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Outline of a theory of action for the Actor-Network Theory: applications and implications

Esboço de uma teoria da ação para a Teoria Ator-Rede: aplicações e implicações

Esquema de una teoría de la acción para la Teoría Actor-Red: aplicaciones e implicaciones

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Abstract: The purpose of this article is to analyze the action of the Strands of Learning based on the Actor-Network Theory (ANT). To this end, we outline an ANT theory of action comprised of the following assumptions: *Actant*, *Performance*, *Collective*, *Program of Action*, *Hybrid actor*, *Translation*, *Intermediary*/*Mediator* and *Uncertainty*. These assumptions were applied to documents produced by a research group in the field of Science and Mathematics Education. Through them, we were able to demonstrate that the Strands can be understood as actants, that is, non-human actors whose essence, as *a priori* categories, can be observed through their performance within the collectives to which they were connected. The analyses also showed that the Strands: formed hybrids; had actions which were uncertain; produced various subprograms of action; underwent several translations; and acted as mediators most of the time. In conclusion, we present some implications of the analyses carried out in this article for future research.
Keywords: Strands of Learning. Actor-Network Theory. Science Teaching.

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Resumo: O presente artigo tem como objetivo analisar a ação dos Focos da Aprendizagem, tendo por base a Teoria Ator-Rede (ANT). Para isto, esboçamos uma teoria da ação da ANT constituída pelos seguintes pressupostos: *Actante*, *Performance*, *Coletivo*, *Programa de ação*, *Ator híbrido*, *Translação*, *Intermediário*/*Mediador* e *Incerteza*. Tais pressupostos foram aplicados a documentos produzidos por um grupo de pesquisa da área de Ensino de Ciências e Matemática. Por meio deles conseguimos demonstrar que os Focos podem ser entendidos como actantes, ou seja, atores não humanos, cuja essência, enquanto categorias *a priori*, podem ser observadas a partir de sua performance nos coletivos aos quais estiveram conectados. As análises também demonstraram que os Focos: formaram híbridos; suas ações foram incertas; produziram diversos subprogramas de ação; passaram por diversas translações; e atuaram como mediadores, na maior parte do tempo. Ao final, apresentamos algumas implicações das análises realizadas neste artigo para a continuidade das pesquisas.
Palavras-chave: Focos da Aprendizagem. Teoria Ator-Rede. Ensino de Ciências.

Resumen: El presente artículo tiene como objetivo analizar la acción de los Focos del Aprendizaje tomando como base la Teoría Actor-Red (ANT). Para ello, esbozamos una teoría de la acción de la ANT constituida por los siguientes supuestos: *Actante*, *Performance*, *Colectivo*, *Programa de acción*, *Actor híbrido*, *Traslación*, *Intermediario*/*Mediador* e *Incertidumbre*. Tales supuestos fueron aplicados a documentos producidos por un grupo de investigación en el área de Enseñanza de Ciencias y Matemáticas. A través de ellos conseguimos demostrar que los Focos pueden ser entendidos como actantes, es decir, actores no humanos, cuya esencia, en tanto categorías a priori, puede observarse a partir de su performance en los colectivos a los que estuvieron conectados. Los análisis también demostraron que los Focos: formaron híbridos; sus acciones fueron inciertas; produjeron diversos subprogramas de acción; pasaron por diversas traslaciones; y actuaron como mediadores, la mayor parte del tiempo. Al final, presentamos algunas implicaciones de los análisis realizados en este artículo para la continuidad de las investigaciones.
Palabras-clave: Focos del Aprendizaje. Teoría del Actor-Red. Enseñanza de las Ciencias.

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Introduction

In a recent article published in this journal (Cher *et al*., 2024), we analyzed the creation, testing, and consolidation of a research instrument called Strands of Scientific Learning (SSL for short), based on Actor-Network Theory or ANT[6]. The SSL, like other sets of strands, which will be mentioned throughout this article, are part of what we generically call Strands of Learning[7], and were produced by research conducted within our group[8].

The creation of the Strands and their subsequent developments consist of a complex history and will not be discussed in detail in this article. A simplified version can be found in Arruda, Portugal, and Passos (2018).

In fact, the Strands have gone through several versions throughout their history:

> The trajectory of the Strands of Learning, from their origin (the SSL) to its synthesized version – the Strands of Learning Knowledge (SLK) – is full of transformations, adaptations and detours, which resulted in different versions of this instrument with applications in different fields of learning (scientific, teaching, research, etc.) (Cher *et al*., 2024, p. 10, our translation)[9].

Table 1 presents the main sets of Strands produced and their order of creation.

Table 1 – Sets of focuses produced by the group

Creation order	Strands	Reference
1	SSL – Strands of Scientific Learning [10]	Arruda *et al.* (2013)
2	STL – Strands of Teacher Learning	Arruda, Passos & Fregolente (2012)

[6] In our work, we have preferred the acronym ANT to refer to Actor-Network Theory, rather than the Portuguese version, TAR.

[7] We emphasize that the Strands of Learning, produced within our group, whose origin dates back to 2010, have no relation whatsoever to the Platform "Foco da Aprendizagem" developed by the São Paulo State Department of Education in 2015. There was simply a coincidence of names since SSL in Portuguese are called "Focos da Apendizagem".

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[9] In the original text: "A trajetória dos Focos da Aprendizagem, desde sua origem (os FAC) até sua versão sintetizada – os Focos da Aprendizagem de um Saber (FAS) – é repleta de transformações, adaptações e desvios, os quais resultaram em diferentes versões deste instrumento com aplicações em diversos campos da aprendizagem (científica, docente, da pesquisa etc.)" (Cher et al., 2024, p. 10).

[10] Although formulated before the STL, the SSL were only published later due to journal scheduling reasons.

3	SLR – Strands of Learning for Research	Teixeira, Passos & Arruda (2015)
4	SLK – Strands of Learning of Knowledge	Arruda, Portugal & Passos (2018)
5	SLTR – Strands of Learning of the Teacher-Researcher	Vicentin *et al.* (2020)
6	SST – Strands of Scientific Teaching	Portugal, Arruda & Passos (2022)

Source: Adapted from Cher *et al.* (2024, p. 11).

