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## ► To cite this version:

Ulises Salinas-Hernández, Luis Moreno-Armella, Isaias Miranda. The discourse of a teacher as a means to foster the objectification of a vector quantity: The case of a novice teacher. CERME 10, Feb 2017, Dublin, Ireland. hal-01937144

**HAL Id: hal-01937144**

**<https://hal.science/hal-01937144>**

Submitted on 27 Nov 2018

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# The discourse of a teacher as a means to foster the objectification of a vector quantity: The case of a novice teacher

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*This article presents the analysis of the discourse of a novice teacher when he tries to clarify what the sign of a vector quantity is. The elements considered for the analysis are language (speech and gesturing) and reference system concept as mediators within the process of meaning-making. Our analysis shows the novice teacher has difficulties promoting the understanding of the (negative) sign of a vector quantity and its relationship with the convention used to solve problems of motion of objects. The results shown here are part of a wider ongoing research concerning discourse analysis and teaching practice in grade 11 of two teachers with different profiles, expert and novice, from the theoretical approach of semiotics—the theory of objectification.*

*Keywords: Novice teacher, classroom communication, objectification theory, sign of a vector quantity, semiotic approach.*

## Introduction

From the discussion on the state of research in mathematics education which arose during the 10<sup>th</sup> *International Congress on Mathematical Education* (ICME-10), and as different works indicate (e.g., da Ponte & Chapman, 2006; Adler, 2000), there is growing attention to the teaching practices compared to what occurred in the past, when such practice was not a primary concern. Sfard (2005) states that it was particularly during the first decade of the 21<sup>st</sup> century when there was a decisive change towards the study of teachers' practices. From the works presented in the work group of mathematics and language in the past CERME9, and related with the interests of this research, it is of great importance to point out the interest on communication and interaction in the mathematics teaching and learning processes. In these processes, the use of gestures is included both in a communicative role and as a resource during teaching practice. Thus, we must highlight the works by Nachlieli and Tabach (2015), who show the elements of teaching practice that promote learning, and the work by Farsani (2015) on the role that deictic gestures play as a communicative tool. There are the works regarding the way in which meanings are produced in the classroom and the role of gestures as mediators of such process (e.g. Miranda, Radford & Guzmán, 2013). In this way we seek to contribute to the discussion on the relevance of interaction and communication on teaching and learning processes from an analysis perspective of semiotic orientation.

## Research problem

Da Ponte and Chapman (2006) agree that, in the 90s, Vygotsky's work came to prominence and evolved in a number of research lines with respect to teaching practices. Considering Vygotsky's concept of semiotic mediation –defined as usage of means [artifacts and signs] by which the individual receives the action of social, cultural and historical factors, and acts upon them (Vygotsky, 2009)–, Mariotti (2009) conducted a research with the aim of observing the teacher's role and the use

the teacher gives to artifacts in order to develop mathematical signs in the students during the teaching-learning processes. Mariotti considers that the teacher, playing the role of cultural mediator, is responsible for introducing specific terms and using his or her judgment to recognize what may be referred to as mathematical concepts. Morgan (2006) considers that: “An important starting point for a social semiotic perspective is the recognition that meaning making occurs in social context and language use is functional within those context.” (p. 220). In the same work, the author emphasizes the multimodal characteristic of communication in which, besides language, gestures and the use of other resources are found. In this sense, Arzarello, Paola, Robutti and Sabena (2009) highlight the dynamic process that takes place during the multimodal semiotic activity of the subjects.

Then, the research firstly goes back to the interest on teacher’s practice (a novice teacher data are reported here), and additionally it considers the use of a sociocultural approach of semiotic orientation to observe teachers’ practices. Our objective is to analyze the teacher’s discourse at the moment when he talks about the sign of a vector quantity in a physics class, in which the use of language and gestures is essential during the process of meaning making and awareness. Therefore, we pay close attention to the semiotic means of objectification [language, gestures and signs] that the teacher uses and encourages in the interaction with the students.

