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Artículos

Scientific Writing within the Framework of a Microbiology Laboratory*

Escritura científica dentro del marco del laboratorio de microbiología

Escrita científica no âmbito do laboratório de microbiologia

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Abstract:

This article addresses the writing practices in the laboratory, particularly recurrent problems in the presentation of laboratory reports. The perceptions of students and professors about these problems are analyzed, and a some recommendations for support related to this writing genre are provided. Laboratory classes were observed, and a blinded random sample of 20 reports was taken. The analysis of this sample focused on the Results, Discussion and Conclusion sections, which pose the biggest difficulties for students. Professors and students were also interviewed. The data collected suggest that the laboratory scenario can promote the teaching of genres such as reporting and allow for presentations and discussions of information and ideas within a community in an academic discipline. The data also reveal that those difficulties faced by students related to participation in experiments, reporting and data interpretation require accompaniment by a professor and feedback strategies. The implications of this study include recommendations to help science undergraduate students to understand their writing problems as learning opportunities.
Keywords: academic writing, scientific laboratory practices, laboratory reports, science teaching, learning.

Resumen:

Este artículo aborda las prácticas de escritura en el laboratorio, en particular los problemas recurrentes para la presentación de los informes de laboratorio. Se analizan las percepciones de los estudiantes y los profesores acerca de estos problemas y se proveen ciertas recomendaciones de apoyo para este género de escritura. Se observaron clases de laboratorio y se usó una muestra aleatoria ciega de 20 informes. El análisis de esta muestra se centró en las secciones Resultados, Discusión y Conclusión, que representan las mayores dificultades para los estudiantes. También fueron entrevistados profesores y estudiantes. Los datos recogidos sugieren que el escenario del laboratorio puede promover la enseñanza de géneros como el de los informes y permiten hacer la presentación y discusiones de la información y las ideas dentro de la comunidad de una disciplina académica. Los datos revelan también que las dificultades que enfrentan los estudiantes en relación con su participación en los experimentos, los informes y la interpretación de datos requieren acompañamiento por parte de un profesor y estrategias de retroalimentación. Las implicaciones de este estudio incluyen unas recomendaciones para ayudar a los estudiantes de pregrado en ciencias a entender sus problemas de escrituras como oportunidades de aprendizaje.
Palabras clave: escritura académica, prácticas de laboratorio científico, informes de laboratorio, enseñanza de la ciencia, aprendizaje.

Resumo:

Este artigo aborda as práticas de escrita no laboratório, em particular, problemas recorrentes para o envio dos relatórios de laboratório. Analisam-se as percepções dos alunos e professores sobre esses problemas e fornecem-se algumas recomendações de apoio para este género de escrita. Foram observadas aulas laboratoriais e usada uma amostra aleatória cega de 20 relatórios. A análise desta amostra centrou-se nas seções Resultados, Discussão e Conclusões, que representam as maiores dificuldades para os

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alunos. Professores e alunos também foram entrevistados. Os dados coletados sugerem que o âmbito do laboratório pode promover o ensino de géneros como os relatórios e permitir a apresentação e discussão da informação e as ideias dentro da comunidade de uma disciplina académica. Os dados revelam também que as dificuldades que os alunos enfrentam em relação à participação nos experimentos, relatórios e interpretação de dados requerem orientação do professor e estratégias de retroalimentação. As implicações deste estudo incluem recomendações para ajudar os alunos de graduação em ciências a entender seus problemas de escrita como oportunidades de aprendizagem.

Palavras-chave: escrita académica, práticas de laboratório de ciências, relatórios de laboratório, ensino de ciências, aprendizagem.

Introduction

Laboratory work has a central and distinctive role in the teaching of science, and laboratory writing is especially used to promote the research and scientific communication among the students. This article analyzes the writing practices related to laboratory reports using the IMRD template (introduction, method, result and discussion) within the framework of Biotechnological Processes (BP) classes. Similarly, work guidelines are developed that provide instructions for the science laboratory and address problems and dilemmas of scientific writing in real contexts and provide possibilities for accompaniment to facilitate this task.

