COMMUNICATION SKILLS FOR TEACHING

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What role do teachers play when introducing an innovative educational proposal?

To ensure that teaching and learning represent the two sides of a single coin or the two sides of any given class is, and always has been, education's main objective. The possibility of organizing teaching in such a way as to foster better learning has been one of the main premises of education since Comenius (1592-1604). However, when dealing with the organization and execution of such teaching in classrooms we find teachers who may or may not have the skills necessary to communicate with their students, skills that can facilitate or preclude fulfillment of the teaching proposal.

Today we clearly understand that any curricular innovation must be accompanied by research that focuses development of said innovation in the classroom and that describes not only the activities proposed for introducing the innovations, but the communication skills that teachers must develop to ensure that their students attain the intended objectives.

Science teaching has established itself in recent years as a field of research and theoretic systematization focusing the various facets that characterize science teaching. This conglomeration of knowledge has been lending support for the planning of courses whose proposals would be to lead students to produce significant knowledge regarding not only the content of the scientific disciplines, but also, and more importantly, the construction of science itself.

Various researchers have shown that science can be understood as a culture that has its own rules, values and language, and that science teaching and learning should be seen as a process of enculturation (Sutton 1998; Driver and Newton 1997; Roth 1999; Jiménez Aleixandre 2005; Carvalho 2005; Capecchi and Carvalho 2006). This concept of science teaching as enculturation calls for the development of multiple classroom practices aimed to facilitate the difficult task of introducing students to the universe of science by providing new views of the world as well as new languages.

However, this change of focus in teaching will only become reality if the teacher's role in the classroom is also changed and teachers, in addition to their traditional practices, embrace a series of new discourses and new skills. In this paper we intend to seek out these new skills described by the various authors who study teaching and its development in the classroom.

COMMUNICATIVE APPROACHES ACCORDING TO MORTIMER AND SCOTT

Prior to introducing the skills teachers need to put scientific discourse into practice in the classroom, we find it interesting to present the work developed by Mortimer and Scott (2002) who propose research focusing the most traditional existing discursive activities in teaching and that constitute teachers' expositive routines. In the opinion of these authors, the priority is to make existing discursive practices visible, and only then point out how they can be expanded.

Mortimer and Scott present a tool for analyzing meaning-making interactions and the production of meanings in the classroom. The analytical framework presented is based on five linked aspects that focus the teacher's role and are grouped in terms of:

i- teaching focuses – that investigate: 1- teaching purpose, and 2- content;

ii- teaching approach – that focuses: 3- communicative approaches, and

iii- teaching actions – subdivided into; 4 – patterns of discourse, and 5 – teacher interventions.

To these authors, the 'communicative approach' concept is the core of their analytical framework because it provides the perspective of 'how' teachers show their teaching purpose when dealing with the chosen content. They identify four classes of communicative approach that are defined by means of characterization of the discourse between teachers and students, or among students, in terms of two dimensions: *dialogic* or *authoritative* discourse, and *interactive* or *non-interactive* discourse.

These four classes of communicative approach are inter-linked as shown in the following chart.

	Interactive	Non-interactive
Dialogic	Interactive/dialogic	Non-interactive/dialogic
Authoritative	Interactive/authoritative	Non-interactive/authoritative

In regard to communication in the classroom, the authors show that an important characteristic of the distinction between the dialogic and authoritative approaches is that a discursive sequence can be identified as dialogic or authoritative regardless of its having been enunciated by one sole individual, or interactively. As they explain, "What makes talk functionally dialogic is the fact that it expresses more than one point of view, more than one voice is represented and taken into account, and not whether it was produced by a group of individuals, or by an individual alone." This interpretation of dialogic discourse therefore relates to the second dimension of the communicative approach that distinguishes interactive discourse – that which allows the intervention of more than one person – and non-interactive discourse in which only one person speaks.

These four classes of communicative approach describe teachers' skills in conducting discourse in the classroom and show how they interact with their students in the various stages of the class.

The *interactive/dialogic* class indicates the interval of the class when teacher and students explore ideas, formulate questions, and work different points of view. This class of communicative approach shows the teacher's important skill in exploring students' ideas, encouraging all to express themselves openly. Apart from communication skills, this requires planning skills to address the creation of problems or challenging situations related to the content to be developed in order to engage students both intellectually and emotionally.