What the Strands generally assume is that learning can be investigated based on a number of variables (indicators or dimensions) related to interest, knowledge (theoretical and/or practical), reflection, community, and identity. Table 2 exemplifies what we mean in the case of the Strands of Scientific Learning (SSL).

Table 2 – Strands of Scientific Learning (SSL)

N.	**Strand**	**Description of learning indicators**
1	Scientific Interest	The student demonstrates interest, emotional involvement, curiosity and motivation to learn about Science and interpret the phenomena of the natural and physical world, according to scientific concepts.
2	Scientific Knowledge	The student understands and uses the main concepts, explanations, arguments, models, theories and scientific facts created to understand the natural world.
3	Scientific Practice	The student engages in scientific practice, manipulating, testing, observing, generating and explaining scientific evidence, redefining theories and building new models based on observation and experimental data.
4	Reflection on Science	The student reflects on Science as a way of knowing, on its history, on scientific processes, concepts and institutions and on their own process of learning scientific concepts and phenomena.
5	Scientific Community	The student participates in activities developed in a scientific community and learns practices from others, using scientific language and tools, assimilating the values of that community.
6	Scientific Identity	The student thinks of themselves as a learner of Science and develops an identity as someone who knows, uses, and sometimes contributes to Science.

Source: Adapted from Cher *et al.* (2024, p. 10).

As already mentioned in the previous article, the first Strands to be formulated (the SSL) were created from a set of scientific learning objectives called *Strands of Informal Science Learning* (NRC, 2009, p. 43), in a process called *expansion of an idea* (Cher *et al*., 2024, p. 14). This process was analyzed based on some central concepts of Actor-Network Theory, in particular, the concept of translation, defined, broadly speaking, as the displacement or deviation of an agent's goals (Cher *et al*., 2024, p. 6-8). Subsequently, the Strands underwent other transpositions, partially changing their form, but maintaining their essence.

Initially, we intended to analyze the "action" of the Strands in the network(s) in which they participated, drawing on concepts from Actor-Network Theory. However, this goal led us to an initial difficulty: we found no explicit theory of action in ANT, nor in Latour's texts, nor in the texts of other relevant authors in the field. Ideas about action are almost always implicit in the texts in the field.

However, by reading some of these texts, we realized that it is possible to characterize elements of how action is understood in ANT, particularly based on certain texts by Latour, and to develop what we might call an outline of ANT's theory of action. From this outline, as we will demonstrate, it is possible to analyze the Strand's action as a non-human actor (actant). In this sense, we set two general objectives for this article, indicated below:

(i) Develop an outline of an ANT theory of action, explaining the main assumptions that constitute it.

(ii) Based on the theory of action outlined, analyze the action of the Strands of Learning from the available data.

The first objective, of a theoretical nature, will be addressed in the next section. The second objective will be addressed in the fourth section of this article.

Outline of a theory of action for the Actor-Network Theory

Before describing what we understand by an ANT theory of action, it is important to explain to the readers our relationship with the Actor-Network Theory.

For over ten years, we have been investigating, through direct classroom observation, the actions that teachers and students perform. These investigations are part of a research program called PROACTION[11] (Arruda; Passos; Broietti, 2021). Essentially, such research has

[11] Research Program on Teacher Action, Student Action and their Connections (PROAÇÃO in Portuguese).

as its main objective to investigate what we call *teacher action* and *student action*, which led us to reflect on the concept of action.

Considering the philosophical, sociological, and psychological difficulties in defining action – especially teacher and student action – we decided to explore the theoretical potential of two opposing foundations, which generated two distinct research subprograms. The first subprogram considers action to be intentional and is grounded in traditional sociological theories of action. The second considers action to be indeterminate and is based on Actor-Network Theory. The series of articles we are publishing in this journal is part of the second subprogram.

Before reflecting on how Actor-Network Theory understands action, we must clarify that ANT adopts a view of sociology that differs profoundly from traditional sociology by denying that there is a specific phenomenon that could be called society. For Latour, "there is no social dimension of any sort, no 'social context', no distinct domain of reality to which the label 'social' or 'society' could be attributed" (Latour, 2005, p. 4). Rather than using general social categories to explain a given state of affairs, ANT proposes to trace the associations (connections) between various actors, redefining sociology:

> [...] not as the 'science of the social', but as the tracing of associations. In this meaning of the adjective, social does not designate a thing among other things, [...] but a type of connection between things that are not themselves social (Latour, 2005, p. 5).

We can say that ANT, as well as the theory of action implicit in it, has as its first foundation this new approach to sociology, as a search for connections between things (human and non-human).

Let's return to the theme of action. Indeed, the question of action is essential in some of Latour's texts and, of course, in other ANT texts. In the book *Reassembling the Social*, the author asks: "When we act, who else is acting? How many agents are also present? How come I never do what I want? Why are we all held by forces that are not of our own making??" (Latour, 2005, p. 43). He then adds:

> Action is not done under the full control of consciousness; action should rather be felt as a node, a knot, and a conglomerate of many surprising sets of agencies that have to be slowly disentangled. It is this venerable source of

> uncertainty that we wish to render vivid again in the odd expression. of actor-network (Latour, 2005, p. 44).

In other words, action is *uncertain* and cannot, in principle, be attributed to a single actor. It seems that we do not have complete control over our own actions.

Secondly, Latour, when considering *agency*, defined in traditional sociology as "the individual's capability to act or to intervene in his or her world" (Appelrouth; Edles, 2021, p. 46), separates actors into two types: *intermediaries* and *mediators*. The course of an action is not modified when it passes through an *intermediary*, as it functions as a black box: "defining its inputs is enough to define its outputs"; in the case of *mediators*, however, "their input is never a good predictor of their output" (Latour, 2005, p. 39). The mediator *translates* what passes through them, introducing part of the uncertainty about the action to which Latour refers.