The questions guiding this article are: "What problems do frequently occur when writing laboratory results? What problems do frequently occur when writing the Discussion and Conclusion sections in a laboratory reports? What are the student's and professor's perceptions about these problems? What possibilities of support for writing in this genre can be identified?"

Undergraduate writing is an opportunity (Carter, 2007; Wallace, et al. 2004; Yager, 2004) since students experience some situations typical for scientists who write articles, books and procedures. In their writing, scientists share theoretical and empirical frameworks and validation criteria that allow them and others understand the scientific method. Students see how they can reflect this in their writing of reports. It is these writing practices in the laboratory, and not the abstract and uncommitted theories, that primarily define what disciplines are and how knowledge is coded and codified (Bazerman, 1988; Hyland, 2000, 2006).

Latour and Woolgar (1986) have suggested that the modern research laboratory devotes more effots to produce articles than to make discoveries, and that scientist's time is devoted largely to the discussion and preparation of articles for publication in competition with other laboratories. It is precisely within that struggle to write in a way that is clear, concise and stylistically consistent with conventions and standards of science that this study emerged to investigate the writing practices of the BP laboratory reports. The intention is to analyze and intervene into the most frequent writing problems in this genre.

The laboratory as a learning space and a social space

The laboratory is a space where activities are carried out promoting the development of logic, research capacities and problem-solving skills through the learning of concepts and procedures guided by the scientific method. Reading and writing texts provides the knowledge necessary for students to conduct experiments, select and control variables, and think about materials and instruments. The activity is mediated by a professor in the role of expert researcher. Specifically, the work done in this kind of class is related to bioprocesses [1] .

Through discussion, a space is created where students must think like scientists. This implies that they tap into the professional sphere since the laboratory reflects what can happen in the industry. In this sense, they put into practice diverse professional competencies. The laboratory is a scenario where students acquire the skills to perform and monitor bioprocesses. Therefore, they require theoretical foundations and competencies in applying quantitative techniques and the importance of collaborative work. All this shall be used for evaluating the behaviors of various microorganisms and the production of metabolites. Quantitative techniques include the use of production parameters that provide important information about raw materials and processing times

Numerous studies have shown the central role laboratories play in the training of scientists by involving students in knowledge construction activities (Read, 1969; Anderson, 1973; Hofstein and Lunetta, 1982, 2004; Tobin, 1990; Lazarowitz and Tamir, 1994; Lunetta et al., 2007). As stated by Read (1969) "scientific attitudes of mind must be taught, both by criticisms of student's efforts and by examples. The sooner this is taught the better since these attitudes are the essence of experimentation" (p. 78).

Laboratory writing

Laboratory work requires writing reports that are a fundamental part of learning in science (Moore, 1993). Integration of the practices of experimentation, reading and writing articulated to the structure of a discipline allows developing skills as well as constructing and keeping the scientific knowledge. Research has addressed the importance of writing in science (Greenbowe et al., 2007; Hand and Choi, 2010; Walker et al., 2011; Walker and Sampson, 2013; Grooms et al., 2014; Hand and Choi, 2010). In fact, as the laboratory is a space of verifiable facts, the production of written texts allows scientists to condense processes, resources, procedures, and operations that give rise to a natural phenomenon. Writing is a discipline-defining practice because knowledge is agreed upon and codified (e.g., Bazerman, 1988; Hyland, 2000, 2006).