The *non-interactive/dialogic* class shows when teachers, in the course of their explanation, consider several viewpoints that their students have already repeatedly made explicit, highlighting similarities and differences. This class of communicative approach reflects the teacher's skill in giving form to the meanings introduced based on discussion that has already taken place.

The *interactive/authoritative* class reflects the teacher's action in guiding students toward a specific objective by means of a sequence of questions and answers. This type of communication reflects a quite common skill in traditional teaching when development of the content plays an outstanding role in the classroom.

The *non-interactive/authoritative* class shows the teacher's action, presenting a specific point of view. This communicative approach demands that teachers have the ability to express their ideas very clearly.

OTHER COMMUNICATION SKILLS ESSENTIAL TO THE INTRODUCTION OF INNOVATIVE TEACHING PROPOSALS

In our opinion it is also necessary to introduce other types of discourse in classrooms with a view to engaging students' interest in the languages characteristic of science. To achieve this objective we must discuss the communicative skills teachers require to develop understanding of the processes involved in building up this knowledge, which goes beyond the traditional discursive practices but does not relinquish them.

Driver et al. (1999) defend the premise that to understand the symbolic world of science it is necessary for students to have contact not only with finished products, but also with meaning-making processes based on the use of languages stemming from the scientific culture, and as Ogborn et al. (1996) show:

> ***"We have tried to go further, and to look at all the activity of the classroom – talk, gesture, pictures, graphs, and tables, experimenting, doing demonstrations – as a ways of making meanings"***.

The study of how the different science languages are being used in the teaching and learning of scientific content in the classroom is a very fertile field of research and ever greater numbers of papers on this theme are being published in the main science teaching journals – Kress et al. 1998, 2002; Lemke, 2000, 2003; Jewitt et al. 2001; Jewit e Scott 2002; Roth 2002, Piccinini 2003; Capecchi e Carvalho 2006; Grandy e Duschl 2007. Generally speaking, these authors question the supremacy normally attributed to verbal language in research that features teaching and learning, showing that other languages mediate the construction of knowledge in the classroom and that these other languages are worthy of research.

Lemke (1998), in a study on scientific texts, calls attention to the origin and integration of different languages (semiotic modes) used in communication. The author recalls that verbal languages are always accompanied by gestures and facial expressions, and that written language comes accompanied by tables and graphs. We must therefore also pay attention to the visual languages that always accompany verbal language.

Kress et al. (2001) call attention to the functional specialization that different modes of communication undergo according to their uses in the course of history. One mode may develop better than another in certain directions and will therefore have greater potential for meaning-making or impose further limitations. This fact was also shown by various other studies (Lemke 2003; Jewiit et al 2001). These authors observed that different modes represent specific roles in the construction of concepts in the classroom. The specialty of any given mode of communication can make it more or less appropriate for communication in the classroom because, as Lemke (1998) shows:

> *"We can indicate modulation of speed or size, or complex relations of shape or relative position, far better than we can with words, and we can let that gesture leave a trace and become a visual-graphical representation that will sit still and let us re-examine it at our leisure. (p.3)"*.

The specialization acquired by different languages in the classroom makes it possible to build meanings by association, and this aspect is essential to the construction of scientific knowledge.

Lemke (1998) also shows us that mathematical language, greatly used in the production of scientific knowledge, also presents a semiotic modality that unites two aspects: typological – related to the communication of differences and classifications, predominantly in verbal language; and topological – related to the communication/representation of interactions and relations, represented by visual language. Thus, graphs, very widely used in physics classes, present a character of continuity stemming from visual modes, and a grammar implicit in the reading of them that stems from verbal language.

Therefore, in order for us to study the communication skills necessary for teaching that proposes to introduce students to the universe of the sciences, we must aggregate the verbal skills traditionally found in the classroom to other modes of communication that will help students in the construction of scientific knowledge.

We will present some of these communication skills by introducing a brief theoretic reference of analysis followed by examples of physics teaching for the middle level and for the first grades of elementary school.

THE SKILLS TO AROUSE ARGUMENTATION IN THE CLASSROOM

The skills to lead students to argue deserves to be worked by teachers in classrooms since it is by the argumentative exposition of their ideas that students construct explanations of phenomena and develop rational thinking.

