En Plane, Sylvie, Bazerman, Charles, Donahue, Christiane, Rondelli, Fabienne, Boré, Catherine, Carlino, Paula, Marquilló Larruy, Martine, Rogers, Paul y Russell, David, *Research on Writing: Multiple Perspectives*. Fort Collins (Estados Unidos): The WAC Clearinghouse and CREM.

Reading to write in science classrooms: Teacher's and students' joint action.

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23 Reading to Write in Science Classrooms: Teacher's and Students' Joint Action

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By means of a study of didactic design in secondary school classrooms, we describe the actions that two teachers take so that students read and write to widen their understanding of difficult concepts related to Molecular Biology. Our observations show that students resorted to reading only when the teacher was able to involve them in a reading purpose and gave them situated guidance on how to use the texts. Furthermore, students turned to reading to write about Protein Synthesis when the teacher delayed the institutionalization of concepts and monitored how to check divergent interpretations through consulting the literature. On the contrary, reading was considered superfluous when the teacher provided early validation to incipient students' knowledge.

Cette étude didactique décrit les interactions enseignants-élèves observées lors de l'intégration du travail de lecture et d'écriture dans deux classes du cours de biologie du secondaire. Elle vise à identifier les démarches des enseignants favorisant ou contrariant l'engagement des élèves dans l'activité de lire pour élargir leur compréhension. Notre étude porte sur une séquence didactique consacrée à la synthèse de des protéines et comportant sept séances, menée dans deux classes, pour des élèves en douzième année de scolarité. Nos observations montrent que les élèves n'ont recours à la lecture que lorsque l'enseignant a pu les engager en leur fournissant un but de lecture et leur a donné des indications sur l'utilisation des textes. Plus précisément, les élèves se sont engagés dans la lecture afin d'écrire au sujet de la synthèse des protéines lorsque le professeur a différé l'institutionnalisation des concepts et les a engagés à mettre à l'épreuve les interprétations divergentes en consultant la littérature scientifique. À l'inverse, la lecture est apparue comme superflue lorsque l'enseignant a validé précocement les interprétations orales des élèves.

1. Introduction

In Argentine secondary schools reading and writing tasks across different subjects are usually limited to the teacher assigning a text to read, students reading the text (or not) on their own, and then completing simple questionnaires.[1] It is seldom considered that reading and writing may enrich students' learning. In this context, we wonder what teaching situations can promote students' interaction with "difficult subject matter" by means of reading and writing. Since these teaching situations are not typical, we resorted to a study of didactic design in which researchers together with teachers planned a teaching sequence on Protein Synthesis intertwining reading comprehension practices with subject matter. In this chapter, we analyse the implementation of this teaching sequence in two Biology courses, each in a different secondary school. Through the analysis of classroom interactions, we identified which teacher actions promoted student engagement with reading and writing as a means to widen their understanding of the concepts that they were dealing with.

Our study aims to discern and characterize the learning opportunities that are created when teachers integrate reading to write tasks while teaching science concepts. Authors such as Hand, Prain, Lawrence and Yore (1999), Hohenshell and Hand (2006), Jorba, Gómez, and Prat (2000), Lemke (1997) and Sutton (2003) state that reading, writing, and talking must become *objects of teaching* in order to work as *tools for learning*. However, what does this mean? Two different approaches emerged in our literature review.

Some authors (e.g., Izquierdo and Sanmartí, 2000; Márquez & Prat, 2005; 2010; Morgan, 2013) suggest teaching reading and writing in sciences in the same declarative way conceptual lessons are taught. They propose, for instance, that the teacher explains types of texts ("description," "argumentation," etc.) for the students to apply when reading and/or writing science texts. They also suggest creating communication situations in the classroom to work on aspects of language and, in parallel, the subject content.

In contrast, other authors analyze experiences in which reading, writing, and talking about texts are intertwined—as study practices—with the teaching of the subject content (Carlino, 2005; Carlino et al, 2013; Espinosa, Casamajor, & Pitton, 2009; Hand, 2012; Hohenshell & Hand, 2006; De Micheli & Iglesia, 2012; Orange, 2012; Roni & Carlino, 2013). As an example, Biology teachers share with students their conceptual knowledge along with their practical knowledge about taking part in specialized literacy events. This implies, for instance, guiding students in selecting ideas in a text to answer challenging questions, debating divergent interpretations related to reading

material, helping them to weigh the value of some fragments or quotes to solve comprehension problems, and discussing how to highlight and annotate texts to hierarchically organize and relate ideas, etc. According to these authors, teaching reading and writing in the content areas means enculturating students into such events through supporting their participation.

This chapter describes the study of a teaching sequence that, following this second approach, interweaves molecular biology topics with literate practices. Our research aim was to explore its learning potential and, in particular, to critically ascertain which teacher actions promote or hinder secondary school students from adopting these practices as epistemic tools.[2]

2. Conceptual Framework for the Design of the Teaching Sequence

The teaching sequence integrated reading, writing and multivoiced dialogue into Biology classwork to increase students' cognitive activity regarding the content being taught. Following the principles of writing across the curriculum, reading and writing to learn, and dialogic teaching (Bazerman et al., 2005; Dysthe, 1996; Dysthe, Bernhardt, & Esbjorn, 2013; Russell, 2002; Tynjälä, Mason, & Lonka, 2001), we tried to involve students in situations of interaction with disciplinary topics through reading, writing and talking about science texts. This was a challenge, since introducing reading and writing as classwork does not ensure their epistemic use, which depends on the conditions in which these activities are performed (Carter, Ferzli, & Wiebe, 2007; Langer & Applebee, 2007; Ochsner & Fowler, 2004; Wells, 1990).

In order to plan teacher's interventions, we resorted to the Theory of Didactical Situations (Brousseau, 2002; 2007) and the Joint Action Theory[4] (Sensevy, 2011, 2012; Sensevy & Mercier, 2007), in which teachers are expected to perform four actions (define, devolve, regulate and institutionalize) to help students build the necessary knowledge to learn.[3]

The teacher ***defines*** the "didactic milieu" (educational setting) when he or she explains the rules that the student will have to observe to interact with a challenging object of knowledge. Additionally, she ***devolves*** (i.e., returns) problems (makes questions and pauses, poses tasks) that seek to genuinely engage students, and shows reticence (does not explain everything she knows). This function is based on the premise that learning is possible as long as students experience the need to search for more knowledge. The third function, ***regulation***, occurs when the teacher guides the task; e.g., when she encourages students to refocus their work towards the lesson objectives.

