Sertão, to promote reflections on studies linked to the ANT and their contributions to health and different areas of knowledge.

Currently, researchers have associated the ANT constructs to the education field as a relevant theoretical-methodological framework (Gomes & Thomé, 2020; Silva et al., 2020; Lima, 2022); however, education research that dialogues with the ANT is scarce, highlighting a field to be investigated (Schlieck & Borges, 2018). In the area of mathematics education, we found few works at the national level; we highlight one in ethnomathematics (Oliveira & Souza, 2019), one in the history of mathematics (Pinheiro & Rios, 2010), and three in teacher education (Carvalho, 2007; Klaus et al., 2021; Santana, 2023). Santana (2023), for example, has associated her studies with ANT from a post-human perspective, focusing on the relationships between a subject and an object. In the research mentioned earlier, the author describes and maps the associations that involve a heterogeneity of human and non-human elements in the context of a continuing education program (Continuing FormAction) in mathematical modeling in the remote mode. As a contribution, the author argues that associations can serve as guiding elements for modeling practices in remote mode due to the nature of groups, objects, actions, and facts.

At the international level, we also find research linking the ANT and mathematics education, among which we highlight one related to continuing teacher education (Unsworth & Tummons, 2020) and one related to practical classes mediated by digital technologies (White,

2019). Although all these publications in different areas of knowledge address essential themes to which Bruno Latour's work can contribute, many do not cover what Latour considers to be the heart of his contribution: the possibility of looking at nature, objects, and things symmetrical to humans. Perhaps the biggest challenge faced by researchers who use ANT contributions is examining the *actants* and how they connect and promote hybrid associations to ensure the continuity of the sociotechnical network. Inspired by Latour (2012), we understand that association is a relationship between actions promoted by distinct *actants* that come together temporarily when they act. The study of associations is dedicated to following the *actants*, those who act and who, in action, lead several others, whether human or not, to act.

Lima et al. (2018) noted that the more specific and technical the themes of journals on education and teaching, the less likely it is to find articles that cite the work of Bruno Latour and ANT contributions. This clearly reveals that education, especially mathematics education, has not yet reached the heart of Latour's work. Given this, we will seek, with this essay, to present some contributions to research in mathematics education, aiming to inspire other researchers to link the ANT to their investigations.

Traces left by the actor-network theory

Dear reader, ANT began to be formed in France in the late 1970s and early 1980s. This current has as precursors three sociologists associated with the Center for Sociology of Innovation in Paris: Bruno Latour (1947-2022), Michel Callon, and John Law (Cavalcante et al., 2017). The ANT, also known as the sociology of associations, seeks to associate science, technology, and society, joining the science studies (STS). Monteiro et al. (2020) say this theory investigates the dynamics of knowledge production by equating humans and non-humans in a flat horizontal relationship. In other words, the main attribution is not given only to the human, just as objects do not only assume the intermediary role,[8] as both are considered *actants* and protagonists.

Taking Silva et al. (2020) as a reference, we emphasize that humans are not completely in control of practices but rely on the superposition that the objects -things- also participate and contribute to their formation. Given this, the ANT seeks to combine human and non-human actions without weighing in on either side. Thus, new approaches are explored, and the concept of *actant* is established abstractly to everyone and everything associated with something or

8 Intermediaries are only responsible for transportation without changing what they transport. They do nothing but convey and displace traits aimed at nature and society without managing any action (Latour, 2012).

someone to form a network (Latour, 2012). In this sense, the *actants* must not necessarily be limited to humans. However, they must also cover all entities that can mediate an association and promote the continuity of the sociotechnical network.

In the ANT, knowledge is not produced through a privileged scientific method or a specific *actant* but through a social product or effect of a network of associations. Hence, Latour (2012) opposes analysts of the sociology of the social (traditional sociology) understanding that sociology can be redefined not as a science of the social but as a search for associations. In this case, redefining and ordering the social must be left to the *actants*, not social representatives.

The sociology of associations does not present answers but rather uncertainties regarding the nature of groups, actions, things, facts, and how to know and write about the social. Faced with such uncertainties, Latour (2012) points out that there are no groups; instead, there is the formation of groups. To justify this conception, we will seek to raise the topic of the best moment, the one being best discussed, that is, the one at its peak. How about reading a newspaper? Undoubtedly, we have a starting point that is as good as any.


FOLHA DE S.PAULO

CORONAVÍRUS

Necessidade de máscara contra Covid independe de vacinação, diz OMS

Ao comentar decisão dos EUA, que liberou imunizados de usar equipamento, entidade diz que ponto-chave é controlar transmissão comunitária

Figure 2.

Newspaper headline recommending the use of masks against COVID-19 (Adapted from Pinto, 2021).