However, teaching students to argue is not an easy task and it requires a great deal of skill on the part of the teacher. To attain this objective, teachers must, by means of short questions, lead students to ponder the explanatory power of each statement, recognize contradictory statements, identify evidence, integrate different statements by pondering such evidence, and so on.

It is important for teachers to keep in mind that although an initial condition for argumentation is discord, in cases where this strategy is used to construct explanations in physics classes, the group must necessarily arrive at a synthesis or consensus (Capecchi, 2002).

For this to occur, students must have the opportunity to express their ideas in the classroom, and to make this possible, teachers must create an encouraging environment that will allow students to acquire confidence and involvement in the scientific practices. It is teacher-student interaction that makes students aware of their own ideas and gives them the opportunity to rehearse the use of a language that is appropriate for dealing with nature in a scientific manner (Carvalho 2007).

For some time now, researchers in the areas of science teaching (Candela, 1999; Duschl et. al. 1999; Jiménez – Aleixandre et. al., 1998; Driver et. al., 1999; Villani, 2002) have been focusing argumentation as a discursive tool of the scientific culture. Capecchi

(2004), in a bibliographic survey of these works, showed that they can be separated into two groups according to the focus adopted in regard to the argumentation theme. While Candela's studies cover general characteristics of argumentative discourse in science classes, the other works cited focus structural aspects that approximate arguments constructed in the classroom to those employed within the scientific culture.

Candela (1997, 1999) observed that when discursive practices are increasingly encouraged in science classes, the students increasingly grasp new forms of expressing themselves, thereby acquiring more independence and more confidence in their own ideas. The main focus of Candela's research was to investigate students' capacity to express their opinions and take an active part in the knowledge negotiation processes.

To investigate structural aspects of arguments that make it possible to approximate them to scientific argumentation, the authors of the remaining studies cited above adopt a pattern designed by Toulmin (1958) as reference.

Within the perspective of science learning as enculturation, Driver and Newton (1997) suggest the creation of activities aimed to stimulate argumentation among students in the classroom, and present categories for the analysis of such arguments based on the argument pattern designed by Toulmin (op. cit.). The categories drawn up emphasize the presence of conflicting theories and syntheses in classroom discussions. Thus, a quality level is attributed to each category based on both the complexity of the arguments used and on the existence – or lack – of interaction between different ideas. The authors classify incomplete arguments that lack justification as level 0, and arguments that may be incomplete but that do present justification as level 1. When we find competitive statements we classify them as level 2 arguments, and if the students use qualifiers or refutation, we classify the argumentation as level 3. Making judgments by integrating different arguments – level 4 – indicates a strong grasp of the nature of the scientific knowledge. When students seek a synthesis in a discussion in regard to some certain science-related phenomenon or theme, they are seeking more wide-ranging explanatory models, and this necessarily implies drawing up more complete arguments.

An example featuring a physics class in a middle school

The teaching episode we are about to present was extracted from a class on calorimetry given to a first-year middle school class (Silva 1995) that was later analyzed from the point of view of the arguments developed in the classroom (Capecchi, Carvalho e Silva 2000).

In this class, prior to the sequence analyzed, the teacher had carried out some experiments in the laboratory with the students, comparing a microwave oven and a conventional oven. Below is the transcription of the phase of the class in which the teacher asked the students to read aloud what they had written about the two different types of oven based on discussions in previous classes.

> *Student 8: Teacher ... what I wrote is similar to what J wrote ... I wrote that the waves interact directly with the food ... they don't interact with the container or with the air ... that's inside there ... so this energy of agitation of the molecules of the food will be greater ... than the energy ... of the molecules of air over there in the normal oven [a gas oven] ... so there's a larger difference in temperature ... there will be more propagation of heat ... so it will also evaporate more water and it will get drier.*

> *Teacher: Wait a minute ... Student 8 pointed out a new situation: he mentioned molecules of food ... food basically consists of what molecules?*

Student 9: Water ...

Teacher: Water and what else? Food is made up of what?

Student 10: Starch ... carbohydrates ...and other things.

Teacher: Do the microwaves interact as a whole? ... on all the molecules? ... Do you suppose they interact with all of them?

Student 5: I think it's with the water ones, isn't it?

J: Yeah, and then the water molecules pass it [the heat] on to the other molecules of the food.

Teacher: Great! Tell me, João, at what temperature does water begin to evaporate? At what temperature will it start to boil?

J: 100 degrees ...