Latour and Woolgar (1986) posit that material resources and laboratory routines are configured as *instruments of record.* In other words, they are signs that are "...materially embodied in some medium, such as paper or computer monitors. Graphs, tables, lists, photographs, diagrams, spreadsheets, and equations are characteristically classified as inscriptions. Because of their material embodiment, inscriptions are publicly available, so that they are primarily social object" (Roth et al., 1998, p. 37). This idea is about "transforming a material substance into a figure or diagram" (Latour and Woolgar, 1986, p. 63). Here you are an example:

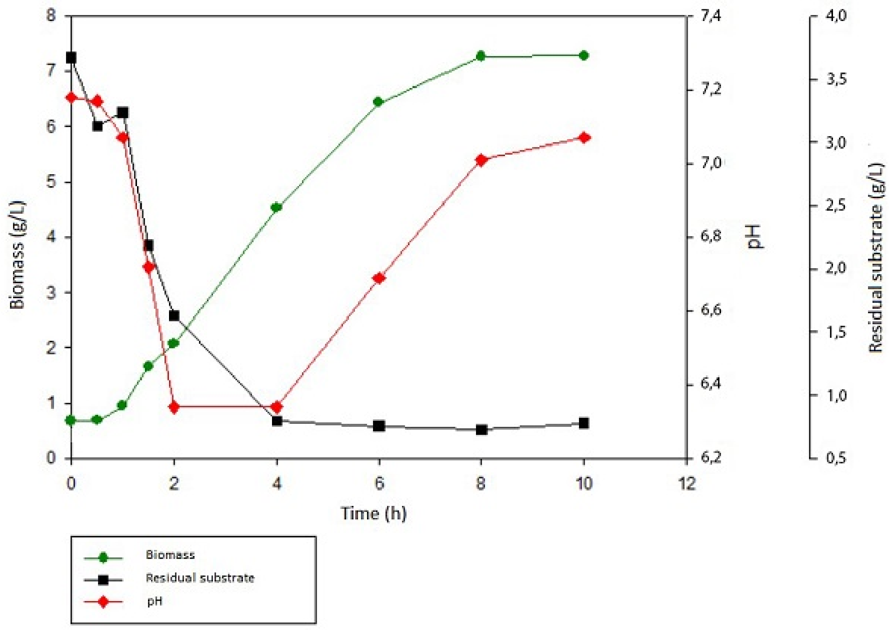


FIGURE 1.
Growth kinetics of *Escherichia coli* in BHI medium
Source: Laboratory report by a student

Figure 1 shows the growth of E. *coli* bacteria at 37° C in a medium that provides the nutrients needed for growth. Samples are taken over the time, and measurements of biomass, residual substrate and pH are made in the laboratory for each sample. The representation of these measurements in Figure 1 allows an easy analysis of their relation to bacterial growth.

The laboratory report

Although both oral and written communication are fundamental to the teaching of sciences, writing implies a level of training and a significant commitment to collaborative work with professors. Studies show the need to involve students in the real practice of reading scientific literature, which allows them to develop critical thinking skills while learning the scientific method and the specific characteristics defining the genres of scientific writing in each discipline. In other words, a writing assignment is intended to help students learning how to read and interpret scientific articles, which can significantly influence their scientific literacy. This includes understanding how science is done, how scientific articles are structured, and how to interpret and draw conclusions from data (Krontiris-Litowitz, 2013; Moreno et al., 2016). This is in accord with Tobin's (1990) ideas about what is done in the laboratory, "Laboratory activities appeal as a way to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science (p. 405)."

In the training of scientists, students are expected to learn how to solve problems that arise in various contexts, including the laboratory. Reports are written in scientific article style as formal records of the experiments. This genre is intended to help students acquire skills of documentation, interpretation, argumentation and drawing conclusions from laboratory practices. Opportunities to write in the undergraduate science classroom is important for several reasons. First, writing is an essential aspect of scientific research. Second, and perhaps most important, it helps undergraduate students better understand the content under research. Writing promotes and supports metacognition and acquisition of deeper insights on any content. A written statement is more easily examined, checked, contradicted, doubted, challenged or affirmed (Sampson and Walker, 2012).

Methodology

This is a case study that focuses on "a limited number of facts and situations in order to address them as deeply as required to reach a holistic and contextual understanding" (Vasilachis de Gialdino, 2006, p. 218). The aim is to delimit the object studied in relation to its particularities and within the framework of its complexity, specifically examining the writing practices in the laboratory of a scientific community. Teaching activities are looked at, in terms of writing, as a portal to learning so that a description of everyday situations is provided showing how social life and scientific practice are intertwined in the interactions between students and professors exposed to writing and the mastery of discursive genres in the laboratory.