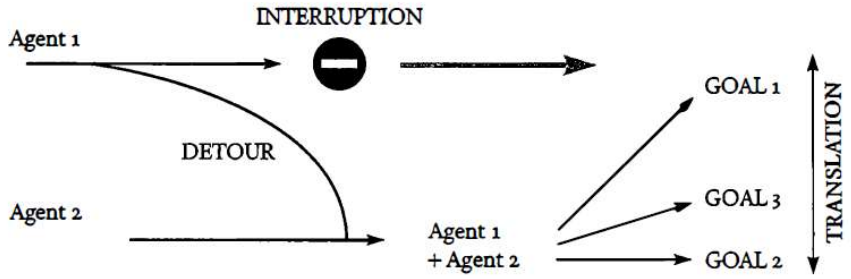
Other characteristic elements of Latour's action can be extracted from his concept of *technical mediation*.

To discuss the different meanings of mediation, Latour begins to reflect on the relationship between weapons and people (Latour, 1994; Latour, 1999). If someone kills another with a firearm — for example, a revolver — who was the primary agent: the person or the revolver? The problem here is determining responsibility for the action.

For those who want to control the free trade of firearms, it is guns that kill people: citizens are good people who, when wielding a gun, change, becoming a *gun-person*; the gun is primarily responsible for death. For those who advocate for the liberalization of gun sales, it is not guns that kill, but people: the gun is neutral, but when wielded by a malicious individual, it becomes a *person-gun*; the person is primarily responsible for death. Latour argues that the answer to this dichotomous question depends on what we understand by *mediation*. To this end, Latour establishes four meanings for this concept. However, taking objective (i) into account, we will consider here only the first two meanings presented by Latour.

The first meaning of mediation Latour calls an action program, which includes a "series of goals, steps and intentions" of the agents involved, in particular the translation of their goals (Latour, 1999, p. 178; Latour, 2017, p. 212). It was with this meaning that we used the concept of translation in the previous article (Cher *et al.*, 2024). Eventually the action program includes one or more subprograms, "nested within each other" (Latour, 2017, p. 215). The goal translations in the case of the person x gun example are represented in Figure 1:

Figure 1 – First meaning of mediation: goal translation



Source: Latour (1999, p. 179).

Regarding Figure 1, as explained in Latour (1999, 2017, Chap. 6), agent 1 (person) had goal1 1; however, the course of their action undergoes a detour (interruption, represented by the black circle) when they encounter agent 2 (gun). This connection *detours* or *translates* the goals of agent 1. Agent 1, when connecting to agent 2, gives rise to a new agent (agent 1 + agent 2) formed by the union of the two, which we will call agent 3.

From this example, we can point to two more elements in Latour's theory of action. First: not only does agent 1 (the person) have a program of action (e.g., to hurt someone), but agent 2 (the gun) does as well. What goals would constitute a firearm's program of action? There could be several: superiority in combat over bladed weapons, ease of use, self-defense, hunting, etc. This is another characteristic of action in Latour: we can also attribute goals, intentions, and a program of action to the gun, that is, to objects, artifacts, and non-humans.

The second element is related to the idea that the association between agents 1 and 2 translates the goals of both and transforms their essences:

> This translation is wholly symmetrical. You are different with a gun in your hand[12]; the gun is diff erent with you holding it. You are another subject because you hold the gun; the gun is another object because it has entered into a relationship with you. (Latour, 1999, p. 179).

According to Latour, the mistake in the aforementioned dichotomous question (who kills: the gun or the person?) is the distinction between the *essence* of what we understand by a person and the *essence* of what we understand by an object. The basic ontological hypothesis

[12] "With a revolver in your hand you're a fierce beast. Without it, you walk with a sway and even change your voice" [Você com revólver na mão é um bicho feroz. Sem ele, anda rebolando e até muda de voz]. Song "Bicho Feroz", by Bezerra da Silva, available at https://www.letras.mus.br/bezerra-da-silva/205902/

(for Latour) is that there is no entity (an actor), *a priori*, that composes the world, be it a subject or an object: the nature of the actor is defined by what they do, that is, by their *performance* (Latour, 1999, p. 303). By connecting, the gun and the subject transform themselves as actors, that is, they end up composing a third entity, a *hybrid actor*:

> These examples of actor-actant symmetry force us to abandon the subj ect-object dichotomy, a distinction that prevents the understanding of collectives. It is neither people nor guns that kill. Responsibility for action must be shared among the various actants. And this is the first of the four meanings of mediation. (Latour, 1999, p. 180).

The second meaning of mediation has to do with the *composition of actions*. In the example of the gun and the subject wielding it, who performs the action? Neither the subject nor the gun: "Action is not the property of humans, but of an association of actants, and this is the second meaning of technical mediation" (Latour, 1999, p. 182; Latour, 2012, p. 216), also explained by Latour in this sentence:

> [...] the continuity of any course of action will rarely consist of human-to-human connections [...] or of object-object connections, but will probably zigzag from one to the other (Latour, 2005, p. 75).

From what has been presented in the previous paragraphs, we believe we can outline the assumptions of what we are calling an ANT theory of action, based primarily on some of Latour's texts. In short, we can suggest that a theory of action in Actor-Network Theory (or at least na outline of it) would have the assumptions described in Table 3.

Table 3 – Outline of a theory of action by Latour

N.	Assumption	Description
1	*Actant*	In ANT, the word actor or agent is best described by the word Actant, which includes both humans and non-humans as actors[13].

[13] "Since in English 'actor' is often limited to humans, the word 'actant', borrowed from semiotics, is sometimes used to include nonhumans in the definition." (Latour, 1999, p. 303).

2	*Performance*	The essence of an actor, be it a person or an object, is defined by what they do, that is, by their *Performance*[14].
3	*Collective*	Action is not the property of a specific actor, but consists of the connection between different actors, human and non-human (*actants*): action is collective, that is, it implies associations between humans and non-humans that form *Collectives*.
4	*Program of action*	*Programs of action* are a series of goals and intentions, which can be attributed to both human and non-human actors, in a given story.
5	*Hybrid actor*	When actors connect, they end up composing a third entity, a *Hybrid Actor*.
6	*Translation*	*Translation* means a change (deviation, displacement) of goals that can occur when one actor connects with another in the course of an action.
7	*Intermediary/ Mediator*	The actors[15] can be separated into *Intermediaries* or *Mediators*: *Intermediaries* do not change the course of action; *Mediators* transform it.
8	*Uncertainty*	Action is uncertain, it does not occur under the control of consciousness.