The topic addressed in the newspaper headline above is controversial and can promote disagreements, tensions, and conflicts among the most diverse groups. According to Latour (2012), when people disagree on an issue, they mobilize allies to form groups. In this case, we may have people with favorable or contrary opinions and undecided people. These groups are temporary because new controversies[9] may soon emerge and be modified; some components leave, and others enter. In forming these groups, Latour (2012) also suggests the agency of non-humans, as they interfere and integrate them. For example, the COVID-19 virus, a non-human

[9] We emphasize that the focus of this study was not on the concept of controversy; therefore, we did not expand on this concept throughout the text.

virus that killed people, forced companies and schools to close, changed the flow of the sociotechnical network, and promoted social isolation. Furthermore, it mobilized other non-humans, such as masks and alcohol gel, which became part of our daily lives.

For Latour (2012), group formation leaves many more traces in its wake than the groups and connections already established, which, by definition, must remain silent and invisible. Group formation, in turn, if visible, is being constituted and will generate new and interesting data. In this sense, Cavalcante et al. (2017) address that the ANT makes sociology less anthropocentric, pointing out non-humans as *actants* full of rights, which help to understand humans and society. For the authors, the ANT can contribute to understanding innovations and their influence on the community. It comes from associations between *actants* and follows their steps in the sociotechnical network without dividing their lives, without making isolated cuts, continuing what happens and what is interconnected, interfering, and suffering interference.

Given this, Latour (2012) demands action. When we act, who acts the most? How many agents show up? Although we never know who or what leads us to act, actions are responsible for an achievement. If it is invisible, does not promote transformation, does not make a difference, does not leave traces, or is part of a story, it does not constitute an action. Therefore, if inequalities are generated, other *non-human actants* come into play and manage the continuity and group formation in the sociotechnical network. Thus, as a matter of fact and not interest, non-human entities must play a more significant role (Latour, 2012). Returning to Figure 1 ("Choose to flatten the curve"), a matter-of-fact construction would not be possible if non-humans (statistics, graphics, computer programs, viruses, hospitals) were not mobilized. Finally, it is necessary to write risk reports. A good report is a narrative, description, or proposition in which all *actants* do something and do not just observe, without promoting or transporting effects, without transforming and performing differences (Latour, 2012).

There is no society from which to start for the sociology of associations. If mapping is not immediate, if the party is not held today, if the newspaper is not printed now, the researcher could simply lose the grouping, as it is not a building waiting for restoration but a movement that needs to continue. It is necessary to follow the flow of the sociotechnical network; therefore, social aggregates should not consist solely of human ties (Latour, 2005; 2012). To understand the diversity of actions in the world, the ANT turns to the search for "associations," bringing them as synonymous with links and connections. The sociology of associations is responsible for following the *actants*, those who act and, in action, affect several others. The ANT treats action in a heterogeneous, collective, and hybrid way, carried out by several *actants*. According to Salgado (2018), when regrouping the social and following the *actants* while

acting, they recognize the instability of the social aspect and demarcate the pragmatic dimension of the sociological approach proposed by the ANT. Given the conceptual bases described in the sociology of associations, it is possible to understand that an academic text written within the parameters of the ANT needs to function as a laboratory where the most diverse *actants* can speak.

Interlocution between references of the actor-network theory and mathematical knowledge

We will begin this section by tracing the associations for understanding the term mathematical knowledge. Analytically, we will rely on the ANT to investigate how specific entities associate with others, constituting networks. It may seem ambitious, but we will argue that when focusing on mathematical knowledge, we seek associations between entities, which form heterogeneous collectives, focusing on the mathematics to teach. We follow the traces left by Shulman (1987); there is a variability of typologies linked to professional knowledge in which the teacher is the protagonist, disregarding the agency of objects. In the network flow, in the same direction, we found studies circulating in the area under different denominations, such as Mathematical Knowledge for Teaching (MKT) or *Conhecimento Matemático para o Ensino* (CME), Mathematics Teacher's Specialized Knowledge (MTSK) or *Conhecimento Especializado do Professor de Matemática* (CEPM) and Mathematics for Teaching (MfT) or *Matemática para o Ensino* (MpE), given their wide dissemination (Hoover; Mosvold; Ball; Lai, 2016).

From this perspective, Ball and collaborators differentiate *common content knowledge* from *specialized content knowledge.* The first refers to mathematical knowledge and skills not used in teaching environments. In the second approach, these knowledge and skills are used specifically in teaching (Menduni-Bortoloti & Barbosa, 2017). For both, mathematics knowledge for teaching involves relevant knowledge in mathematics teaching (Ball et al., 2008; Nyikahadzoyi, 2015). Thus, they present a compartmentalized image of how the domains of content knowledge for teaching would occur (Figure 3).

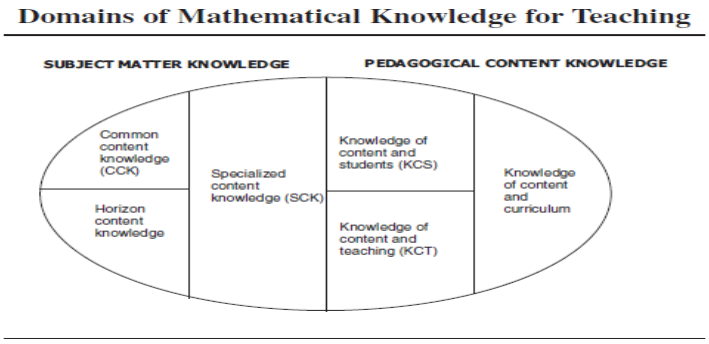


Figure 3.