Teacher: 100 degrees Celsius ... now I ask you the following: is this microwave going to interact with a protein molecule?

J: The water molecules...

Teacher: Student 8 said something important: that the temperature to which the food was submitted in the microwave oven is greater than that to which it was submitted in the gas oven. Do you all agree?

Student 11: I disagree...

Teacher: Tell me ...

Student 11: If a water molecule evaporates at 100 degrees, the maximum that it will heat up is to 100 degrees Celsius ... in the microwave oven. Then it will evaporate ... and in the [gas] oven the temperature is higher because it heats up all the molecules ... not just the water molecules ... When we open up the microwave oven we see lots of steam ... and in the [gas] oven what we feel is a just a gush ... of hot air ... (Silva, op. cit., p. 231 e 232)

In this sequence, the students present affirmations with justification, hypothesis, refutation, and synthesis as well. But this was only possible thanks to the teacher's communication skills. Starting with the affirmation of Student 8, the teacher begins asking questions that call the students' attention to new aspects of the problem. The teacher creates a classroom environment in which students are at ease to express their ideas freely, but the basic knowledge already shared by the class is emphasized by means of directive questioning.

The teacher also sought to call the students' attention to what their colleagues say. When the teacher began taking part, alternating discursive patterns, the students' attention was directed to fundamental aspects already discussed previously, pushing toward the formulation of a synthesis (level 4). Harking back to basic knowledge was fundamental to arriving at the final conclusion, and taking advantage of Student 8's spontaneous talk substantially enriched the discussion.

THE SKILLS TO TRANSFORM EVERYDAY LANGUAGE INTO SCIENTIFIC LANGUAGE

Considering the role of argumentation as a scientific tool reinforces the need for teachers to devote special attention to the languages students use during discussions held in the classroom. As Lemke (1990, p.105) points out

> *"In teaching science, or any subject, we do not want students to simply parrot back the words. We want them to be able to construct the essential meanings in their own words... ...But they must express the same essential meanings if they are to be scientifically acceptable..."*

And this skill, this ability to transform students' everyday language into scientific language, requires great care on the part of teachers – teachers must not reprimand students when leading them to express themselves scientifically. The passage from everyday to scientific language must be made naturally to prevent students from feeling oppressed and refusing to continue to take part in the debate. And this is not easy. We see that the phenomenon of students speaking increasingly less as they progress to higher levels of schooling is not an exclusively Brazilian phenomenon. Grandy and Duschl (2007) show that children in the first years of school ask questions, but these questions are not necessarily scientific and what was observed in many classroom environments is that instead of the students learning to ask scientific questions, they simply stop asking questions.

An example from a physics class in a middle school

This is a short excerpt from the end of a lab class that featured an attempt to obtain the level of the temperature of water when it reaches the boiling point. The students are analyzing the data obtained by the different groups. The sequence below was taken from a paper by Capecchi (2004). The numbers in parentheses correspond to the sequence of the teaching episode chosen. The letter "A" stands for student, and "P" stands for teacher.

> *(10) A14: because the water was almost ninety-seven... more or less...*
>
> *(11) P: ah ((student says something)) the temperature ... the temperature of ALL ...*
>
> *(12) A2: almost all...*
>
> *(13) P: ALMOST all ... but ... ah:: ninety-seven ... ninety-seven and a half ... ninety seven ... ninety-eight ... ninety-six and a half ... ninety-six – continuation of the fifth - ... ninety-six and a half... ninety-six point nine... ninety-seven... then – from the comparison of results in all the groups ... ((30' pause)) ... in all ... the temperature stabilized at around ninety-seven degrees... [P writes on the blackboard: "From the comparison of results of all the groups, we have: a) all began with the same temperature (room temperature); b) in all the temperature stabilized at approximately 97^{o}C]*

The teacher encourages student participation and does not reprimand them, but he is very cautious in regard to scientific language: the contribution of A14 – "because the water was almost ninety-seven... more or less" (sequence 10) – is transformed into "in all, the temperature stabilized at approximately ninety-seven degrees Celsius", when presented in writing.

In sequence 13, the teacher accepts the contribution of A2 and checks the data of the table, supporting the student's participation. Here also we see the difference between the students' everyday language and its transformation into scientific language by the teacher. From the point of view of A2, the differences found in the temperatures obtained are important, while for the teacher, who represents the scientific discourse, they can be disregarded. The teacher unifies the discourse in the sequence – "*then – from the comparison of results in all the groups ... ((30' pause)) ... in all ... the temperature stabilized at around ninety-seven degrees*".