Source: The authors.

It is important to emphasize that the order in which the assumptions appear in Table 3 does not imply that we must follow said order when they are being applied to the investigation of a given *Actant*'s action. We also remember that these assumptions are based on a new sociology proposed by Latour, which defines the social as a connection between things, which is clearly demonstrated in Assumption 3.

Methodology

Having established the theoretical foundations of this article, summarized in Table 3, we describe in this section the types of data that will be used in the analyses and how they were obtained. The data come from two sources: (1) records prepared by the research group; (2) articles that were produced, using the Strands as a basic reference.

[14] Some authors prefer to use the term *enactment*, because the term *performance* "has been widely used in ways that link it either to theatre, or more generally to human conduct" (Law, 2004, p. 159). But the two terms are practically synonymous.

[15] We're using the word *actor* to mean the same thing as the word *agent*. We're also prioritizing the word actor" over agent to maintain consistency with the term *actor-network*.

Type (1) data consists of excerpts from what we call *records*, which are written acounts of research group meetings prepared by the members themselves, under the general supervision of one of the researchers. More information about the records is available in Passos *et al*. (2008). The collection consists of 120 records, recorded between 2010 and 2019[16], which contain at least one mention of the word Strands. More detailed information about the data collection procedure through records was presented in the previous article, already published in this journal (Cher *et al.*, 2024).

Data type (2) consists of articles published in journals by researchers from the group between 2012 and 2025, which cited one or another version of the Strands. Articles not from the group were located through *Google Scholar*. We did not consider conference papers, books and/or book chapters, theses, or dissertations. A total of 51 articles were located, a list of which is presented in the Appendix. The articles are coded A1, A2, A3, through A51.

The general research methodology, of the qualitative type, used Bardin's Content Analysis procedures (2021). The eight assumptions that make up ANT's (supposed) theory of action, presented in Table 3, were used as *a priori* categories.

In the next section, we analyze the action of the Strands of Learning based on Table 3 and the data mentioned.

The action of the Strands of Learning

To understand the Strands' actions, we need to consider the assumptions indicated in Table 3, seeking to clarify which of them can be attributed to the Strands' actions. We will begin our analysis in the order in which the assumptions were presented, seeking to demonstrate that the Strands, throughout their history, have exhibited all of these characteristics.

Assumption 1 (Actant). In Actor-Network Theory, the word actor or agent is best described by the word Actant, which includes both humans and non-humans as actors.

To confirm Assumption 1, we need to demonstrate that Strands are Actants, that is, non-human actors. To do this, we will resort to what Latour calls *inscription*, defined as:

[16] Due to the pandemic, group meetings began to be held remotely from 2020 onwards, which altered the way meetings were recorded. These records were not considered in the analyses of the development of the Strands of Learning considered in this article.

> A general term that refers to all the types of transformations through which an entity becomes materialized into a sign, an archive, a document, a piece of paper, a trace (Latour, 1999, p. 306).

Let us assume that there are two types of Strands registration: an *internal inscription* within the research group, whose information was obtained from records; and an *external inscription*, which considers publications, in particular, articles in periodicals[17].

Looking at the dialogues recorded in the research group meetings, we realize that, although the Strands only appeared in periodicals from 2012 onwards (Arruda; Passos; Fregolente, 2012), their inscription began well before, in 2010. In this year, the set of strands presented in Table 2 (or something similar) was already circulating in the research group. The word *strands*, for example, is recorded for the first time in record number 70, from April 2010:

> We are studying this theoretical basis and this framework says that informal learning occurs in situations outside of school, and they divide it into six strands (Record70GQ-28april2010, our translation)[18].

In other records from 2010, the expressions *strand* 1, *strand* 2, etc., are also found:

> But we're still in the process of testing references. This isn't just appearing in your work; I am seeing it in other works I am reading. I think that more generally, the tendency is to focus on 1, 2, and 3, with 4 and 5 appearing in specific cases and 6 apparing in even more specific ones (Record76GQ-18august2010, our translation)[19].

Furthermore, in record 81, we found a seminar held by one of the researchers, in which the preliminary version of an article was presented (Arruda *et al*., 2013), in which the Strands were used to investigate scientific learning in everyday life (Record81GQ-27october2010).

We believe that these three examples are sufficient to indicate evidence of the *internal inscription* of Strands in the EDUCIM group in 2010.

[17] The expressions internal and external used here only serve to characterize two networks, which were not in fact separate, but maintained connections.
[18] In the original text: "Nós estamos em estudo desta base teórica e esse referencial diz que a aprendizagem informal, ocorre em situações fora da escola, e eles dividem em seis focos" (Memo70GQ-28abril2010).
[19] In the original text: "Mas nós estamos em uma fase de testar referenciais ainda. Isso não está aparecendo só no seu trabalho, eu estou vendo ocorrer isso em outros trabalhos que eu estou lendo. Eu acho que de forma mais geral, a tendência é ficar no foco 1, 2 e 3, só em caso específico aparece 4, 5 e o 6 aparece com mais especificidade ainda" (Memo76GQ-18agosto2010).

At the same time, in 2010, Strands began to be used as research tools for analyzing data obtained in various contexts and educational levels. These phases included *testing* Strands as a new idea and then *consolidating* them as a research tool. (Cher *et al.*, 2024, p. 18-19). The results of these investigations, which explicitly cited the Strands in one or more of their versions, were disseminated in events, book chapters and/or journal articles, many of them mentioned in Arruda, Portugal and Passos (2018, p 102-105).

This second type of mention of the Strands is what we consider *external inscriptions*, represented by citations in publications, particularly journal articles. As mentioned in the previous section, 51 articles were located that explicitly cited the Strands, a list of which can be found in the Appendix.