### **Conceptual framework**

The research is supported by the theory of objectification (Radford, 2014; 2008) that includes Vygotsky’s notion of semiotic mediation as well as the importance of the use of artifacts and gestures in the processes of knowledge production. Radford (2014) considers that the main objective of the theory of objectification (TO) is that of mathematics education as: “[A]s a political, social, historic and cultural effort with the aim of creating ethical and reflective individuals who take a critical position in mathematics practices historically and culturally constituted.” (Radford, 2014, p. 135–136, free translation). Thus, this formation of the individual involves an analysis between being and knowing in which both of them are closely interrelated. The principle of *labor* or activity represents the fundamental principle of the TO (Radford, 2014). It is through *labor* that the individuals are developed and continuously transformed and that we find the Other and the world in its conceptual and material dimensions. Through labor we find the systems of ideas of culture (systems of scientific, legal, and artistic ideas, etc.) and cultural forms of being as well. Radford and Roth (2011) introduce the concept of joint action, which implies more than a spatial notion where the interaction takes place. It represents the place in which the students and the teacher think and act together in pursuit of a common goal. It is important to emphasize that from TO approach, what mediates is the activity. Where both students and teacher are immersed. However, artifacts and signs continue play a relevant role. They are also part of the activity and are defined as semiotic means of objectification; which are: “These objects, tools, linguistic devices, and signs that individuals intentionally use in social meaning-making process to achieve a stable form of awareness, to make apparent their intentions, and to carry out their actions to attain the goal of their activities” (Radford, 2003, p. 41).

This approach also revisits the notion of consciousness as something concrete; it is a subjective reflection of the world. Then, any consideration regarding learning must also comprehend the field of consciousness in which the students’ thought and emotional orientations are included. Consciousness can be captured through its manifestations: discourse, gestures and all the other sensual actions. In order to recognize the forms of expression, action, and reflection, that are the

mathematical objects, the student goes through a social and physical process of awareness, which is mediated, in turn, by the activity; and where the artifacts and signs both physical and psychological belong to this activity (Radford, 2014; 2008). Therefore, gestures and artifacts act as important elements of the activity and are essential to the reflection processes. In this way, in TO, knowing and individuals are produced in the classroom through labor or activity. One way of identifying how meanings of mathematical objects are produced is through language and gestures.

Within the aim of this work, we include the teacher's practice to seek to characterize how the novice teacher promotes the objectification of the sign of vector quantities. In other research works, the role of gestures and the character of artifacts and signs as mediators has been developed; Roth (2000) particularly points out the importance the use of gestures has in the relationship with speech and in the road towards the scientific language. Roth indicates that, in the absence of an appropriate scientific discourse, gestures help to explain and describe the phenomena among the students. Additionally, he stresses that, during the emergence of the [scientific] discourse, both the iconic and the deictic gestures precede the spoken words associated with them. For their part, Moreno-Armella and Sriraman (2010), consider that the access to [mathematical] objects is not direct, but through mediation. The way in which we interact with our environment and the rest of the people—for instance, through language—is part of our symbolic nature. They state that: “Only humans possess, (...) what can be termed *explicit cognition* that allows us to go from learning to knowledge. Explicit cognition is symbolic cognition. The symbol refers to something that, although arbitrary, *is shared and agreed by a community.*” (Moreno-Armella & Sriraman, 2010, p. 216).