When defining, devolving and regulating the classroom task, the teacher

situates students in the role of producers of knowledge, although this knowledge is not eyet xplicitly related to the subject knowledge. For that to be possible, the teacher ***institutionalizes*** it, i.e., validates the knowledge produced by students and establishes links between their knowledge and subject concepts, helping them become less dependent on the teaching context and therefore potentially more capable in the future in another situation.

To sum up, in the design of the teaching sequence we took into account the contributions of two main traditions: the US WAC movement and the French Didactics. This chapter analyses whether and how reading, writing, and talking about texts, in two Biology classrooms, were useful for involving students in study practices.

3. Methodology

We developed a design-based study (Sawyer, 2006; Kelly & Lesh, 2000; Kelly, Lesh, & Baek, 2008) inspired by Didactical Engineering (Artigue, Douady, Moreno, & Gómez, 1995; Buty, Tiberghien & Le Maréchal, 2004). This methodological approach is used to understand the functioning of unusual teaching systems (the interaction among teacher, students, and knowledge to be taught) that have to be built by the research team so as to be observed in the classroom (Brousseau, 2007; Chevallard, 1997; Sensevy, 2012). The design combines top-down and bottom-up components because the teaching situation to be studied is based on theoretical knowledge and, at the same time, the analysis of classroom observations empirically supports (reasserts, specifies) or challenges (limits, questions) the validity of the educational theories on which it is based (Pieters & Jochems, 2003; Rickenmann, 2006; 2007; Sandoval, 2004; Vanderlinde & van Braak, 2010).

Two teachers from different secondary schools were selected to participate. They showed high commitment to the learning of their students and were enthusiastic about working together with the research team. The teachers belonged to contrasting institutions, attended by students of different socio-economic backgrounds. Classroom A school exhibited an educational project of high academic expectations for its students, who belonged to middle-class families with a university background. In contrast, Classroom B school was attended by students of working-class families, with parents that had not always been able to finish their secondary education. Many of the students in Classroom B had repeated grades or interrupted and, then, started over, therefore being overage. Both teachers taught the penultimate grade of the secondary level.[5] Classroom A had 27 students between 16 and 17 years, and Classroom B had 20 students between 16 and 20 years.

The research process, as a study of teaching design, was developed in three stages. In the first stage, we worked with both teachers for a year and a half in order to develop shared criteria to design the teaching sequence. Six-months before implementing the final teaching sequence, a pilot sequence was jointly designed and performed so that teachers and students could become familiar with reading and writing to learn tasks. The pilot sequence was also an opportunity to get used to the presence of an observer in their classes.

As a result of the first stage, a final teaching sequence of seven lessons about the process of Protein Synthesis (PS) was designed. We chose this topic based on two criteria: it was an important content in the syllabus and it had been usually found difficult by students, according to the teachers' experience. Designing the sequence around this content contrasts with most published studies or innovative experiences, which have dealt with more peripheral or less challenging topics (Roni, Rosli, & Carlino, 2010).

During the second stage, teachers implemented the final sequence and had weekly meetings with the first author to monitor purposes, maintain or modify agreements and consider the unexpected. The first author observed and recorded the lessons, and took notes about them. Her notes and class transcripts were then entered into a written record of the interactions (Guber, 2001). Classroom documents and teachers' field diaries were collected. Teachers and 9 students in each school were interviewed before and after carrying out the sequence. The implementation of the planned lessons in Classroom A always preceded that of Classroom B by one week. As a consequence, the situations arising in Classroom A were revised and slight changes in the sequence were agreed with the teachers before the lesson was given in Classroom B. As well, emerging challenges were periodically discussed with the second author and with other members of the GICEOLEM (Group for an Inclusive and Quality Education by Taking Care of Reading and Writing in all Subjects, https://sites.google.com/site/giceolem).

In the third stage, a qualitative analysis of the data from the lessons was conducted using a descriptive-interpretative approach. We focused on the "didactic action" (Brousseau, 2007; Chevallard, 1997; Sensevy, 2012). To understand how the teacher's interventions fostered or discouraged involvement with reading/writing to learn, we analyzed 28 hours of observation data (14 hours in each classroom), transcriptions of teacher and student interviews (1 hour and 20 minutes each on average, respectively), and the teachers' field diaries.

For this chapter, we examine lessons III and IV, in which new content knowledge was introduced (the processes of Transcription and Translation of PS). The records of both lessons were independently scrutinized by each of

the authors, who categorized the teacher's interventions according to function (definition, devolution, regulation and institutionalization), discussed their categorization, and reached a final agreement. This descriptive analysis was used as a basis for an interpretative analysis to identify what teacher actions had promoted specific student actions related to reading and writing to learn. Thus, recurrent and distinctive patterns were identified, from which explanatory hypotheses about the relationship between teacher actions and student activities were formed.[6]

3.1. Teaching Situations Analysed as a Didactic Milieu

Lessons III and IV of the teaching sequence comprised two situations: *watching to discuss what is beginning to be understood*, and *reading to understand more and write*. Both situations, which took place during the same lesson, constitute a didactic milieu (Brousseau, 2007; Sensevy, 2012), i.e., a setting for teachers' and students' joint action regarding the specific content of transciption (lesson III) and translation (lesson IV) in the proteirn synthesis process. The same didactic milieu was recreated four times: twice in Classroom A and twice in Classroom B (Figure 23.1).