Having presented the Strands' *inscription* in the research group and in journals, we can conclude that the Strands can, in fact, be considered non-human actors, that is, *Actants*. Let us now move on to the second assumption.

Assumption 2 (Performance). The essence of an actor, be it a person or an object, is defined by what they do, that is, by their Performance.

Over time, the descriptions of the strands have undergone several changes, mainly due to adaptations to other fields of application. Take as an example the (summarized) description of the strands in the SSL, STL, and SLR:

Table 4 – Description of the strands in the SSL, STL and SLR

STRAND	**SSL** Arruda *et al.* (2013, p. 487)	**STL** Arruda, Passos & Fregolente (2012, p. 32)	**SLR** Teixeira, Passos & Arruda (2015, p. 528)
Strand 1	Development of interest in Science	Interest in teaching	Interest
Strand 2	Understanding scientific knowledge	Practical knowledge of teaching	Knowledge
Strand 3	Engagement with scientific reasoning	Reflection on teaching	Methodology
Strand 4	Reflection on the nature of Science	Teaching community	Creativity
Strand 5	Involvement with scientific practice	Teacher identity	Community

Strand 6	Identification with the scientific enterprise		Identity

Source: The authors.

Despite the enormous differences, due to the specificities of the fields of application, one thing remained constant throughout the transformations of the Strands: the action they performed in the research work. In other words, when we observe the *performance* of the Strands in investigations, we realize that they have always acted as a *set of a priori categories of analysis*, which can be verified in some citations. Let's consider three of them: the first related to the SSL, the second to the STL, and the third to the SLR:

> The reference [the Strands] provides a set of *a priori* categories that allowed the analysis of data obtained from dialogues between a mother and her daughters, which occurred spontaneously in everyday life, and from interviews conducted with people who were in public places, chosen at random (Arruda *et al.*, 2013, p. 481, our translation)[20].
>
> The first step (according to DTA procedures) is to read each participant's speech. Next, the work of deconstructing these accounts begins (in this case, keeping in mind the STLs, assumed as *a priori* categories). (Arruda; Passos; Fregolente, 2012, p. 36, our translation)[21].
>
> For the data categorization movement, we used the SLR as categories determined *a priori*, defined by Moraes and Galiazzi (2007, p. 73) as those that precede the units of analysis and have an objective and deductive nature (Teixeira; Passos; Arruda, 2015, p. 533, our translation)[22].

Such citations show us that the Strands, non-human actors, as already demonstrated, *performed* in the networks as *a priori* categories, which constituted their *essence* as *Actants*.

Subsequently, we concluded that the Strands could be summarized into 5 signifiers (interest, knowledge, reflection, community, and identity), which allowed us to group the SSL,

[20] In the original text: "O referencial [os Focos] fornece um conjunto de categorias a priori que permitiram analisar dados obtidos de diálogos entre uma mãe e suas filhas, ocorridos espontaneamente no dia a dia, e de entrevistas realizadas com pessoas que se encontravam em locais públicos, escolhidas ao acaso" (Arruda *et al.*, 2013, p. 481).
[21] In the original text: O primeiro passo executado (segundo os procedimentos da ATD) é a leitura do discurso de cada um dos participantes. A seguir, inicia-se o trabalho de Desconstrução desses relatos (neste caso, tendo-se em mente os FAD, assumidos como categorias a priori) (Arruda; Passos; Fregolente, 2012, p. 36).
[22] In the original text: Para o movimento de categorização dos dados, utilizamos os FAP como categorias determinadas a priori, definidas por Moraes e Galiazzi (2007, p. 73) como aquelas que precedem as unidades de análise e possuem natureza objetiva e dedutiva (Teixeira; Passos; Arruda, 2015, p. 533).

STL, and SLR strands into a single set, called the Strands of Learning of Knowledge (SLK). Let us now move on to the third assumption.

Assumption 3 (Collective). Action is not the property of a specific actor, but consists of the connection between several actors, human and non-human (Actants): action is collective, that is, it implies associations between humans and non-humans that form Collectives.

If actions consist of connections, this implies that they are collective. To demonstrate that Strands follow this assumption, we must describe how actions circulated in the networks associated with them. That is, we must follow human and non-human actors, tracing their connections:

> Using a slogan from ANT, you have 'to follow the actors themselves', that is try to catch up with their often wild innovations in order to learn from them what the collective existence has become in their hands, which methods they have elaborated to make it fit together, which accounts could best define the new associations that they have been forced to establish (Latour, 2005, p. 12).

We will attempt to locate the networks in which the Strands connected, first using records and then articles. In both cases, numerous actors or *Actants* can be traced.

We will use an excerpt from a quote of one of the researchers in the EDUCIM group during a 2010 meeting. The topic addressed by the researcher concerned the presentation of papers by four undergraduate students at the ASIM (Annual Scientific Initiation Meeting). Each of these students would present a paper (a project) that would be based on the Strands. The following is an excerpt from the quote present in the record:

> The thing is, we have until the end of the month to submit [to ASIM] the SIP [Scientific Initiation Program] projects. The focus is informal learning, and we have a research initiation group [RIG]. The data are records, recordings, interviews. The basis is informal. We are studying this theoretical framework, and this framework states that informal learning occurs in situations outside of school, and they divide it into six strands. So, project one focuses on interest and how that interest occurs. Project two is about content learning. Project three is about the practices they developed, and it also incorporates other strands. And project four is about scientific identity (Record70GQ-28abril2010, our translation)[23].

[23] In the original text: "É o seguinte, nós temos até o final do mês pra enviar [ao EAIC] os projetos do PROIC [Programa de Iniciação Científica]. O foco é aprendizado informal e temos um grupo de iniciação à pesquisa [GEI]. Os dados são as memos [memórias], as gravações, entrevistas. A base é informal. Nós estamos em estudo desta base teórica e esse referencial diz que a aprendizagem informal ocorre em situações fora da escola, e eles

Some of the actors that can be assumed in this short excerpt are: the human actors (researchers, students, etc.) and non-human actors (desks, tables, projectors, laptops, etc.) who were present at the time of the meeting; the institutional events and programs mentioned (ASIM, SIP), which, in turn, are immense networks made up of people, objects, regulations, etc., belonging to various educational and research institutions; the theoretical concepts mentioned (strands, informal learning, etc.), which lead to many other non-human actants. We can see, from this example, that it is practically impossible to locate all the actors who were associated with the Strands at the time of the meeting. On the other hand, it is clear that the actions unfolded among actors who were all connected.