Domains of content knowledge for teaching (Retrieved from Ball et al. (2008, p. 403).

Today, we can perceive the duality between the two types of knowledge proposed, as if both were mobilized in a compartmentalized way without links. This vision aligns with the terms proposed by the ANT, which seeks to associate nature and society, modern and non-modern, subjects and objects, to create and transform sociotechnical networks (Latour, 2012). From this perspective, common and specialized content knowledge can be indicated in association as a heterogeneous network contributing to the construction, transformation, and continuity of the MKT instead of being proposed separately.

By problematizing such dichotomies, in this section, we will seek to discuss the relationship between humans and non-humans considering the MKT, a concept that permeates the way a teacher uses mathematics in teaching, different from the way other professionals use it in their respective tasks (Coutinho, 2015; Davis, 2012; Santos, 2017). For this discussion, we mapped the associations between the ANT and the MKT, seeking to highlight the concept of inscription.

The concept of inscription refers to every type of transformation that seeks to materialize an entity. Inscriptions are always subject to superposition and combination; they are always mobile, enabling other transformations and connections while keeping intact some forms of associations (Latour & Woolgar, 1997). Given Latour and Woolgar's (1997) concept of inscription, we will seek to intertwine these study themes that are usually investigated separately.

Inspired by Latour (2019), we start with the MKT model, arguing that objects also act. As a theoretical model, it is linked to different ways of learning-teaching a mathematical concept, associating humans and non-humans in a symmetrical relationship that aims to materialize their forms of agency through a theoretical structure. We understand that a mathematical concept is a set of realizations associated with the word that designates it (Davis & Renert, 2014). Realizations are associations that appear and can be recognized as formal or

intuitive definitions, algorithms, analogies, algebraic symbols, applications, gestures, drawings, or manipulative objects (Davis & Renert, 2014).

We also emphasize that the MKT as a theoretical model is built around specific concepts. In this essay, we will not take a specific concept as an inscription parameter but present some examples to raise conjectures and reflections about what the ANT proposes. We also highlight that we analyzed four works: two focused on building a theoretical mathematical model for teaching the concept of proportionality and function, respectively (Menduni-Bortoloti, 2016; Santos, 2017); one on investigating the expansion of the knowledge base on teaching rational numbers (Rogeri, 2015); and another on investigating how the teacher interacts with digital technology to produce mathematical knowledge during classes (Bretscher, 2015). We used the research by Patrono and Ferreira (2021) as a basis for locating national research, as the authors present a survey of Brazilian research on mathematical knowledge for teaching, taking as a reference the Catalog of Theses and Dissertations of the Coordination of Improvement of Higher Education Personnel (Capes) and the Brazilian Digital Library of Theses and Dissertations (BDTD). The research cited takes studies with teachers (subjects), textbooks, and documents (objects) as objects of analysis. In our study, the models will be presented based on data from the study with teachers, as we will try to map the associations between humans and non-humans as an inscription procedure, arguing that objects also have agency.

After more than a decade of research on the topic, authors such as Ball et al. (2008) focused on the individual, while Davis (2012) focused on the dynamic, emerging, tacit, and constantly developing character linked to teaching. In those researchers' studies, we found no traces of objects that can act, such as mathematical concepts. Given this gap, we sought, according to the assumptions of the ANT, to promote associations, conjectures, and implications, not distinguishing between people and objects, as the social is performed as a function of associations. The main objective is to present the sociotechnical networks constituted at every moment, referring to the idea of alliances, bonds, connections, and mediations to form concepts (Latour, 2005, 2012). The concept of agency breaks with the dominant idea that humans control actions and are above other entities, social formations, and collectives. There is no denying the differences, but instead of treating the *actants* separately, it is possible to consider them according to their relationships (Latour, 2019). In this work, we sought to highlight the agency of objects in the constitution of the sociotechnical network.

Analyzing the work produced by Menduni-Bortoloti (2016), who sought to build mathematics for teaching the concept of proportionality based on literature, basic education

teachers, and textbooks, we can identify inscription devices and elements that enable the extension of the flow of the sociotechnical network through the relationship between humans and non-humans (Figure 4).

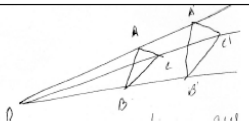
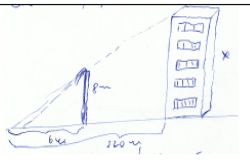
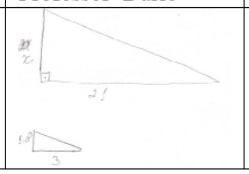
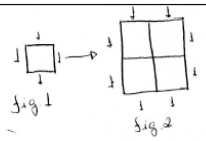
a) Realização do Professor Radival	b) Realização do Professor Noreslei	c) Realização do Professor Dario	d) Realização do Professor Eric
			
$\frac{2}{3} = \frac{1{,}5}{B'A'}$	$\frac{x}{120} = \frac{8}{6}$	$\frac{x}{1{,}8} = \frac{21}{3}$	$\left(\frac{P_1}{P_2}\right)^2 = \frac{A_1}{A_2}$

Figure 4.