Example in a science (physics) class for an elementary course

This is a segment from a class given in an elementary school. The students were given experimental material consisting of a ramp that ended in a loop. At the top of the loop there was a small basket. The students, divided into small groups, were asked to solve the following problem: From what point on the ramp should you release a little ball to make it fall into the basket?

In the segment transcribed below, the students, already having solved the problem, are explaining to the teacher what they did – why the little ball fell into the basket.

> *Teacher: Why did the little ball fall into the basket?*
>
> *Student 1: The speed was too fast for the little ball to stay up there at the top and fall in the basket, so it made the whole loop, and then we figured, and figured until it worked right.*
>
> *Student 2: When it was at the start, it was too fast, so it didn't... work... . Then lowering it a little, and then we went too low, and it didn't work because there wasn't enough pressure, so then we put it up just a little bit higher and it worked right.*
>
> *Student 3: The less speed you put, the little ball ... goes right in the basket. We discovered that.*
>
> *Student 4: When we put the little ball at a certain point, then when it spins, it loses pressure and falls in the basket.*
>
> *Student5: We put it down lower, it doesn't make the whole loop. It stops in the middle and falls in the basket.*
>
> *Student 6: Because when it's up at the top, it gets too much pressure and when it's lower down it gets less pressure and doesn't make the whole loop, it goes a little less and falls in the basket.*
>
> *Teacher 1: Okay kids, now we have one little question, because some of our colleagues, when they explain the experiment, explain it talking about speed, speed of the little ball. Others say pressure of the little ball – are these two different things, or not? So, I want you to tell me if it's speed, or if it's pressure, or if they're both the same thing.*
>
> *Student 5: It's speed. When we put it at a certain point, it ran... ran a little faster. We put it a little lower and it worked.*
>
> *Student 2: It's speed, because when you put it on that little black point there, it goes a little faster and falls (pointing with a finger) in the basket.*
>
> *Student 3: Because up there, it's steeper, so it gets up more speed.*

The teacher's intervention was important to make the students aware of their explanations. By counterposing the two words, 'speed and pressure', the students were led to choose the most appropriate word for their explanations themselves and to use only the word 'speed'. This was the first time that these students had come into contact with physical phenomena and they must be initiated in physical explanations with the words that are scientifically most appropriate.

THE SKILLS TO INTRODUCE STUDENTS TO MATHEMATICAL LANGUAGES – TABLES, GRAPHS, EQUATIONS

To discuss the skills involved in introducing students to the various aspects of mathematical languages we must return to two concepts we presented when we discussed the various scientific languages: the specialization/cooperation of the different modes of communication for the construction of meanings (Kress et al.2001; Márquez et. al., 2003), and the typological/topological aspects of mathematical language (Lemke 1998), since verbal and written languages alone are not sufficient for communicating scientific findings.

One important communication skill in science teaching is to ensure that the languages used by teachers are able to:

- Cooperate: when two or more languages attribute one same meaning to a concept or phenomenon, carrying out similar functions. For example, when teachers say that a graph shows a linear increase in temperature, they can, at the same time, use a gesture that represents the curve shown on the graph, or point directly to the point of the increase. Therefore, speech, gesture, and curve are used cooperatively to express the same idea.
- Specialize: when two or more languages attribute a meaning to a concept or phenomenon that carry out different functions. For example, when teachers explain the variation of an entity on a graph, they can use speech to point out an increase or decrease, while the curve can show how that variation came about – linear, exponential, logarithmic, etc. Thus, these two languages are used for meaning making in a specialized manner.

According to Lemke (1999), science is not made or communicated solely by verbal or written language, because science language is a semiotic hybrid that contains, at the same time, a verbal-*typological* and a mathematical-graphic-operational-*topological* component.

Typological resources are understood to be any sort of classification that involves discrete categories such as: hot and cold; far and near; high and low; angular momentum and linear momentum; conduction, convection, and irradiation; etc. They serve to analyze and classify the cultural contexts by means of these categories that, generally speaking, are opposite to one another.