Research context

The study was conducted during the first semester 2018 in the BP course of the Industrial Microbiology program at Pontificia Universidad Javeriana. This course includes lecture classes, workshops, class work, and laboratory work. Microorganisms and the processes derived from them are studied aiming to obtain products of interest. This prepares the students for working in industries such as biotechnological processes, technological development and goods production. Class and laboratory work of 30 students in seventh semester was observed. A blind random sample of 20 laboratory reports was taken. Analysis of these reports focused on problems when writing the Results, Discussion and Conclusion sections. Some lecture classes were also observed, and students and professors were interviewed.

Analysis of information

The information was analyzed following the tasks proposed by Miles & Huberman (1994): data reduction, synthesis, and grouping and verification of results. An interpretive qualitative analysis sought to translate all significant meanings from the course into the categories of a coding framework (Schreier, 2012). The coding scheme focused on discursive units related to *writing, laboratory reports and learning*. This scheme was validated by an language expert and a science expert, so that the confrontation in the coding would guarantee its reliability. Based on the interviews, the perceptions of teachers and students about the laboratory space and the writing of reports were analyzed. Being an exploratory research with a relatively small sample of interviewees, the quantification of data was not deemed pertinent. Only the distribution was identified in relation to the kinds of recurring writing problems in the laboratory reports. The results are not intended to be generalizable; rather, they offer preliminary answers on how students and professors perceive the role of writing in the context of the laboratory reports.

Results

This section presents our findings related to the contextualization of reading and writing practices in the classes observed, the interviewee's perception of the laboratory, and the genre of laboratory reports. It also analyzes the problems most frequently found and alternatives that arise through these activities, tasks and achievements.

The classroom context: the importance of solving problems under the framework of a BP Class

College laboratory practices aim to help students learn but, in the industry, these are large-scale processes and require knowledge of kinetic behavior, balance of matter and energy, and other topics. When problems arise, students are expected to solve problems by following some steps in a sequence as is shown in Figure 2. The aim is that students develop the ability to decide whether a result is appropriate or not by comparing a potential solution to possible values from a theoretical point of view. Then, in accordance with the laboratory findings, students propose new strategies to meet the objective sought with this problem. Problem solving seeks to provide tools for students to apply in the biotechnological processes they will face later in the industry. Specifically, the course addresses the development of bioprocesses [2] , as an interdisciplinary challenge.

Possibilities for using cells and enzymes are studied with the support of engineering principles. Engineering is fundamental in many aspects of bioprocessing, "...including design and operation of bioreactors, sterilizers and product-recovery equipment, development of systems for process automation and control, and efficient and safe layout of fermentation factory" (Doran, 1995, p. 3).

Out in the industry there is a wide variety of biotechnological processes and that's why microbial production is one its main focuses. Microbial production depends not only on knowledge of processes, but also on the ability to apply acquired knowledge of microbiology, biochemistry and calculus in order to analyze and discuss results of laboratory practices involving bacterial growth curves, enzyme production, chemical analysis techniques, immobilization of cells, treatment of dyes with fungi, and solid fermentation. In this sense, the objective of this course is to develop the student's understanding of concepts applied to the function of microbial populations and to contribute to the formation of Industrial Microbiologists in terms of their ability to apply basic concepts of microbial kinetics, immobilization of microorganisms, rheology, balance of matter and energy and development, control and optimization of biotechnological processes.

The class articulated the practical element and the application of concepts dealt with in the laboratory. This fact implied that the students observed, posed questions related to the topics studied in the book and research articles, reviewed what is known about experimental tests, used materials and instruments to collect, analyze and interpret data, hypotheses and explanations, used mathematical models, and communicated their results through reports presented in class. The aim was to create a learning environment connected to the reality in order to articulate theoretical knowledge and practicality so that students would develop their understanding of scientific concepts, scientific research skills, and their perceptions about the nature of science through different laboratory activities.