Inscription procedure with the notion of proportionality communicated by different meta-rules (Retrieved from Menduni-Bortoloti, 2016, p. 73).

In Menduni-Bortoloti (2016), we saw that teachers contextualized different meta-rules to ensure that the concept of proportionality was characterized as equality between two ratios. Inspired by Latour and Woolgar (1997), we can see the use of inscription devices, with the materialization of the study through drawings, addressing the similarity of triangles in (a), (b), and (c), for example, constructed by teachers participating in the study. We observe that not only did the subject-teacher participate in the action, but also mobilized other *actants*, constituting a sociotechnical network.

This network could still have been expanded, mobilizing objects such as the *software GeoGebra* for construction, expansion, a change of perspective, and comparison between present quantities. This software could promote a better understanding of the notion of proportionality between quantities and between perimeter and area, mobilized in drawing *d*. Furthermore, the network could still be built on electronic devices, such as tablets or computers, when downloading software or using it online, which could facilitate sharing with other human and non-human elements, expanding the flow of the sociotechnical network. In this sense, the agency of non-humans is a combination to stabilize a circulation movement that can be transported to other places and make inscription possible (Cardoso & Hirata, 2017).

Such inscription procedures create parameters that allow, on the one hand, ordering different mathematical relations in a single inscription (formalization of the concept of proportion). Our understanding is that in all drawings, the inscriptions thus produced compose the same procedure in the constant construction of the concept. Thus, the centrality of inscription procedures establishes power relations to stabilize sociotechnical networks, forming

an increasing number of heterogeneous aggregates and allies (Latour & Woolgar, 1997). We will try to expand this discussion later.

Analyzing the constitution of the drawings as inscription procedures, we can still verify the mobilization of non-humans present in both. These range from the triangles to the post (the shadow of the post), the building (the shadow of the building), and the window. This movement highlights Latour's (2012) third source of uncertainty and shows the agency capacity of non-humans. Those *actants* affected teachers and affect each other to promote mobilizations for the construction of the MKT of proportionality. Reflecting on the inscription procedures, these *actants* can behave like something hot, under construction, to capture the movement of the emergence of the new object, since they can be studied from the perspective of humans' and non-humans' bonds over time (Latour, 2005). In this sense, both *the common content knowledge and the specialized content* knowledge can be mobilized.

Rogeri (2015) investigated the expansion of the knowledge base for teaching rational numbers based on theoretical foundations and curriculum guidelines, a systematic literature review, and work with a group of teachers working in an elementary school –final years. Observing the activities developed with teachers, we can identify inscription procedures (Figure 5).

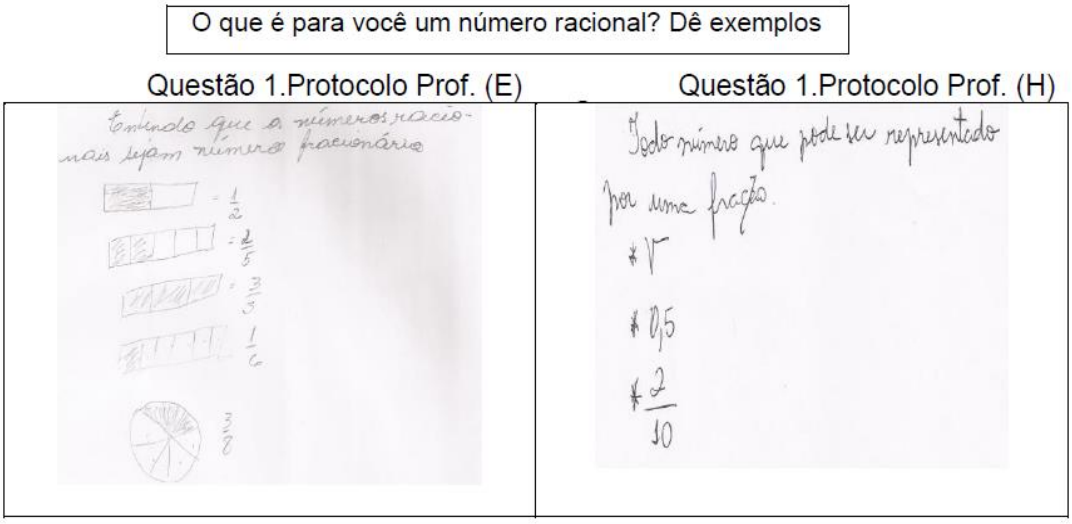


Figure 5.

Inscription procedure through performed examples (Retrieved from Rogeri, 2015, p. 132-133).