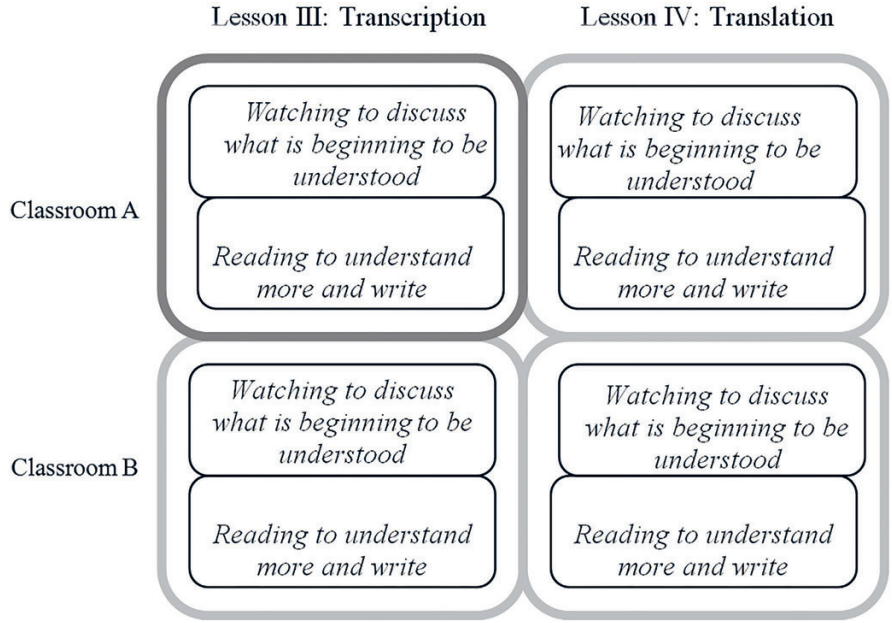


Figure 23.1. A similar didactic milieu in classrrom A and B during both lesson III (protein synthesis) and IV (protein transcription)

In the first situation, students watched an animation about the two stages of the PS process, during which they took notes and discussed their interpretations.[7] In the second situation, *reading to understand more and write*, students were required to write explanatory figure legends of images taken from the animation, for which they had to consult class notes and texts from a reading dossier. (Texts for the *dossier* were selected from different sources. They supplemented each other in information and level of complexity.)

Hence, the designed didactic milieu involved familiar situations (e.g., note-taking and exchanges with the teacher), but also posed challenging tasks to promote learning. Particularly it required that students, in order to write the figure legends, link ideas discussed orally about the animation with information in the reading material.

4. Results

In Classrooms A and B, the situation we referred to as *watching to discuss what is beginning to be understood* aimed to prepare students to write figure legends after a reading activity (*reading to understand more and write*). However, the functions embodied by the teachers led to different actions on the part of the students.

Our analysis reveals that in the first three implementations of the milieu, two in Classroom A (lessons III and IV) and one in Classroom B (lesson III), the teacher institutionalized the conceptual subject knowledge before reading. As a result, students did not feel the need to read in order to write the figure legends. The premature institutionalization of knowledge had the undesired effect of discouraging students from making use of subject texts to access richer conceptual and rhetorical meanings. In contrast, when this didactic milieu was recreated for the last time in Classroom B (lesson IV) and subtle changes based on the previous experiences were made, the institutionalization of subject knowledge was delayed. First, the teacher encouraged students to read specific texts to validate their oral interpretations of the animation and regulated how this validation was done. Consequently, when writing the figure legends, students resorted to this reading procedure, which was meaningful for them due to the teacher's prior interventions.

Further insight into this analysis is provided through lesson transcripts.

4.1. Interactions Centered on Conceptual Content

Lesson III in Classroom A began with students watching the animation and taking notes. The teacher encouraged them to share their interpretations and then reformulate them using the scholarly knowledge corresponding to the

subject. He devolved problems, regulated student efforts, and institutionalized their converging answers. Table 23.1 shows their interactions.

Table 23.1. Classroom A - Lesson III. Situation "Watching to discuss what is beginning to be understood." The teacher institutionalized the concepts before the students read.

203. [0:09:39] Dina: I wrote that "*a gene is a DNA nucleotide sequence that carries a protein's amino acid sequence*." So I am adding what the nucleotide sequence does to what Silvio wrote. [Silvio had already read his gene definition]	
204. Teacher: She is saying that the DNA has the information to construct a protein; we already know this from the other [previously read] definitions. But Dina is also clarifying that the DNA shares its database.	**Micro-institutionalization** of the information that has been agreed on and **regulation** of the discussion.
205. Joaquín: It depends on how the databases are arranged.	
206. Julia: But . . . Doesn't it depend on the order of the amino acids?	
207. Teacher: Who can answer her question?	**Devolution** of the responsibility to define the relationship between bases and amino acids.
208. Sonia: Could you repeat the question?	
209. Teacher: Go on.	
210. Julia: You [Joaquín] talked about the order of the databases, but we had only discussed the arrangement of the amino acids. How does that work?	
211. Teacher: Could we come up with a single definition for both of these concepts? [Students are taking notes in their notebooks.]	**Regulation** by focusing attention on how two components relate to one another and **devolution** of the problem so that the students are the ones to answer the question.
212. Juan: The arrangement of nucleotides will affect the arrangement of the amino acids.	**Autonomous and converging exchanges** of students on the functions of the nucleotides and the amino acids in the translation process.
213. Tito: Sure, one determines another.	
214. Julia: The arrangement of the nucleotides determines the arrangement of the proteins [she should have said *the arrangement of the proteins' amino acids*].	
215. [0:12:40] Teacher: Exactly. The gene is in the DNA; therefore, the gene information is in the arrangement of the nucleotides. Now, by means of these two processes we are studying, first transcription and then translation, we finally obtain a protein that has an arrangement of amino acids.	**Institutionalization** of the knowledge constructed by the students.

Note: The speaking order has been numbered for clarity since the start of the lesson (at 0:00).

Table 23.2. Classroom B—Lesson III. Situation "Watching to discuss what is beginning to be understood." The teacher institutionalized the concepts before the students had read or discussed them.