Topological resources, in their turn, are continuous, or quasi-continuous variations on some property of material objects, i.e., they are the meanings contained in the proportions between the entities that we construct. They represent the continuous variables such as size, shape, distance, proportion, intensity, time, velocity, temperature, pressure, voltage, concentration, density, etc., and each of these entities can vary within the topology of real numbers. Among these resources we also have: drawings, gestures, graphs, and any type of visual representation. According to Lemke (1998)

> *Natural language is very limited in its ability to describe continuous variation, shape, and movement in space. Gesture is a more suitable language in which to express such meanings. And drawings and visual depictions, which are in many ways the lasting traces of gestures, standing to gestures as writing does to speech, are the time-independent medium of choice for such expressions of meaning. For quantitative relationships, we have furthermore extended natural language with the language of mathematics, and learned to use mathematics as a bridge between verbal language and the meanings we make in visual representations.* (p.4).

Therefore, in order to introduce students to the world of science, teachers must be capable of integrating in their classes verbal discourse, mathematical expressions, graphic and visual depictions, and in this teaching process create an environment in which, little by little, students also begin constructing their meanings with the different languages.

The importance of the skill that teachers must have in integrating all the different languages in their teaching communication stem from the fact that to scientists, a graph or a formula is practically the actual phenomenon under discussion, while to students these are other languages to be decoded, and if they are not explicitly related to a phenomenon, they become just one more formalism, to be memorized, devoid of meaning.

This fact is very common in the formal teaching of science when the content of the disciplines is often reduced to mere operational treatment of the mathematical formulas, without taking into account their origins and meaning-making processes. Students' understanding of the advantages and limitations of the various languages for making meanings within the scientific culture is what makes the difference in students' learning.

Examples from middle-school physics classes

The examples below were taken from classes recorded in first year middle school classes within the Thermodynamics Teaching Project (Carvalho, 1999). These teaching episodes were among those chosen and analyzed by Carmo (2006) when studying the construction of mathematical language in these classes.

In these episodes, in addition to the verbal language, we will also analyze the teacher's gestural language and graphic language (blackboard), and for this reason the transcripts are presented in a different format and in compliance with specific codes[1].

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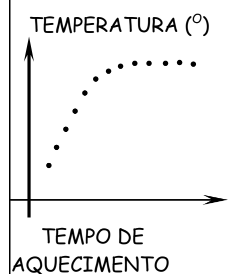
[1] P stands for teacher; A1..., A2... students; A? unidentified student; the capital letters show a stronger voice intonation; when the words are underlined, it means that the teacher is drawing or writing on the board at the same time; the words between (( )) are observations by the person who transcribed the episodes.

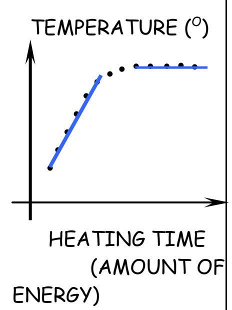
Episode 1

Verbal language / *Actions*	Visual / Written
1. P: *((the teacher is standing facing the group in the middle of the classroom))* OK ... let's pay attention here for a minute ... I asked you NOT to connect the dots ... we're not making a mathematical graph ... mathematical graphs represent exact equations ... you ... assign values for x ... calculate y ... *((comments from students))* and everything works perfectly ... we DO NOT know... the result of this graph... we have a SERIES of measurements... we put them on the graph to see what happens... and everyone ended up with something more or less.. like this... OK:: I walked around the room... I saw what the drawing looked like... it looked more or less like this... right...?	Drawing dots on the graph 
2. A2: Yes	
3. A?: Right...	
4. P: Didn't it!	
5. A2: uh-huh...	
6. A7: yeah ...	
7. A4: But... ()	

In sequence 1, it is important to point out the teacher's skill in communicating to her students the specificity of the nature of a graph used in physics, emphasizing that in scientific research there is no certainty as to what results will be obtained. This communication skill shows the teacher's concern about treating the graph in a manner similar to routine scientific use.

She uses the *specialization* of languages when the meaning of the verbal language is supported by the visual language because the verbal language alone is not sufficient to represent the idea being focused. Using the specialization of languages, the teacher is introducing students to the *topological* meaning of the curve, a meaning that would be very hard for students to grasp were the teacher to use only verbal language.