The construction of the explanatory text, the symbols used, and the pictorial representation evidence an inscription procedure, seeking to materialize possibilities entwined with the statement. Cardoso and Hirata (2017) state that inscriptions are shown based on

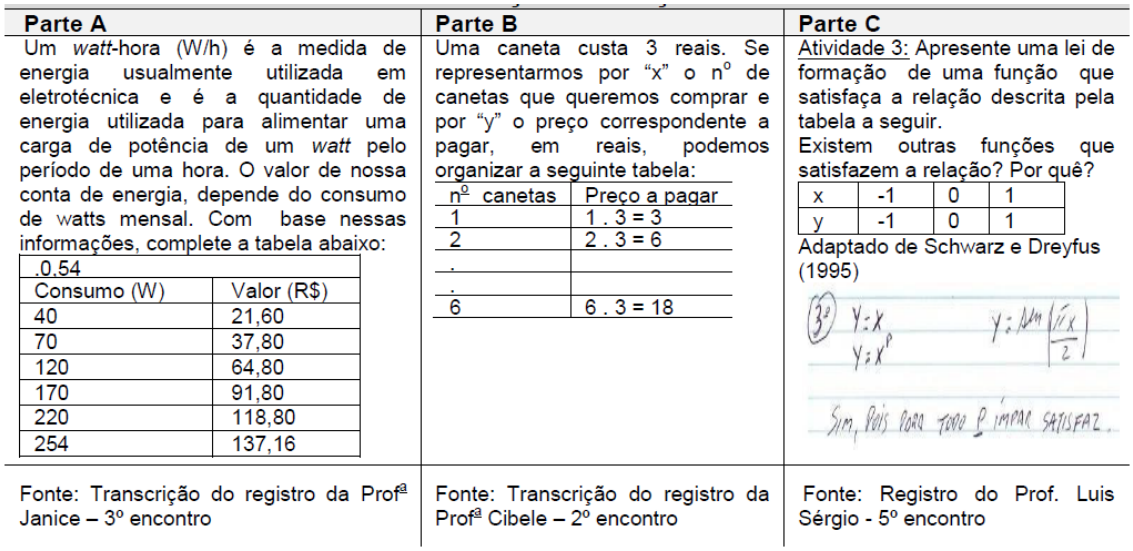
ethnographic examples, performed as strategies, networks, and devices,[10] whether due to the knowledge they produce, the goals and technologies they implement, or the categories they create and transform into norms.

We observed that, in addition to the identification of rational numbers being placed as a synonym for fractions, the representation of examples redefines the collective through the association with the part-whole (continuous magnitude), mobilized by pictorial and numerical representations. Inscriptions are always subject to transformation, superposition, and combinations, enabling connections, associations, and transformations of hybrid agents (Latour & Woolgar, 1997).

Analyzing how to materialize the reflection on rational numbers mentioned with the use of the radical, square root symbol ($\sqrt{}$), we can conjecture that the momentary thought was to press this key on a calculator; for example, the inscription performed would reveal a decimal number on the device's display, which would be a rational number, without taking into account the possibility of the device inscribing an irrational number. As Rogeri (2015) shows, non-humans (pictorial, symbolic, and numerical representation) act as an inscription procedure, affecting the construction of the concept of rational numbers. Latour (2012) affirms that scientists are troubled by issues relating to identity, participation, and the collective, among others. This leads us to bring non-humans (inscription procedure) to the center of the debate as *actants* that help us understand humans even more (teachers). And follow the *actants*, in this case, is to follow them in their intertwining with things, as they also act, as they can authorize, allow, provide, encourage, suggest, influence, block, hinder, etc. Pictorial representations, for example, facilitate the visualization of the divided whole and the part considered, and this can be performed manually or through digital technologies, such as *GeoGebra*. Those *actants* influence the actions of others, with the possibility of promoting animations, enlargement, reduction, change of perspective, and generalization, among others. In this sense, graphs, tables, numbers, drawings, and representations acquire argument value, and whoever provides such materials for constructing the argument is called an *inscriber* (Latour & Woolgar, 1997).

Santos (2017) constructed a theoretical mathematics model for teaching the concept of function based on a systematic literature review, achievements in mathematics textbooks, and a collective study with teachers in basic education. Observing the activities developed with teachers, we can identify inscription procedures (Figure 6).

10 In this study, we call devices all forms of representation used to explain something, through drawings, representations, constructions, technologies, etc.



Parte A

Um *watt*-hora (W/h) é a medida de energia usualmente utilizada em eletrotécnica e é a quantidade de energia utilizada para alimentar uma carga de potência de um *watt* pelo período de uma hora. O valor de nossa conta de energia, depende do consumo de watts mensal. Com base nessas informações, complete a tabela abaixo:

.0,54

Consumo (W)	Valor (R$)
40	21,60
70	37,80
120	64,80
170	91,80
220	118,80
254	137,16

Fonte: Transcrição do registro da Profª Janice – 3º encontro

Parte B

Uma caneta custa 3 reais. Se representarmos por "x" o nº de canetas que queremos comprar e por "y" o preço correspondente a pagar, em reais, podemos organizar a seguinte tabela:

nº canetas	Preço a pagar
1	1 . 3 = 3
2	2 . 3 = 6
.	
.	
6	6 . 3 = 18

Fonte: Transcrição do registro da Profª Cibele – 2º encontro

Parte C

Atividade 3: Apresente uma lei de formação de uma função que satisfaça a relação descrita pela tabela a seguir.
Existem outras funções que satisfazem a relação? Por quê?

x	-1	0	1
y	-1	0	1

Adaptado de Schwarz e Dreyfus (1995)

Fonte: Registro do Prof. Luis Sérgio - 5º encontro

Figure 6.