162. [1:20:12] Teacher: Do you realize how short this video is? Let's examine it frame by frame. Here is the first image. [. . .] What is this? [pointing to DNA on the screen]	**Definition** of the milieu: watching frame by frame and identifying what is there.
163. Students: The DNA.	
164. Teacher: All the DNA?	**Regulation** by asking students to distinguish between the DNA and the gene.
165. Germán: No, part of it.	
166. Teacher: Which part? What's it called?	
167. Students/Germán [shouting]: The gene.	
169. Teacher: So this is the gene. Now some of you are taking notes. [She says this so that other students will also take notes.] And the gene has a region known as a promoter. What is a promoter? It is a transcription start site, a signal. Who receives the signal? The enzyme. So, the gene has a transcription start site biologists call the TATA box. Why is it called TATA?	**Micro-institutionalization** of the information about the gene. **Regulation** so that every student takes notes. Further explanation.
170. Fernando: Because it only has Ts and As.	
171. Teacher: Very good! Thymines and Adenines.	Micro-institutionalization and precise information.
172. Flor: What's it called? [She is asking the teacher to dictate.]	
173. Teacher: The TATA box sequence. That is the promoter of the gene, [i.e.,] the transcription start site. That would be the promoter. So transcription starts when the enzyme called RNA Polymerase recognizes the promoter.	Teacher answers and explains further (instead of devolving the question to the classroom group).
174. Germán: What's the enzyme called?	
175. Teacher: RNA Polymerase. [Everybody copies in silence. Natalia repeats the questions and the teacher repeats the answer. The lesson has become a dictation.]	Teacher answers (instead of devolving the question).
[. . .]	
179. Fernando: What does it recognize? [He wants the teacher to complete the sentence.]	
180. [1:29:26] Teacher: . . . the promoter. Let's take a look at the next image. The enzyme recognizes the promoter and binds to that promoter . . .	

As observed on Table 23.1, Classroom A students were able to express their ideas because the teacher shared his responsibility in interpreting and delivering the information. By not answering Julia's question immediately

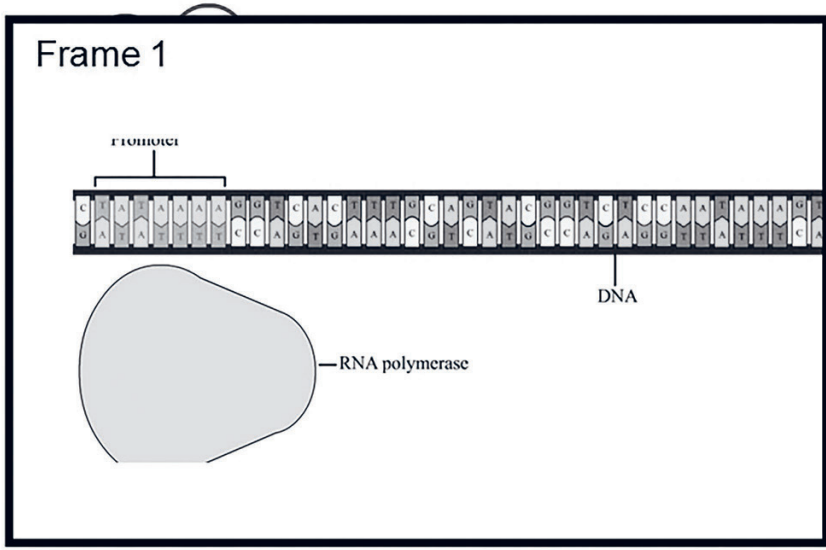
(206), he encouraged peer interaction and consistently devolved the problem to the whole group (207, 209, 211), serving as merely a guide throughout the exchange (204, 211). These actions helped students to connect different interpretations (205, 212), improving or adding on to their peers' interventions (203, 213), and building pertinent knowledge (214). The teacher institutionalized (215) the understanding that had been reached once the students' ideas converged. He corroborated the agreement reached by the class and presented it in a way that approached the scholarly knowledge.[8]

However, in the following situation, *reading to understand more and write,* when students began to write the figure legends, they did not feel the need to consult the reading material. They expressed: "My notes have all the information and they're easier to understand," "I don't understand the readings," "It's a lot of work to do in the classroom," "The information we discussed in class is enough." Thus, despite their familiarity reading difficult texts, students did not consider it necessary to consult the readings in order to do the required writing assignment. Their notes taken during the animation were enough. The same occurred in lesson IV.

Likewise, during lesson III in Classroom B students did not consult the reading dossier to write the figure legends, although the activity had been slightly modified based on the results in Classroom A. During the discussion, students were asked to take notes on photocopies showing images of the animation. They would then re-write their initial notes informed by the readings.

However, this did not happen; on the contrary, the authorized voice of the teacher was even more pervasive than in Classroom A. The activity *watching to discuss what is beginning to be understood* turned to a radial exchange between students and teacher, who unintentionally began to dictate how each frame of the animated lesson should be interpreted (Table 23.2). As shown in Table 23.2, the teacher's knowledge took precedence (169, 173, 175 and 180) over the intended exchange of interpretations. She provided the students with the text for their figure legends. Later, in the activity *reading to understand more and write*, they did not take it upon themselves to look up information in the reading material to enrich their knowledge. As a result, their figure legends were conceptually poor, similar to the notes they had taken during the animation.

The figure legends of this frame (Figure 23.2) should have read as follows: "The transcription process begins when the enzyme RNA Polymerase recognizes the DNA promoter sector, called the TATA Box due to its thymine and adenine bases." Marcos's and Julia's legends left out the element that recognizes the promoter, providing an incomplete explanation. Facundo and Marcelo, who decided to work together, did not write any legend at all.



a- [Marcos]
Gene ⟶ Promoter (initiation sequence)
RNA Polymerase recognizes the promoter

b- [Julia]
When the DNA sequence transcription begins it recognizes the promoter

c and d- [Facundo and Marcelo]

Figure 23.2. Figure legends by Marcos, Julia, and Facundo with Marcelo - Lesson III of Classroom B

As reflected in the students' output, the teacher's actions in Classroom A and during this particular lesson in Classroom B did not encourage students to make sense of the proposed activity: "I read because I need to know more in order to write the figure legends." We believe this happened because teachers explained the contents of the text instead of helping to understand the purpose and procedure of reading. As a result, students did not have any reason to carry out the laborious task of reading because during the oral exchange

they had obtained an explanation of the PS process, written a sentence for each projected frame and handed in what they assumed the teacher expected. The teacher's voice ranked higher as a reference than their own work with the material. Through resorting to specialized texts, they could have written figure legends that approached scholarly knowledge, but they did not adopt this as their objective, or rejected it as inaccessible.