## Method

This is a qualitative research performed through a case study. The pilot study was carried out in a high-school (grade 11) from Mexico City. The participants were two teachers (expert and novice) who teach physics and who have over 20 years and 2 years of experience, respectively. This article reports the data collected from the novice teacher. The instrument to collect the data was non-participant observation of the *Physics I* classes. In the classes, the teacher addressed mechanics topics, specifically, Newtonian dynamics. The teacher considered the concepts of force, displacement, and interpretation of Cartesian graphs. The classes lasted two hours (twice per week) and one hour (once per week). We observed 12 sessions and obtained 20 hours of recording. We used two cameras controlled by the researcher. One camera remained fixed and was directed to the board while the other was moved to focus on the interactions during the students' participations. In addition, we used a voice recorder placed on the teacher to obtain audio recordings of the classes. After the data were collected, we watched the videos from the classes to identify moments when key concepts had been addressed. Once the moments (class segments-excerpts) were identified, we transcribed what occurred in those segments. Our analysis is based on those transcriptions.

## Analysis and discussion of results

Below we present excerpts that show the discourse of a novice teacher who tries to clarify the purpose of using the sign in a vector quantity on a free fall problem. In its entirety, the teacher's discourse lasts around 10 minutes. To carry out the analysis, we identified three main excerpts that deal with the teacher's discourse regarding the concept of a vector quantity. The excerpt starts after a student [who does not take part in the dialog] goes to the board to write a response and uses the value of

acceleration of gravity (“ $g$ ”) with a positive sign (see Figure 1-Photo 2). It is two students (S1 and S2) have a question about the sign that the teacher’s explanation starts. The excerpts correspond to a class in Spanish, in such a way that a translation in English is presented, trying to maintain dialogues fidelity.

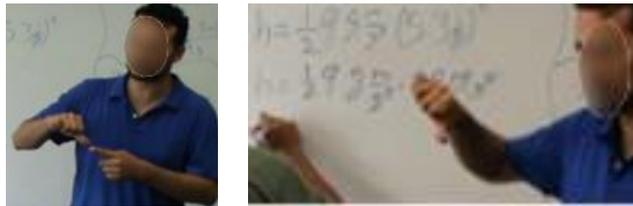
### Excerpt 1- Is gravity negative?

S1: Teacher, is gravity negative?

Teacher: It is negative.

S2: Is it?

Teacher: Gravity will always be negative, right? But in this case (...) I’d told you that acceleration was a vector, right? Then, for example, if you want to speak in, let’s say, a vector manner, you must express gravity with its negative. Because it will always point down [*makes a gesture; see Figure 1-Photo 1*], right? But in this case, if you place it like this, in a scalar manner (...) we’re only looking at the magnitude of the gravity. Which would be 9.8. I mean, gravity will always go down [*A student says: “but not now”*] on the axis and down. Let’s leave it at that for now [*with the positive sign*].



**Figure 1: Photos of gestures used by the teacher to represent the sign of gravity in two moments (Photo 1-left; Photo 2-right).**

The intention of the teacher is that the students understand the sign of  $g$ ; that is to say, the students have to be aware of the meaning of the sign of gravity. The teacher seeks to encourage this awareness through a speech in which he includes gestures. However, from this point it is evident there is no articulation between the teacher’s verbal arguments and his gestures. The teacher stressed that  $g$  “will always be negative.” However, the argument the teacher uses gesturally links  $g$  with the type of motion (free fall) and not with the mathematical relationships of the function of motion (position with respect to time). When he says “Because it will always point down”, the teacher does not explain that “down” —or “up”, given the case—depends on a frame of reference involving a starting point (origin) from which measurements and directions (orientations) are taken to obtain numerical values. That is, the set of conventions used is arbitrary.

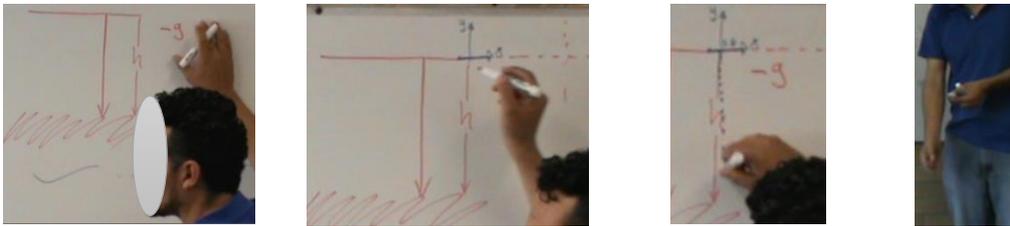
### Excerpt 2- The system of reference

S3: And if I did it using the minus nine point eight? [*referring to  $g = -9.8m/s^2$* ].