*Inscription procedures from a tabular overview (*Retrieved from Santos (2017, p. 116).

According to Latour and Woolgar (1997), materializations through charts and tables represent registration procedures, promoting data organization for results. For Santos (2017), the tabular panorama is characterized by the arrangement of input data and the organization of the corresponding output data in a functional relationship in rows or columns of a table.

In part A of the table (instrument), the functional relationship that associates monthly consumption in watts and the corresponding price to be paid on the electricity bill is materialized, considering R$ 0.54 as the price per watt. To materialize the amount to be paid at the end of a month, simply multiply the number of watts consumed at the constant price of a watt, highlighting the inscription procedure. The concept of inscribers reveals that the objects and phenomena of the study do not depend on the material that the researcher has in hand for analysis, but on the entire path taken that led the material to the researcher. These materials are "entirely constituted by the instruments used." (Latour & Woolgar, 1997, p. 61).

The instruments produce a visual set of inscriptions, and the researcher often functions as the spokesperson[11] in this procedure; he talks about what is on the device's display and thus becomes the author. These strategies used by the researcher give him credit, as these instruments speak in a language that must be translated by someone who masters it (Latour, 2012, 2019; Latour & Woolgar, 1997). Hence, "we believe these gifted instruments provide us

11 Melo (2006) affirms that acting as a spokesperson means assuming a translator's stance, a manufacturer of facts. This will be in the position of someone who speaks in place of something or someone who cannot or does not know how to speak.

with optical reading that our fragile human eyes cannot achieve, but, on the other hand, we combine with the machine eye what we have best, and inscribers lack: the intelligence to interpret" (Méllo, 2016, p. 370).

In the context above, we can notice non-humans acting. In the confection of the table, for example, we see the notion of dependence variations, considering that the price to be paid (dependent variable) varies because of consumption (independent variable), and this variation obeys a pattern, a law (multiplication of consumption by the fixed value of the watt). For Latour (2005), the *actants* must be described as they act so we understand the plurality of actions and *actants* entangled in situations configured as communication. Furthermore, Santos (2017) recognizes that the tabular panorama can favor the recognition and legitimization of the notion of variation, dependence, and regularity as the shapers of the network of interpretation of the concept of function. In this sense, it is possible to conjecture that, when organizing the information, the agents (table, variables, numerical values, lines, columns) contribute to identifying the constant of variation by dealing with other connections, for example, a generalization. At this moment, the action is assumed, prioritizing the heterogeneous nature of the ingredients that constitute the sociotechnical network (Latour, 2012).

Observing part B of the table, we identify the procedure for inscribing a functional relationship, demarcating the one-to-one connection that works as a criterion for inscribing the concept of function. In other words, each element of the input procedure (independent variables) is associated with a single element of the output procedure (dependent variables).

In turn, part C of the table presents a variety of functional relationships, as it is possible to follow the flow of the sociotechnical network and verify how the *actants* unfold (answers presented), satisfying data from the same tabular panorama. The notion of a "network" for the ANT does not constitute a framework through which *actants* circulate, but rather their circulation and the way of describing them. The network is a way of delineating the circulation of hybrid entities, which associate when they act (Latour, 2005; Salgado, 2018). Therefore, the materialities of tables are the agencies that make them exist. Thus, the agency proposed by the ANT dichotomizes the relationships between subjects and materialities without belittling the human but with an attentive look at the relationships established with objects and vice versa.

Bretscher (2015) showed how and to what extent the mathematical knowledge made available through a teacher's interaction with technology is distributed between the teacher and technology, theoretical studies, and an investigation with teachers. Once again, by analyzing the study carried out with teachers, we traced clues of inscription procedures in the interaction with technology to produce mathematical knowledge available in the classroom (Figure 7).

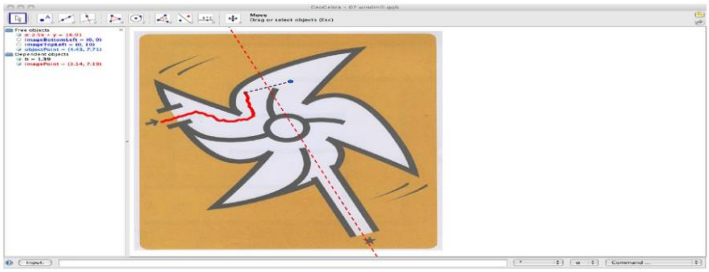


Figure 7.

Inscription procedure through the GeoGebra Labyrinth (Retrieved from Bretscher, 2015, p. 141).

Using coordinates and input algorithms for the agency with images and points in the Cartesian plane to address the issue of symmetry and reflection strains an inscription procedure and the preservation of its properties, seeking to materialize concepts and make them less abstract. The inscriptions are performed based on elements that best explain a fact, providing strategies, rules, texts, codes, images, and technologies to better visualize the knowledge produced (Cardoso & Hirata, 2017Latour & Woolgar, 1997).