4.2. Interactions Centered on Content-Area Reading and Writing

By the fourth implementation, the activity had been redefined as *watching **and reading** to discuss what is beginning to be understood*. Table 23.3 shows how the teacher repeatedly encouraged students to consult the dossier to defend, enrich, and validate their interpretations about the location and function of codons and anticodons in the translation process. Specialized concepts and reading practices were thus taught simultaneously.

Table 23.3. Classroom B—Lesson IV. Situation "Watching and reading to discuss what is beginning to be understood." The teacher institutionalizes based on students' reading

[The teacher stopped the animation and, asked students to read out loud a brief text containing an illustration of the tRNA and the mRNA in the Translation process. Students were then asked to share what they had understood from both the animation and the reading. Marcos mistook codons (or triplets) with anticodons (a frequent mistake) so the teacher decided to pause to address the concept through the reading to solve the problem.]	**Definition** of which text would be useful for students to understand the animation. **Regulation** on what topic to focus the interpretation work.
72. [0:33:11] Teacher: Let's see . . . Marcos says that tRNA has three tips, and that these are the triplets [or codons]. Does everyone agree?	**Devolution** of Marcos's interpretation as a question for the rest of the class, searching for convergences and divergences regarding the location of codons.
73. Alejandro: Which one is the anticodon?	
74. Teacher: Which one is the anticodon? [Is it in the tRNA or in the mRNA?]	**Devolution** of Alejandro's question to the rest of the class.
75. Jonathan [almost inaudible]: The anticodon is in the lower part of the tRNA. [He points to the illustration and contradicts Marcos.]	
76. Teacher: He [Marcos] pointed to the three tRNA tips [in the illustration], and here Jonathan is saying that they actually form the anticodon. Let's see, what part of the text helps you identify which is the codon or triplet?	**Devolution** of two opposite interpretations regarding the location of codons. **Defining** a specific reading purpose. Regulation of how to read

[. . .]	
79. Juan: But isn't the triplet these three alone? [He insists on solving the problem by pointing to the illustration instead of reading nearby in the text.]	
80. Teacher: It's these three down here [referring to the illustration]. Can you see that it says UGA? These are the three nucleotides, the anticodon. And where is the triplet or codon? Are they in the tRNA? Go back to the reading to find where the codons are.	Upon Juan's insistence, she **micro-institutionalized** and **devolved** part of the question that Juan left unanswered regarding the location of the codon **regulating** the reading.
[. . .]	
96. Teacher: Keep looking [in the text], find where the codons and the anticodons are. It is in the text. Look for that part. Do not look for the answer in the illustration: use the text, guys. The text is what helps you understand the illustration.	**Regulation of how to read** in order to answer the question by explaining that it is necessary to relate the illustration (paratext) to the text.
[. . .]	
105. Natalia: mRNA! [She points to words in the text].	
106. Teacher: Please read that part.	**Devolution and regulation** to show that the text would enable the student to justify her claim.
107. Natalia reads: "The message that the messenger RNA has is decoded three nucleotides at a time. Each of these units of the ribonucleotide sequence is called a triplet or codon."	
108. [0:36:03] Teacher: Where are the codons or triplets? In the messenger RNA. So the transfer RNA has anticodons that are complementary to the mRNA codons, right?	**Institutionalization** of the conceptual content.
[. . .]	
119. [0:37:25] Teacher: OK! Underline that part of the text because it will be useful when you're writing your figure legends. Look at my text [she shows some pages of the readings that have been highlighted and annotated]. It has a lot of notes and is underlined. Let's work directly with the text to see if it gives me the information there.	**Regulation of how to read** by showing that reading to learn requires underlining and making notes on the margins.

As shown in Table 23.3, Classroom B students were involved in building knowledge when the teacher repeatedly devolved a question on how to interpret the animation (72, 74, 76 and 80). In this case, the teacher did not institutionalize student interventions that seemed to be approaching scientific knowledge (75, 79 and 105).[9] In contrast, she pointed out the differences in their interpretations (76), devolved the problem to the students and monitored text use to gauge their understanding of the animation (76, 80 and 96). In intervention 106, she asked Natalia to read out loud to account for her interpretation. The text -not the teacher- validated the student's understand-

ing (107). The teacher finally corroborated the resulting knowledge (108) and regulated the reading practice by showing her text annotations (119).

This excerpt exhibits an intricate exchange that gave sense and purpose to reading. By devolving responsibility, delaying the institutionalization of knowledge and guiding students in their reading, the teacher also gave them the opportunity to build conceptual, rhetorical, and procedural reading knowledge. Consequently, as the situation progressed, students increasingly used the reading dossier to understand the animation images (Table 23.4).

Table 23.4. Classroom B—Lesson IV. Situation "Watching and reading to discuss what is beginning to be understood." The teacher institutionalizes based on students' reading

120. [40:26] Teacher: OK, let's take a look at the next one. [She changes to the next animation frame.] What happened here? The transfer RNA comes . . .	**Regulation** to start with the tRNA to discuss the projection.
121. Fede: . . . with an amino acid.	
122. Teacher: With an amino acid, what else do we have?	**Devolution** and **regulation** to alert students that there is more information to be obtained.
123. Natalia: The large subunit	
124. Teacher: The ribosomal large subunit, right? So, here comes the messenger RNA . . . Find the part of the text that explains this.	**Regulation** making the information given by Natalia more precise, and focusing on one element in order to guide the reading.
125. Jonathan [reads]: . . . .The messenger RNA is decoded three nucleotides at a time."	
126. Teacher: Is that information relevant to what we just watched?	**Devolution and regulation of how to read** by asking students to determine whether the text helps to interpret the projection.
127. Germán: No.	
128. Teacher: Part of it is, why?	**Regulation** by guiding the solution to her question in 126 and **devolution**
129. Federico: To know that it will happen three nucleotides at a time.	
130. Teacher: Right, to know that it will happen three nucleotides at a time. But there is something more. Keep on reading. Let's see . . . Ana [who was raising her hand], read it out loud, so everyone can hear.	**Microinstitutionalization** and **regulation** by stating that something more is expected, and that students should continue reading.