Let's now attempt to trace the Strands network associated with the articles. Considering the 51 articles that mention Strands (Appendix), we see that these articles were published in the 29 journals listed below in alphabetical order. The numbers in parentheses represent the number of articles published in each journal.

Acta Scientiarum (1); Alexandria (5); Aondê (1); Aracê (1); Caderno Brasileiro de Ensino de Física (5); Ciência & Educação (4); Ciência & Ideias (1); Colloquium Humanarum (1); Docência do Ensino Superior (1); Educação & Realidade (1); Educação em Foco (1); Educação Matemática Pesquisa (1); Ensaio: Pesquisa em Educação em Ciências (1); Ensino & Pesquisa (2); Ensino, Saúde e Ambiente (2); Experiências em Ensino de Ciências (1); Indagatio Didactica (1); Investigações em Ensino de Ciências (5); Linguagens, Educação, Sociedade (1); Ludus Scientiae (1); Research, Society and Development (2); Revista Brasileira de Ensino de Ciência e Tecnologia (4); Revista de Produtos Educacionais e Pesquisa em Ensino (2); Revista Electrónica de Enseñanza de las Ciencias (1); Revista Eletrônica de Educação Matemática (1); Revista Internacional de Pesquisa em Didática das Ciências e da Matemática (1); Revista Prática Docente (1); Science & Education (1); Vydia (1).

The journals listed in the previous paragraph demonstrate that all articles are connected through their references (the Strands). On the other hand, if we consider that each of these references refers to countless others, the boundaries of the network become blurred, revealing the difficulty in delimiting the network or *Collectives* associated with the Strands. In other words, in general terms, the network that can be associated with the Strands appears limitless.

dividem em seis focos. Então, o projeto um foca no interesse e como ocorre esse interesse. O projeto dois é sobre o aprendizado do conteúdo. O projeto três é sobre as práticas que eles desenvolveram, nele está embutido outros focos também. E o projeto quatro é sobre a identidade científica." (Memo70GQ-28abril2010).

In short, from the examples presented, we can understand that the task of accurately and in detail describing or tracking the network associated with the Strands is a virtually impossible one. The number of actors involved since its inception — both internal, within the group, and external, in the periodicals — is immense, perhaps incalculable, which indicates that the question of defining the *Collective*(*s*) with which the Strands have associated themselves has no definitive answer.

Despite this, it seems clear that Strands were and still are associated with networks or *Collectives*, as it is impossible to think about them or observe them in action without connecting them to other actors, whether human or nonhuman. In conclusion, the Strands' action was, in fact, a collective action, in which human and nonhuman actors remained connected throughout the entire time a given activity was underway.

Assumption 4 (Program of Action). Programs of Action are a set of goals and intentions that can be attributed to both human and non-human actors in a given story.

We can say that the Strands' general program of action was to perform as a set of analytical categories. Initially (at least in 2010), the program, which operated primarily in the field of Science, did not include the transposition of the idea to other areas such as Teaching (STL) or even Research (SLR). However, as such transpositions eventually occurred, we observed that each of the Strands, especially the first three presented in Table 4 (SSL, STL, and SLR), produced their own subprograms of action, providing guidelines for investigating learning in the areas in which they operated (*performed*). Several articles were produced based on these subprograms, some of which are mentioned below. We note that we are using the coding in the Appendix.

SSL Subprogram (some published articles that investigated scientific learning, with SSL as *a priori* categories): A3; A4; A7; A8; A23; A24; A29; A45.

STL Subprogram (some published articles that investigated teacher learning, with STL as *a priori* categories): A1; A2; A11; A12; A13; A19; A31; A32; A43.

SLR subprogram (some published articles that investigated learning for research, with SLR as *a priori* categories): A10; A15; A33; A47.

In summary, the general program of the Strands consisted of performing as categories of analysis, which was transferred to specific fields (Science, Teaching and Research), generating new research subprograms.

Assumption 5 (Hybrid Actor). When actors connect, they end up forming a third entity, a Hybrid Actor.

In the second section of this article, we present how Latour discusses the hybridization of actors, using the association between a person and a gun as an example. Similarly, we can consider that when a student uses Strands in their research, a *Hybrid actor* is created. A student + Strands is a hybrid that performs similarly to the person + gun hybrid. When these two actors connect, the joint action they perform can result in a new idea, a new application of the Strands, a thesis, a dissertation, na event paper, an article, etc. Most of the time, other actors — internal and/or external to the group, human and/or non-human — almost always participate in the outcome. This is easily perceived when we read acknowledgments in a thesis, dissertation, or article, which are often not just formalities but actually express how other actors participated in the development of that product, such as advisors, group colleagues, friends, funders, etc.

Assumption 6 (Translation). Translation means a change (detour, displacement) of goals, which can occur when one actor connects with another in the course of an action.

Considering that *Translation* is a modification of goals, we can certainly say that the goals of the Strands have changed several times, as reported in Cher (2024) and Cher *et al.* (2024).

After the creation and *testing* of the Strands, in their version as the SSL in the field of Science, came the stage of their *consolidation*, a process that opened up several possibilities for exploring the idea, such as: the transposition of the Strands to other fields such as Teaching (STL[24]) and research (SLR[25]); the combination of Strands from different fields (SLTR[26]); the proposition of the generalization of the Strands called Strands of Learning Knowledge (SLK)[27];

[24] Arruda, Passos & Fregolente (2012).
[25] Teixeira, Passos & Arruda (2015).
[26] The SLTR, or Strands of Learning of the Teacher-Researcher, are a combination of the SSL, the STL and the SLR (Vicentin *et al.*, 2020).
[27] Arruda, Portugal & Passos (2018).

and the exploration of a particular strand, in particular the Interest in Teaching[28]. These developments were the subject of numerous research projects by the group, which led to the publication of several articles, theses, and dissertations. Later, the idea of the Strands of Learning was transposed to teaching, leading to the creation of the Strands of Science Teaching[29].