According to Bretscher (2015), digital technologies link demands related to teachers' individual knowledge, transforming mathematics teaching. Thus, it is possible to note that the inscription procedures mobilized in *GeoGebra* for the performance of the labyrinth on symmetries and reflections give clues to a type of conception favorable to the use of technology, that is, to the use of mathematical affordances (action possibilities) of the software to affect student learning, which, without this employment, would not be so easy. For Latour and Woolgar (1997), the function of the inscription is to persuade readers. However, they only become completely convinced when all sources of cajoling mobilized seem to have already been exhausted.

We risk conjecturing that, without the connection between humans and digital technologies, it would be unlikely that geometric relations would be preserved under the "drag" of the blue and red points of the labyrinth, symmetrical to the line of reflection; in this case, the bisector of the line segments connecting corresponding points on the object and the image. When dragging the blue point (on the right of the symmetry axis), for example, it causes the red point (on the left of the symmetry axis) to move the same distance, preserving the length and direction parallel to the line of reflection and reversal of direction on the axis perpendicular to the line of reflection, i.e., when the blue point is dragged up or down, the red point moves in the same way, but when moving the blue point to the left or right, the red point moves in the opposite direction. The inscriptions are performed; they manage visibility in the occurrence of

actions and associate the materialization of concepts and properties of reflection through digital technologies. Facts often do not speak for themselves, requiring the presence of inscribers to materialize and/or interpret their theoretical characterization (Latour & Woolgar, 1997). In this case, the inscription promoted by the agency of non-humans guarantees the properties of reflection.

Implications for the field of study

In this section, we highlighted some implications for mathematics education from inscription devices. We revealed the nature of groups, actions, objects, and facts, risking ethnography of a risk report, as proposed by Latour (2012).

We used the conjecture that inscribers are responsible for consolidating research materials such as maps, diagrams, graphs, documents, concepts, etc. (Méllo, 2016). This fact can be associated with the formation of groups, as these include non-humans who interfere with and associate with other *actants* (Latour, 2012). According to Latour (2012), group formations are temporary, as sociotechnical networks can transform with the entry and exit of new components that support or disagree with a specific idea. In this sense, we can glimpse the construction of mathematical knowledge, for example. Associations that can be linked show inscription devices. “Through the notion of inscription, we seek to articulate research themes that are usually worked on separately” (Cardoso & Hirata, 2017, p. 77). Therefore, given what the ANT presupposes, we think that the *common content knowledge and specialized content knowledge* can be associated with and promote links in the construction of mathematical knowledge.

At the same time, these associations can be evidenced, through inscription procedures, with the nature of the actions. According to Latour (2012), an invisible action that does not generate transformation, that does not make a difference, that does not leave traces, and that does not enter a narrative is not an action. If we mention an action, we must present a narrative, making the observed features explicit. Therefore, mathematical knowledge acquired through graphs, tables, diagrams, numbers, and document analysis acquires argument value. Generally, those who provide an apparatus for materializing and elaborating the argument are the so-called inscribers (Latour & Woolgar, 1997). Therefore, the actions that can be enacted by the most

diverse *actants* during the construction of mathematical knowledge are part of a narrative and are responsible for some achievement. They can, therefore, affect many things. In this way, the *actants* in the sociotechnical network assume responsibility for the action (Latour, 2012).

Furthermore, the construction of mathematical knowledge through inscription procedures can be associated with the nature of objects since one action is taken over by other actions but is also marked by the realization that hierarchies, asymmetries, and inequalities exist. And, if inequalities are generated, other types of *actants* other than social factors come into play; that is, objects can also act, promote actions, and generate group formations. Hence, non-humans (ants, bees, maps, diagrams, software, documents, tables) begin to conceive a social world that is understood as a network of interactions. Often, the instrument (object) produces a visual set of inscriptions (Latour & Woolgar, 1997), and the researcher acts with the function of translating (spokesperson) what is on the instrument display. This strategy the researcher uses shows that the instrument speaks in a language that needs to be translated by someone who masters it (Méllo, 2016). In this sense, we understand that, in the construction of mathematical knowledge, these instruments provide us with optical reading that human eyes often cannot reach; however, we group in the machine's eyes the best we have that the inscribers (instruments) lack: the intelligence of interpretation.

Finally, we can associate the construction of mathematical knowledge through inscription procedures with the nature of facts, as the agency of non-humans (drawings, software, tables, fractions, symbols, graphs, reflections, among others) promoted the continuity of the sociotechnical network. For Latour (2012), the great advantage of visiting sites under construction is that they offer a vantage point to witness the liaison between human and non-human beings. In this sense, it is worth highlighting the centrality of "inscribers" in the constant measurement and comparison of different results and activities when creating tangible objectives and ways of achieving them that can be organized into goals (Cardoso & Hirata, 2017).