Teacher: If you did it with the minus, that means that, what does it mean? That when you were talking about this problem... [*He is interrupted by another student*].

S1: But you said that it was if it was falling, then...

Teacher: I'm telling you "g" will always be negative, right? [See Figure 2-Photo 1] Now, you will take a point of reference (...) [the teacher draws a system of coordinated axes; see Figure 2-Photo 2]. If you take a point of reference here. Here, it would be y [vertical], x [horizontal], right? Then, if you take the point of reference there, what is the value of this point? [pointing at the origin of the Cartesian system he drew] It is the origin, what is its value? [S1 answers: "zero, comma zero"] Right now, we are only acting on y, then the value will always be zero at x. Then, if this [the stone] is falling towards here [simulates the fall of the object with respect to the diagram; see Figure 2-Photo 3], that is why we have a negative value in y. Because y that goes down is negative. (...) Because the point of reference, we are up here [points at the origin of the Cartesian system] and we are measuring how the little ball falls down, but from my point of reference [makes a gesture using both hands; see Figure 2-Photo 4]. Which would be from the bridge. I won't be measuring this in the water, right? Then, that's why it is negative in this case [the distance (height)] and that's why I'm telling you that this [acceleration of gravity] is negative.



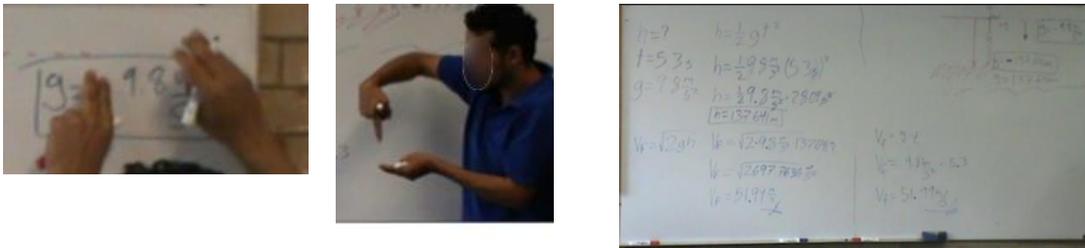
**Figure 2: From left to right, photos of gestures used by the teacher to represent: the phenomenon (Photo 1), the system of reference (Photo 2), the motion of the object with respect to the system of reference (Photo 3), and the measurement of the distance (Photo 4).**

S1 goes back to the notion that the sign and the values obtained depend on the direction of the motion observed. Later, the teacher incorporates a conceptual resource he considers necessary to understand the sign of  $g$ , that is, the concept of system of reference. It is observed that the teacher determines it [system of reference] from the system of coordinated axes (Cartesian graph) and its usual directions (positive: up and to the right; and negative: down and to the left). At this point of his speech, the teacher mainly uses the mathematical concept of system of reference. His use of the language makes him focus on conveying the mathematical meaning of the problem while he uses gestures only when addressing the physics phenomenon. What is observed is that it considers mathematical thinking and physics separately. For instance, the teacher seems to use gestures to exemplify frames of reference oriented negatively down only. The meaning of his gestures only depends on the particular motion of the object (Photos 3 and 4). Thus, the teacher is explicit when he says: "That is why we have a negative value in y. Because y that goes down is negative." Therefore, with respect to the language used by the teacher in this excerpt, it is unclear how students can be aware of the sign of  $g$  from the use of reference systems when the teacher includes the system of reference in his speech.

### Excerpt 3- Two signs for the same problem

S3: But I still don't understand the thing about gravity.