In short, the Strands' history is full of translations.

Assumption 7 (Intermediary/Mediator). The actors[30] can be separated into Intermediaries or Mediators: Intermediaries do not change the course of action; Mediators transform it.

Apparently, the Strands never acted as *Intermediaries*, meaning that action didn't pass through them without being altered. Even in the phase we call *consolidation*, when they established research subprograms, there had always been questions about the meaning of each strand and how to apply them in data analysis. Examples:

> I separated them into strands. The main difficulty is fitting the speeches into the strands (Record153GQ-09april2015, our translation)[31].
>
> When we analyzed the data, I had a lot of difficulty identifying strand 5 (of the STL). Then the professor [...] asked us to adapt. [...] he suggested that we readjust the strands to our case, which is in-service teacher education (Record191GQ-27april2017, our translation)[32].
>
> [...] in practice, we had a lot of difficulty differentiating strands 2 and 3. In my dissertation, when the subject said "I learned", that they learned, we put it in strand 2. And when they said "I think", then it was something further away, we put it in strand 3 (Record191GQ-27april2017, our translation)[33].

[28] Martin, Arruda & Passos (2016).
[29] Portugal, Arruda & Passos (2021).
[30] We are using the word *actor* with the same meaning as the word *agent*. We are also prioritizing the word actor over agent to maintain consistency with the term *actor-network*.
[31] In the original text: "Separei em focos. A principal dificuldade é enquadrar as falas nos focos (Memo153GQ-09abril2015)."
[32] In the original text: "Quando nós fomos analisar os dados, eu tive bastante dificuldade de identificar o foco 5 (dos FAD). Aí o professor [...] pediu para a gente adaptar. [...] sugeriu que fizéssemos a readequação dos focos para o nosso caso que são professores em formação continuada (Memo191GQ-27abril2017)."
[33] In the original text: "[...] na prática a gente teve bastante dificuldade para diferenciar o foco 2 e o 3. Na minha dissertação, quando o sujeito falava "eu aprendi", que aprendeu, a gente jogava no foco 2. E quando ele falava "eu penso", aí era algo mais afastado, a gente jogava no foco 3 (Memo191GQ-27abril2017)".

Apparently, this *Performance* of the Strands as *Mediators* has to do with how the group has understood what it means to do research in the field of Teaching, as we present below.

We assume, as many researchers do, that the main outcome of an investigation is the production of new knowledge about the field under study. The group's research has been characterized by the assumption that the ability to create (new) ideas depends primarily on the ability to perceive relationships between existing ideas. In other words, a new idea is nothing more than a "new combination of old elements" (Young, 1994, p. 33). A new idea, however, needs to be tested. Some researchers believe that for an idea to be tested, it must be confronted with data.

> To conduct research, it is necessary to promote a comparison between data, evidence, and information collected on a given subject and the theoretical knowledge acquired about it. This is generally done through the study of a problem, which simultaneously sparks the researcher's interest and limits their research activity to a specific portion of knowledge, which they commit to building at that moment. (Lüdke; André, 1986, p. 2, our translation)[34].

We believe, however, that the relationship between theory and data is not really a direct confrontation (falsification or verification of hypotheses), but that in the development of research, for example a thesis, the data and theoretical references must *adapt* to each other, as we have already proposed for the theory-experiment relationship in Physics teaching:

> In this work, based on a discussion of the different possibilities of understanding the relationships between theory and experiment, we propose, based on the ideas of Thomas Kuhn, complemented by the thinking of van Fraassen, a new orientation for the Physics laboratory, conceiving it, not as a verification or falsification of hypotheses, but as a process of adaptation between theory and experiment (Arruda; Silva; Laburú, 2001, p. 47, our translation)[35].

[34] In the original text: Para se realizar uma pesquisa é preciso promover o confronto entre os dados, as evidências, as informações coletadas sobre determinado assunto e conhecimento teórico adquirido a respeito dele. Em geral, isso se faz a partir do estudo de um problema, que ao mesmo tempo desperta o interesse do pesquisador e limita sua atividade de pesquisa a uma determinada porção do saber, a qual ele se compromete a construir naquele momento (Lüdke; André, 1986, p. 2).

[35] In the original text: Nesse trabalho, a partir de uma discussão sobre as diferentes possibilidades de entender as relações entre a teoria e o experimento, propomos, baseados nas ideias de Thomas Kuhn, complementadas pelo pensamento de van Fraassen, uma nova orientação para o laboratório de Física, concebendo-o, não como uma verificação ou falseamento de hipóteses, mas como um processo de adaptação entre a teoria e o experimento (Arruda; Silva; Laburú, 2001, p. 47)

Within this perspective, three movements are possible: (i) a top-down movement, based on references and/or models and/or categories defined *a priori*; (ii) a bottom-up movement, which starts directly from the data and prior analyses from which categories and/or models emerge *a posteriori*; (iii) a blend of the two movements. Regardless of the movement performed, the product of the research (thesis, dissertation, article, etc.) must take the form of a text in which references and data must *adapt*, adjust, and/or articulate with each other.

Thinking in terms of ANT, we treat references and data without distinction of position: what really matters is the *connection* that can be established between them. However, this is not just any *adaptation* or *connection*. We believe that the text or final product (thesis, dissertation, article, etc.) should present five qualities, called O1C4: originality (the text brings new ideas), clarity (the text is clear, well written), coherence (the text is consistent with other research in the area), conciseness (the text is concise, not wordy) and cohesion (the parts of the text are consistent with each other) (Arruda; Passos; Broietti, 2021, p. 238).