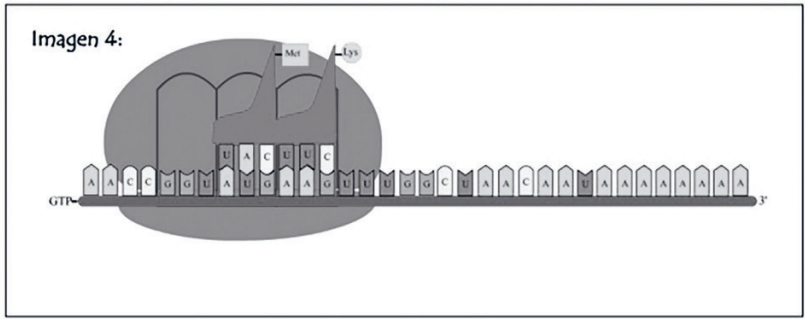
131. Ana: "Now the transfer RNA appear; each contains the corresponding amino acid."	
132. [0:43:42] Teacher: Very good! Look, the text continues to refer to the ribosome that is moving. However, Ana has gone back to the earlier segment corresponding to this particular moment: "*Now the transfer RNA appear; each contains the corresponding amino acid*." So, is that the only useful excerpt? Let's keep reading . . .	**Institutionalization** of Ana's contribution and of her practice of reading previous paragraphs. **Regulation of how to read**: continue reading to determine if there is more relevant information.

Table 23.4. shows how the teacher prompted students to identify whether the text provided the information they were searching for (126), and insisted that they kept reading to see if the subsequent text was still relevant (130, 132). In contrast with lesson III (Table 23.2), students did resort to reading to understand the images (125, 129, 131). Ana even took the lead by going back in the text to find the information.

Students' actions can be thought of as a "reaction" (Sensevy, 2011) to consistent teacher interventions (Tables 23.3 and 23.4). The teacher guided students on reading to develop and rework their interpretations of the animation, taught them how to use the text to validate these interpretations, showed them how to search for additional information, link the illustrations with the written word, determine whether the information they read served a specific purpose, etc.

The approach used in lesson IV affected the next activity, *reading to understand more and write*. Classroom B students immediately turned to the dossier after the assignment was explained. The recording and observation notes of the classroom account for more than 40 minutes of uninterrupted work in pairs with the texts when writing the figure legends. It was also noted that students worked for several minutes past break time until they considered the task was ready to hand in to the teacher. We believe this happened because the teacher had successfully shared not only the tools for performing a specialized reading practice but also the reason for doing so.

The resulting figure legends (Figure 23.3) were different from those produced in lesson III (Figure 23.2). Students offered sophisticated explanations of a major process, briefly describing element, location, and function, etc. In addition, two of the students who had not completed the activity in lesson III were able to do it this time. One of the students, Facundo, received the following comment from the teacher on his legend: "*Way to go, Facundo! This is the first time I've read a text of yours because you hadn't written them or handed in a blank piece of paper . . . keep up the good work!*"



a- [Marcos] *A new tRNA bound to an elongation factor and to the corresponding amino acid attaches to the next triplet, and the two tRNA are each left with their amino acid side by side.*

b- [Julia] *Then another tRNA is incorporated, that binds to the following triplet, and thus the tRNAs, each containing their amino acids, are side by side.*

c- [Facundo] *Then another tRNA is put into place; this tRNA links to the next triplet, and thus the tRNAs each have their amino acid.*

d- [Marcelo] *Another tRNA is placed with its corresponding amino acid and its complementary nucleotides that attach to its triplet.*

Figure 23.3. Figure legends of Marcos, Julia, Facundo, and Marcelo - lesson IV of Classroom B

Although no figure legends written after consulting the dossier copy the source text word for word they do exhibit the vocabulary that is typical of the subject and reveal that students have adequately used complex concepts that identify the function and location of codons (or triplets) and anticodons.[10]

According to these results, the first three recreations of the didactic milieu (two in Classroom A and one in Classroom B) were not able to engage students with the practice of reading to write. Even in the third recreation, the implemented change had the paradoxical effect of making students more dependent on the teacher's voice. Only the fourth recreation, that had been redefined to enable the joint work of teacher and students around a text, managed to make students subsequently resort to autonomous reading in order to write.

What are the interaction patterns that characterize the four implementations of the didactic milieu studied in this paper? In the first three implementations, the teacher provided a premature *institutionalization* of the subject content through an oral explanation before the students had read, or -without intention—ended up dictating to the students her own understanding of the lesson. Thus, the students chose to take the teacher as the only source, since his or her voice was "easier" to understand and more "concise" than the readings. In contrast, in Classroom B lesson IV, the teacher delayed the validation of incipient knowledge and showed students how texts could be used for this purpose; she made room in class for reading a text to interpret the animation, and regulated text use to deepen the understanding of the topic. Consequently, students then read *motu proprio* texts that usually find too difficult, and wrote from them. Their figure legends reveal an appropriate use of sophisticated concepts, without being a copy of the texts.

Even though by means of the analysis of the interactions it is not possible to state that these literacy practices were firmly learnt, it can be seen that the teacher's action began to create opportunities to that end. Taking into account the fact that Classroom B students came from families in which these academic reading comprehension practices were unusual, the opportunity to perform them together with the teacher was probably a necessary condition to gradually internalizing them.

5. Conclusion

Embedding reading and writing tasks in science classrooms does not necessarily help students make use of their epistemic potential. In this chapter, we have characterized the circumstances in which integrating specialized literacy work when teaching Biology manages to engage secondary students with study practices. Through a qualitative design-based research, in which a teaching sequence on protein synthesis was planned and implemented, we analyzed the interactions between teachers and students in two classrooms.