In each laboratory exercise there were minimum concepts to be studied and learned by the students. Two ways of involving them were providing them with a list of subjects to be handled and assigning an oral presentation on the ongoing laboratory exercise to one group of students. This helped them to practice how to make presentations while improving the order and coherence of their presentation. They had to find answers to questions asked by professors and other students and to develop hypotheses related to the subject of the exercise.

Professors brought fundamental interdisciplinary knowledge in the training of Industrial Microbiologists down to earth, brought students into close contact with bioprocesses, showed them applications that involved cells and enzymes used in the framework of the biotechnology industry to manufacture products and services for the daily life. Support from an expert professor was fundamental in this class. As Moje (2008) puts it:

A person who has learned deeply a discipline can use a variety of representational forms —most notably reading and writing of texts, but also oral language, visual images, music, or artistic representations— to communicate his/her learning, to synthesize ideas across texts and across groups of people, to express new ideas, and to question and challenge ideas held dear in the discipline and in broader spheres. (p. 99)

The open atmosphere for questioning and deepening in the knowledge in this class matched the findings by Schellings and Vanhoutwolters (1995) that students defined the importance of the text based on the tasks, questions and problems posed by professors during the class. Reading and rereading the problem statement, ordering the data, and organizoffing the data in flow charts were all tasks involved in resolution of problems. Later, students analyzed the data and formed hypotheses through calculations and mathematical exercises. They read and re-read definitions and applied them to knowledge from other disciplines such as microbiology, biochemistry and calculus in order to analyze and solve the problem. A scheme that summarizes the process used especially in lecture classes is as follows

(Translation of text in image: Posing the problem, Reading the problem statement, ordering the ideas, Flow chart, Analysis, Ordering the ideas, Application of definitions, Interdisciplinary knowledge, Solution of the problem, New problem)

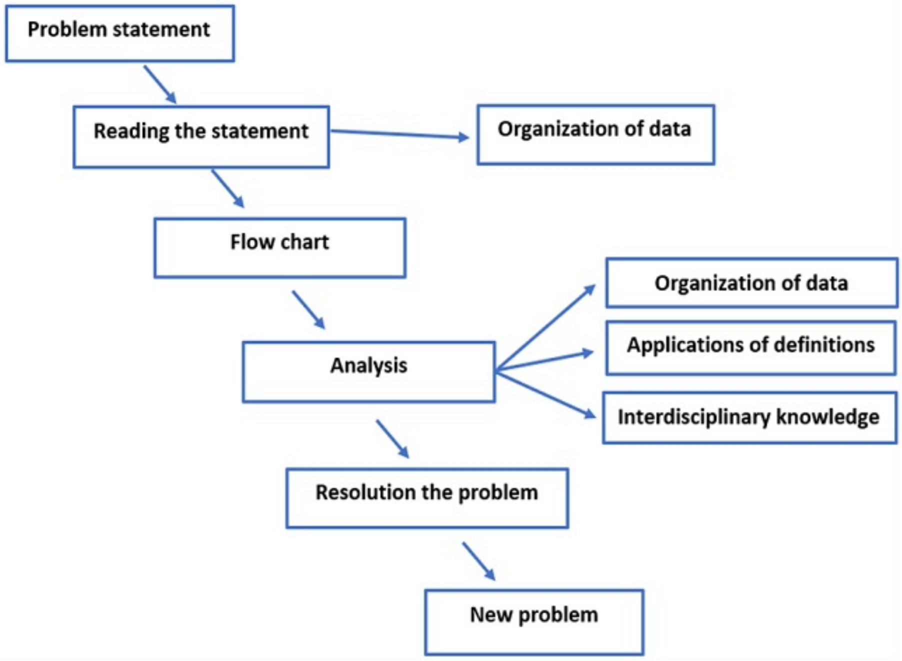


FIGURE 2.
Problem solving scheme in BP class
Source: own source.