The Strands' history clearly shows us that this adaptation process occurred whenever they were applied to data, not only as a result of the *translation* of general goals during the transposition to other fields — from Science to Teaching (article A1), from Science to Research (article A10), from Learning to Teaching (article A44) — but also when Strands were applied directly to data. For example, in article A29, which aimed to analyze astronomy learning in social media, the authors state:

> To interpret what occurred in communities focused on the study of Amateur Astronomy on *Facebook*, we assumed as *a priori* categories what we call Strands of Scientific Learning (SSL) (Arruda *et al*., 2013), in a version adapted to the context of Amateur Astronomy groups (Arruda; Zapparoli; Passos, 2019, p. 385, our translation)[36].

In short, the Strands have always acted as *Mediators*, altering the course of actions of other actors in the group, raising questions about their application and imposing adjustments to the description of their indicators, when used in certain contexts.

[36] In the original text: Para interpretar o que ocorreu nas comunidades voltadas ao estudo da Astronomia Amadora no Facebook, assumimos como categorias a priori o que denominamos de Focos da Aprendizagem Científica (FAC) (Arruda et al., 2013), em uma versão adaptada para o contexto dos grupos de Astronomia Amadora (Arruda; Zapparoli; Passos, 2019, p. 385).

Assumption 8 (Uncertainty). The action is uncertain, it does not occur under the control of consciousness.

From the available data, it's clear that the Strands' actions were uncertain. In the early years, especially, the group's researchers had no idea where the Strands idea would take them, what would be produced, or the consequences for the group's ongoing research and guidance, as some excerpts from the meetings indicate:

> The issue of strands may be something new (Record104GQ-11april012, our translation)[37].

Everything that happened after the Strands' inscription was completely unpredictable, even after the first three sets of strands had already been published in 2015.

> At this point, new ideas may emerge; research requires analysis. This strand is on connecting data with references. In this interplay of theories and data, something new and publishable may emerge... it's the new story no one has told. (Record168GQ-03march2016, our translation)[38].

Even today, after several years, some group members still wonder whether Strands can be applied in unexplored fields. In other words, the Strands' action remains uncertain and unpredictable.

Final considerations

This article was developed from two central objectives: (i) to develop an outline of an ANT theory of action and (ii) based on the outlined theory of action, to analyze the action of the Strands of Learning based on the available data. We believe that both objectives were achieved.

Regarding objective (i), we were able to formulate, based primarily on Latour's texts, what is presented in Table 3: a set of eight assumptions that allow us to analyze the actions of an actor (*Actant*) within a given *Collective*. Regarding teaching and/or learning, Table 3 can be understood as a research tool that allows researchers to analyze, in a general way, from the

[37] In the original text: "A questão dos focos pode ser algo novo (Memo104GQ-11abril2012)."
[38] In the original text: "Nesse momento podem surgir ideias novas, a pesquisa exige que a gente faça uma análise. Esse foco é a articulação dos dados com os referenciais. Nesse jogo de teorias e dados pode surgir algo novo que sejam publicáveis... é a história nova que ninguém contou (Memo168GQ-03março2016)."

perspective of Actor-Network Theory, what teachers, students, and/or other actors are actually doing in the classroom.

Regarding objective (ii), we demonstrate that Strands can be understood as *Actants*, that is, non-human actors, whose *essence*, as *a priori* categories, can be observed from their *Performance* in the networks in which they were inserted. We also demonstrate that the actions carried out by Strands were not planned in advance by the other actors involved, which indicates the *Uncertainty* that falls on the actions carried out by Strands.

On the other hand, we were able to show that the Strands' actions were always connected, developing into *Collectives* whose delimitation, despite being problematic, revealed the various *Programs of action* (or subprograms) evidenced by the Strands' developments over time.

We also comment on other characteristics of the Strands' action, such as: connections with other actors, forming *Hybrid actors*; changes in goals that occurred throughout their history (*Translation*); acting as *Mediators*, most of the time.

Overall, it seems to us that the assumption that action, from the ANT perspective, which can be satisfactorily represented by the assumptions in Table 3, has passed this first test; that is, it has satisfactorily explained the action of a complex *Actant* such as the Strands. This consideration leads us to the following question: What applications and implications can we draw from the results presented here?

First, we understand that the assumptions in Table 3 can be considered as eight categories for analyzing the actions of *Actants* (human and nonhuman) in any setting, particularly the classroom, which is our main *locus* of research. In other words, like Strands, ANT's theory of action, represented in Table 3, can be used in our group as a research tool to investigate the actions carried out in specific *Collectives*. One immediate possibility would be to replicate what we did in this article (analyzing the actions of Strands) with other research tools, particularly for what we call matrices (Arruda; Passos, 2017), whose history, replete with translations, bears similarities to that of Strands.

Another possibility would be to investigate a given subject, having one of the assumptions in Table 3 as its center, which was explored in some of the research group's theses: Corrêa's thesis (2021) addresses the implementation of a new curriculum in a Federal Institute (IFPR) as the creation of a new *Actant* (Assumption 1); Costa's thesis (2023) analyzes the

Performances of a *hybrid* (Assumption 5) called "teacher-experiment", during the construction and use of versions of an experimental set associated with the photovoltaic cell; Cher's thesis (2024) considers the translations (Assumption 6) that occurred in the creation of the Strands of Learning. Of course, as generally occurs when the categories of a set are highly interconnected, in the aforementioned works the authors had to resort to other categories from Table 3, such as *Performance* (Assumption 2). However, in a certain sense, all the theses were analyzing the action of a particular *Actant*.

Finally, two other themes have been investigated in our group for some years: metacognition[39] and intentionality[40]. We also intend, in the future, to address these two themes based on Table 3, describing how metacognition and intentionality are produced in *Collectives* (Assumption 3).

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[39] Passos, Corrêa & Arruda (2017); Corrêa, Passos & Arruda (2018); Corrêa *et al.* (2020); Rosa *et al.* (2021); Passos *et al.* (2022); Passos, Corrêa & Arruda (2023).
[40] Meneguete *et al.* (2023); Arruda *et al.* (2024); Meneguete, Passos & Arruda (2024).

[41] Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
[42] Conselho Nacional de Desenvolvimento Científico e Tecnológico
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APPENDIX

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