Thus, we identified teacher actions that promoted students' reading to develop their understanding of the concepts they were asked to write about. During the implementation of a similar didactic milieu in four opportunities, we noted that students resorted to reading only when the teacher delayed the institutionalization of their incipient knowledge, devolved the responsibility of justifying and adjusting their knowledge through reading, regulated *in situ* how to use texts for this purpose and helped students to perform this study practice. On the contrary, when this incipient knowledge was completed through the teacher's explanation and prematurely validated, students chose to write with-

out consulting the texts, and their figure legends were conceptually poor.

These results contribute to specify ideas originated from two theoretical fields: the North American movement WAC/WID -about how to actualize in the content areas the epistemic potential harbored by reading and writing-, and the French didactic theories (TDS/JAT) -about classroom conditions that enable students to become producers of knowledge instead of mere information recipients.

In this regard, we have attempted to understand what instructional decisions help students gain access to epistemic uses of reading and writing in the disciplines. Our findings reveal that, besides the designing of the tasks, the *functions performed by the teacher* must be taken into consideration. According to our analysis, it was necessary that the teacher devolved to the students the problem of broadening and validating their comprehension through reading-while at the same time she regulated how to do it-so that reading to write about a challenging topic made sense for them.

It is beyond the scope of this study to confirm the general validity of the didactic procedure identified here. Nevertheless, this joint action pattern is worth further study and broader confirmation in a variety of contexts. The recurrent feature that was found--the fact that early institutionalization of knowledge prevents students from resorting to reading in order to write--was not expected during the design of the teaching sequence. On the contrary, the examination of what occurred in classrooms allowed us to redefine the situation to improve the learning opportunities.

Notes

1. Typical questions require finding certain information in the text, which can be accomplished without understanding since the phrasing of the question matches the answer in the text.
2. The study is part of a Research Grant (PICT 2010-0893 *Writing and Reading to Learn. Approaches and Practices in Various Subject Areas*) directed by the second author and funded by the National Agency of Scientific and Technological Promotion of Argentina.
3. The Theory of Didactical Situations (TDS) originated in the ´70s in the field of Mathematics Education. It is based on Piaget's theory on cognitive development as a constructive adaptation process, and Bachelard's notion about the progress of knowledge through tackling epistemic obstacles (Brousseau, 2007; Buty, Tiberghien and Le Maréchal, 2004; Sadovsky, 2005).
4. The Joint Action Theory (JAT) expands the TDS.
5. It corresponds to grade 12 (of a total of 13) of compulsory education in Argentina. Students usually begin when they are 5 years old, and ideally graduate

when they are 18.

6. The microgenetic analysis of classroom interactions helps to explore the incidence of subtle changes of the didactic milieu on students' activity.
7. The stage corresponding to DNA Transcription was projected in lesson III whereas the stage corresponding to RNA Translation was projected in lesson IV. See both animations at http://www.stolaf.edu/people/giannini/flashanimat/molgenetics/translation.swf and http://www.stolaf.edu/people/giannini/flashanimat/molgenetics/transcription.swf.
8. He reformulated the content of previous exchanges, especially 214, in which Julia made a subtle mistake.
9. Note in Table 23.2 that when students seemed to be missing a chunk of information, the teacher supplemented what they already knew.
10. The text that might have inspired the figure legend of the frame included in Figure 23.3 says, "*First, a tRNA that has the complementary anticodon to the AUG codon is delivered to the ribosome. Then another is delivered; this tRNA attaches to the next triplet, and thus both tRNA, each with its amino acid, are side by side,*" (De Micheli A., L. Donato, P. Iglesia, & P. Otero. *Acerca de Organismos, Células, Genes y Poblaciones*. Buenos Aires: Ediciones Villoldo Yanele, p. 5).

References

Artigue, M., Douady, R., Moreno, L. & Gómez, P. (1995). *Ingeniería didáctica en educación matemática*. México: Grupo Editorial Iberoamérica.

Bazerman, C., Little, J., Bethel, L., Chavkin, T., Fouquette, D. & Garufis, J. (2005). *Reference Guide to Writing Across the Curriculum*. Fort Collins, CO: Parlor Press and WAC Clearinghouse. Available at http://wac.colostate.edu/books/bazerman_wac

Brousseau, G. (2002). *Theory of didactical Situations in Mathematics*. New York: Kluwer.

Brousseau, G. (2007). *Iniciación al estudio de la teoría de las situaciones didácticas*. Buenos Aires: El Zorzal.

Buty, C., Tiberghien, A., & Le Marechal, J.-F. (2004). Learning hypotheses and an associated tool to design and to analyze teaching learning sequences. *International Journal of Science Education, 26*(5), 579-604.

Carlino, P. (2005). *Escribir, leer y aprender en la universidad. Una introducción a la alfabetización académica*. Buenos Aires: Fondo de Cultura Económica.

Carlino, P., Iglesia, P. & Laxalt, I. (2013). Concepciones y prácticas declaradas de profesores terciarios en torno al leer y escribir en las asignaturas. *Revista de Docencia Universitaria, 11*(1), 105-135. Available at http://red-u.net/redu/index.php/REDU/article/view/583

Carter, M., Ferzli, M. & Wiebe, E. N. (2007). Writing to learn by learning to write in the disciplines. *Journal of Business and Technical Communication, 21*(3), 278-302.

Chevallard, Y. (1997). *La Transposición didáctica. Del saber sabio al saber enseñado*. Buenos Aires: Aique.

De Micheli, A. T. & Iglesia, P. (2012). Writing to Learn biology in the framework of a didactic-curricular change in the first year program at an Argentine university. In C. Thaiss, G. Bräuer, P. Carlino, L. Ganobcsik-Williams & A. Sinha (Eds.), *Writing Programs Worldwide: Profiles of Academic Writing in Many Places.* Fort Collins, CO: WAC Clearinghouse and Parlor Press. Retrieved from http://wac.colostate.edu/books/wrab2011/

Dysthe, O. (1996). The Multivoiced Classroom: Interactions of Writing and Classroom Discourse. *Written Communication, 13*(3), 385-425.

Dysthe, O.; Bernhardt, N. & Esbjorn, L. (2013). *Enseñanza basada en el diálogo. El museo de arte como espacio de aprendizaje*. Copenhagen: Skoletjenesten.

Espinoza, A.; Casamajor, A. & Pitton, E. (2009). *Enseñar a leer textos de ciencias*. Buenos Aires: Paidós.