During the social constitution of scientific facts, the "construction of facts" was related to the real discourse of verification, i.e., facts are manufactured and are the root of scientific work. This expression reports the remarkable phenomenon of artificiality and reality walking

in step (Latour, 2012). In this way, it is possible to demonstrate the construction of facts during a mathematical knowledge construction laboratory, whether real or artificial. Thus, the inscription procedures that deal with and interfere with the construction of mathematical knowledge mobilize a series of variables that not only come to exist concretely but must be considered in the incessant search for greater effectiveness.

Final considerations

In this essay, we analyze how the ANT can contribute to research in mathematics education, conjecturing the concept of enrollment through the MKT. The notion of *inscription* was the theoretical intertwining point of this study, which made it possible to realize that non-humans mobilize the construction of mathematical knowledge, promoting the continuity of the sociotechnical network. However, few are considered protagonists. Therefore, the inscription is not only the vehicle through which objects gain expressiveness; it is also the mediation that builds the possibility of the occurrence of this phenomenon (Cardoso & Hirata, 2017). Thus, we use inscription procedures to highlight non-humans' agency and the creation of parameters that allow ordering different mathematical relationships. These relationships aim to stabilize the sociotechnical network, forming an ever-increasing number of heterogeneous aggregates and allies. In our study, we emphasize that non-humans' agency contributes to the constitution of the sociotechnical network, promoting movement and a rupture between aggregates and giving clues that knowledge is not compartmentalized (Figure 8). Given this, we propose the concept of *mathematical inscriptions* as a way of leading the action not only of humans –but also of non-humans– in the process of materializing mathematical knowledge for teaching, emphasizing the associations established between both.

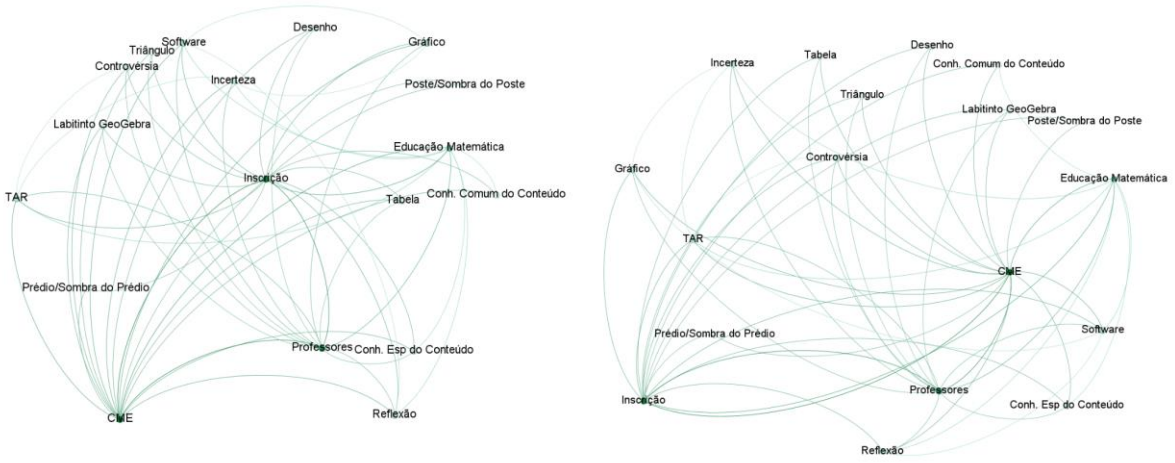


Figure 8.

Sociotechnical Network managing the construction of mathematical knowledge for teaching (Prepared by the authors, 2022).

We highlight that this sociotechnical network is a contribution of our research to the mathematics education community from the perspective that objects also act and mobilize others to act, putting in evidence inscription procedures and, consequently, *mathematical inscriptions*. When paying attention to a mathematics education that values the importance of different knowledge of the teacher, for example, we propose greater reflection on the construction of the MKT because researchers have been differentiating in theoretical aspects *the common content knowledge* (not used in teaching environments) *specialized content knowledge* (applied in teaching environments), prioritizing both in different ways, which, in the parameters of the ANT, generates a discontinuity.

Latour (2012) says that nature and society, modern and non-modern, subjects and objects, must go together, in a hybrid and symmetrical way, and not in a dualistic way, investigated separately. Given this, we highlight the possibility of further exploring the *common content knowledge* in the construction of the MKT. Thus, from Latour and Woolgar's (1997) standpoint, inscriptions are a constitutive part of these strategies, networks, and devices, whether based on the knowledge they produce, the technologies and goals they put into functionality, or the categories and equivalences they develop or transform into a standard.

In this study, we perceived that both humans and non-humans could manage constructions, changes of perspectives, and expansion in the flow of the sociotechnical network,

whether in the digital or analog environment, seeking to manage relationships that aim to stabilize the movement of circulation of *actants*. We observe that these *actants* act and, in action, lead several others to act, affecting the performance of the sociotechnical network and, in this study, the construction of the MKT. These associations can contribute to the development of new research in mathematics education.

As an implication, we must map the associations between humans and non-humans in the current context, seeking to place them at the center of the debate. We consider that different *actants* act, transform, redefine, and configure new associations for the construction of new sociotechnical networks and inscriptions in the construction of the MKT.

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