Teacher: I'm telling you that, in this case, the acceleration is a vector. And if the acceleration is a vector, the acceleration of the gravity will also be a vector, ok? Then, this here [points out at the sign in Figure 2- Photo 1], the negative of the gravity is indicating where gravity is always directing to. Then, it would be something like this [draws an arrow pointing down on the board]. It will always be directed downwards. Now, this will always be [writes: " $g = -9.8m/s^2$ "], this will never change. Now, if you do not want to express this to me [referring to the acceleration of gravity], then give me the scalar, I mean, give me the magnitude of your gravity. Then, if you give me the magnitude, it would only be this here [see Figure 3-Photo 1], yes? I mean, without the negative, 9.8. If you tell me where it is headed to, you're giving me the direction [see Figure 3-Photo 2], which is downwards, really. And in that same way, to get the distance covered. If you tell me, are you going to say it in distance? Or are you going to say it in displacement? Displacement is supposed to be a vector, too. (...) Then, when you get the magnitude, it will always be a magnitude like this [covers the negative sign of the acceleration of gravity again], positive.



**Figure 3: Photos of gestures used by the teacher to represent: the magnitude of a vector (Photo1-left) and the direction of a vector (Photo2-center); additionally, a photo of the board (Photo 3-right)**

What S3 says at the beginning of the excerpt indicates that, so far, the “relativity of the sign” has not been understood and that it depends on the frame of reference used to analyze the physics phenomenon. The teacher goes on with the discourse, explaining that knowing the sign of a quantity means knowing the direction of the motion, and says: “the negative of the gravity is telling [us] where gravity is always directed to.” However, gravity does not go “upwards” or “downwards”, but to the core of Earth, which to our perception is “falling down”. The difficulties arise when trying to explain why. Then, the teacher focuses his attention on the magnitude of a vector (see Figure 3-Photo 1). Again, using a gesture, he hides the negative sign of  $g$  to refer to a probable positive value, yet he relates such value to a scalar quantity and not to the direction of the vector in a system of reference. The teacher implies that one can make reference to the two signs in one quantity in the same problem, which results in an ambiguity to the student.

In teacher discourse, it is important to realize the use he makes of the board, it is noteworthy saying the teacher only writes numbers, symbols (Cartesian graph, vectors) and formulas, but fails to write a single word; and that creates a gap between his discourse (spoken language and gestures) and symbolic language. The students are used to writing down what information is on the board, without adding elements from the spoken language. Therefore, when they go back to check their notes, they can hardly remember the exact words the teacher used, instead, they only see abstract symbols. Thus, reconstructing both the discourse and the discussion that unfolded can be difficult for them. Thus, it would be convenient to carry out research aimed at an analysis of the use of resources by the teacher.

## Conclusions

In this work, we observe the roles language and gestures play in a novice teacher's discourse and the difficulties he faced when trying to stabilize awareness on the meaning of the sign of  $g$ . Then, the way in which the meanings of the mathematical concepts are displayed and understood involves the mobilization of gestures and signs. This is because gestures, artifacts, signs, and the process of meaning making in the classroom, have a semiotic nature. We observed the complexity and the importance of articulating language and other semiotic resources as gestures and concepts—system of reference—in the processes of meaning making. Particularly, we observed there was no satisfactory coordination between the teacher's gestures and language. While the teacher consistently used gestures to point out the negative sign of the gravity when the object “falls down”, he was vague when trying to explain why the sign was negative from its vector character. Then, the teacher focused his language only on the mathematical characteristic of the problem, but he focused his gestures on the physics description of the problem. We observed, however, an attempt to coordinate language and gestures in the excerpt in which he includes the use of the concept of system of reference. It follows that determining the system of reference to solve a given problem in advance is essential. Therefore, the system of reference used as a semiotic resource may allow this articulation between the mathematical meaning and the physics motion of objects to be understood. And this motivates us to conduct further research on this line.

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