Guber, R. (2001). L*a etnografía. Método, campo y reflexividad*. Buenos Aires: Norma.

Hand, B. (2012). The importance of embedding argument within science classrooms. In M. Swe Khine (Ed.), *Perspectives on Scientific Argumentation: Theory, Practice and Research*. New York, NY: Springer.

Hand, B. M.; Prain, V.; Lawrence, C. & Yore, L. A. (1999). Writing in Science Framework Designed to Enhance Science Literacy. *International Journal of Science Education, 10*, 1021-1036.

Hohenshell, L. M., & Hand, B. (2006). Writing to learn strategies in secondary school cell biology: A mixed method study. *International Journal of Science Education, 28*(2/3), 261-289.

Izquierdo, M & Sanmartí, N. (2000). Enseñar a leer y escribir textos de ciencias naturales. In J. Jorba, I. Gómez, & A, Prat (Eds.), *Hablar y escribir para aprender. Uso de la lengua en situaciones de enseñanza-aprendizaje desde las áreas curriculares*. Barcelona: ICE UAB.

Jorba, J.; Gómez, I. & Prat, A. (2000). *Hablar y escribir para aprender. Uso de la lengua en situaciones de enseñanza-aprendizaje desde las* áreas *curriculares*. Barcelona: ICE UAB.

Kelly, A. & Lesh; R. (2000). *Handbook of research design in mathematics and science education*. Mahwah: Lawrence Erlbaum.

Kelly, A.; Lesh, R. & Baek, J. (Eds.). (2008). *Handbook of design research methods in education.*NY: Routledge.

Langer, J. A. & Applebee, A. N. (2007). *How writing shapes thinking: A study of teaching and learning*. WAC Clearinghouse Landmark Publications in Writing Studies. Available at http://wac.colostate.edu/books/langer_applebee/. Originally published in 1987 by the National Council of Teachers of English, Urbana, Illinois.

Lemke, J. (1997). *Aprender a hablar ciencia. Lenguaje, aprendizaje y valores*. Barcelona: Paidós.

Márquez, C. & Prat, A. (2010). Favorecer la argumentación a partir de la lectura de textos. *Alambique,* 63, 39-49.

Márquez, C. & Prat, A. (2005). Leer en clase de ciencias. *Enseñanza de las Ciencias, 23*(3), 431-440.

Morgan, A. M. (2013). "Proof of concept": Beginning to use Design-Based Research to improve science literacies for middle years learners. *Australian Journal of Language and* Literacy, *36*(1), 3-16.

Ochsner, R. & Fowler, J. (2004). Playing Devil's Advocate: Evaluating the literature of the WAC/WID movement. *Review of Educational Research, 74*(2), 117-140.

Orange C. (2012). *Enseigner les sciences: Problèmes, débats et savoirs scientifiques en classe*. Bruxelles: De Boeck.

Pieters, J. M. & Jochems, W.M.G. (2003). Education and educational research: and ever the twain shall meet? *Pedagogische Studiën, 80*, 407-413.

Rickenmann, R. (2006). Metodologías clínicas de investigación en didácticas y formación del profesorado: Un estudio de los dispositivos de formación en alternancia. Colombia: *Congreso Internacional de Pedagogía, Investigación y Docencia*, *Universidad de Antioquia*.

— (2007). Investigación y formación docente: Dispositivos de formación y elementos para la construcción de una identidad profesional. *Ecos Revista Científica, 9*(2), 435-463.

Roni, C. & Carlino, P. (2013). Qué hacen los docentes cuando quieren que sus alumnos lean para aprender ciencias. México: XII Congreso Latinoamericano para el Desarrollo de la Lectura y la Escritura. IV Foro Iberoamericano de Literacidad y Aprendizaje. Available at https://sites.google.com/site/giceolem2010/secundario

Roni, C., Rosli, N. y Carlino, P. (2010). ¿Cómo se lee y se escribe para aprender las asignaturas de la escuela secundaria? Hacia un estado del arte. Buenos Aires: *II Congreso Internacional de Investigación y Práctica Profesional en Psicología, XVII Jornadas de Investigación y Sexto Encuentro de Investigadores en Psicología del MERCOSUR*, *Facultad de Psicología de la UBA.*

Russell, D. (2002). Introduction: Rearticulating articulation. In D. Foster, & D. Russell (Eds.), *Writing and learning in cross-national perspective: Transitions from secondary to higher education*. Urbana, IL: NCTE.

Sadovsky, P. (2005). La Teoría de las Situaciones Didácticas: Un marco para pensar y actuar la enseñanza de la matemática. En Alagia, H., Bressan, A. & Sadovsky, P. *Reflexiones teóricas para la Educación Matemática*. Buenos Aires: Zorzal.

Sandoval, W.A. (2004). Developing learning theory by refining conjectures embodies in educational designs. *Educational Psychologist, 39*, 213-223

Sawyer, R. K. (Ed.). (2006). *The Cambridge handbook of the learning science*. Nueva York: Cambridge University Press.

Sensevy, G & A. Mercier (2007). *Agir ensemble: L'action didactique conjointe du professeur et des élèves*. Rennes: Presses universitaires de Rennes.

Sensevy, G. (2011). *Le Sens du savoir.* Éléments *pour une théorie de l'action conjointe en didactique*. Bruxelles: De Boeck.

Sensevy, G. (2012). About joint action theory in didactics. *Zeitschrift für Erziehungswissenschaft, 15*(3), 503-516.

Sutton C. (2003). Los profesores de ciencias como profesores de lenguaje. *Enseñanza de las Ciencias, 21*, 21-25.

Tynjälä, L. Mason. & K. Lonka (Eds.). (2001). *Writing as a learning tool: Integrating*

theory and practice. Dordrecht, Boston & London: Kluwer Academic.
Vanderlinde, R. & van Braak, J. (2010). The gap between educational research and practice: Views of teachers, school leaders, intermediaries and researchers. *British Educational Research Journal, 36*(2), 299-316.
Wells, G. (1990). Creating the conditions to encourage literate thinking. *Educational Leadership, 47*(6), 13-17.