Episode 2

Verbal language / *Actions*	Visual / Written	Gestures
8. P: everyone... had... a part... where the temperature starts increasing... that corresponds to this slanted part... then here there was a little space that makes a... that sort of curves a little... OK?... it's not very STRAIGHT... and then... the temperature stabilized here... we can SEE... that... THIS HERE LOOKS LIKE a straight line... this here looks like ANOTHER straight line... not here because here:: it sort of curves... but... it doesn't give that impression... LOOKING ONLY AT THE DOTS... that's why I asked you not to connect... to only put in the dots... because here we have a straight line... here we would have a slight curve... and then it connects with another horizontal straight line?	*Draws two straight lines on the graph*  	Simulates ascending straight line Follows dots on the graph with her hand
9. A: uh-huh...*((students answer together))*		
10. A?: More or less...		
11. P: If... we get a ruler... and put in...		
12. A?: straight line...		
13. P: it won't be a straight line...		
14. A17: no ...		Simulates ascending straight line
15. P: but everything points to...		
16. A?: ...it being a straight line...		
17. A17: that it's a straight line ... oh ... gosh ...		
18. P: how can we solve this?		
19. A5: mine didn't give a straight line...		
A18: this here didn't give a straight line....		

In sequence 8, the teacher demonstrates skill in using verbal and gestural language *cooperatively* (simulating an ascending straight line and following the dots on the graph) to emphasize the *topological* characteristics of the phenomenon (linear increase and constancy of the temperature over a certain period of time).

When the students reveal a touch of skepticism (sequences 10, 19, and 20) when answering the question proposed (sequence 9), the teacher demonstrates her communication skill by using cooperation between verbal and gestural language to show the linearity of the increase.

Episode 3

Verbal language / *Actions*	Visual / Written	Gestures
12. P: it's not 10 degrees... it's from 18 degrees to 30... that makes 12 degrees... *((in the group))* 13. A: 12... teacher 14. P: 12 degrees... 12 minutes well it's not exactly that... ((inaudíble))... 29... then it's 11 degrees in 2 minutes... then... for each minute... 5 and a half degrees... 15. A3: you were using a blowtorch... bro ((*Probably looking at the data of the group that the teacher was helping, which was not his group*)) 16. P: then ... that depends on the condi - - we'll see - - it depends on the conditions of each group ((44')) 17. A3: for example he used a blowtorch.... *((P erases the part on the board that showed the function $\theta = a.t + b$ and its respective graph and continues writing the script))* *((In the following minutes P goes on helping the students, until the recess, when some students continue to carry out the activity. This event continued after the recess.))*	the value of "a" corresponds to the inclination of the graph. In other words, how many ^{o}C does the temperature increase per minute. To discover the value of "a", we verify that the temperature corresponding to 1 minute is θ = ... , that is, " "in 1 minute, the temperature rose $\theta 1 - \theta o$ = ... oC. So then we write the function corresponding to our graph: θ = ... t + ..."	

This episode shows how the student understood the graphic language perfectly. A2, when observing colleagues' data, noted that the temperature increase was quite substantial as compared to that observed in previous classes. Thus, although jokingly, his words show how he related the phenomenon to the mathematical representation. In other words, he sees the quick increase in temperature in both the algebraic and in the graphic language, which led him to tease his colleagues about the blowtorch.

As Carmo (2006) pointed out, "this student, like the scientists of Roth (2003), seems to see the phenomenon in the graph and in the function obtained by his colleague".

In these three teaching episodes we see the importance of cooperation and specialization between the languages that teachers use as part of their arsenal of communication skills. On the other hand, it is important to note the gradual construction of topological meanings to represent phenomena. This integration of the different mathematical languages thus becomes just as natural to students as it is to scientists.

ANSWERING THE INITIAL QUESTION

The communication skills teachers require to create an intellectual environment that leads students to scientific enculturation goes far beyond the traditional discursive practices. Such traditional practices are obviously necessary, but by no means are they sufficient.

To promote scientific enculturation in the classroom, students must have contact and become familiar with all the different languages used in the processes of scientific meaning making. And for this to come about, teachers must not only dominate the languages specific to the sciences, but have the ability to hold discussions that allow students to argue, to be attentive and have communicative skill to transform the everyday language that students bring to the classroom into scientific language. The main obstacle in the process of scientific enculturation in schools is how to introduce students to mathematical languages. Our empiric data show that this can be achieved with the teacher has the skills to specialize and cooperate in communication of the different languages, above all when passing from the verbal-typological to the mathematical-graphic-operational-topological language.

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