Definitions and offsetting out an problem exercise are determinants for the solution to reading and writing problems. Apply them is particularly important in the development of mathematical equations. According to one of the authors,

> To do these exercises, students must apply what they have read and remember the mathematics that they have learned because when a [biotechnological] process is done, raw materials and products are quantified. For example, if they want to produce beer or baker's yeast, it is necessary to make a material balance. This involves quantification of raw material, of the mass that is transformed and the mass that is produced. The efficiency of a process can be quantified by the relationship between the quantity obtained and that expected for a given product. If the value is very low, such that the profitability of the process is not adequate, the causes of the problem must be analyzed to find a solution. In general, the search for a solution requires formalization of the problem in writing to make it possible to identify the cause-effect relationship. Once the problem is formalized, that is, once it is stated, the solution is given. (Teacher 2, personal communication, april, 2018)

Perceptions of the laboratory and written reports

Laboratory activities have played a role in the science curriculum long ago, and scientific educators have suggested the benefits of involving students in science laboratory activities (Hodson, 1993; Hofstein, 2004; Hofstein and Lunetta, 2004; Lunetta, et al. 2007). Research laboratories have the potential for developing student's skills including asking scientifically-oriented questions, formulating hypotheses, designing and carrying out scientific investigations, stating and reviewing explanations, communicating and defending scientific arguments (Hofstein et al. 2005). It is a learning space that engages students and professors in the application and verification of scientific knowledge. As long as new scientific problems are raised, background, conceptualizations and experiments are reviewed, equipment and materials are manipulated, explanations are written and explained, and arguments around scientific phenomena are studied.

Students and professors' perceptions about the laboratory and laboratory reports were in agreement with these ideas. Here you are some comments by one of the authors.

> The laboratory is worth a lot because it is where students must acquire skills and apply the concepts they read. The advantage with this learning space is that it combines analysis of the lectures with the delivery of written reports. Analysis of these reports over the time allows us to see whether they have more and more writing difficulties. Discussing results is their biggest difficulty. Students present result tables without analysis or discussion (Teacher 1, personal communication, april, 2018).
>
> Everything they do and read in class is used to make decisions and become more competent at the professional level. The value of the laboratory is that it provides some of the logical thinking and experience necessary for the decision-making. This involves answering questions such as, "What is the process that should be implemented? Why? and Which dimension is the most important for this process: economic, social, or environmental?" (Teacher 1, personal communication, March, 2018). The decision-making process is one of the most difficult to consolidate within professional training (Teacher 1, personal communication, april, 2018).

In accordance with this, activities that promote research skills and problem solving through understanding concepts and procedures, and which are guided by the scientific method, are performed within the laboratory space. Students read articles that provide them with the knowledge necessary to develop experiments, select and control variables, think about materials and instruments and finally provide input and a model for writing a laboratory report. The activity is mediated by a professor who is a research expert.

Here are perceptions of several students about laboratory reports:

> I think that what we read in articles and what we do in the laboratory are not independent, because, although the methodologies are different, the former serves as a model to follow. (Student interviewed_1, discussion group, May, 2018)
>
> We debate the articles a lot, so if an article is experimental, it must have a theoretical basis. For this reason, we refer to them not only to understand how an experimental part was. Many of them give us concepts that we need for making reports. (Student interviewed_2, discussion group, May, 2018)
>
> At the moment that you make a report, you guided by some standards that have been established by professors as well as the authors of some of the articles. For example, what we did now was report a cell count from a Neubauer counting chamber. The way to do it is standardized like the process with ethanol units. From there we base ourselves on the results. (Student interviewed_1, discussion group, May, 2018)
>
> In the results, well writing...writing isn't a problem because you show what was given to you and you put it there. The problem of writing is when we begin an argument. (Student interviewed_3, discussion group, May, 2018)
>
> It's just that sometimes the discussion gets confused with the writing of the theoretical framework. For example, if you are going to discuss the percentage difference of discoloration of fungus that was given to me here in the laboratory and how it was given to person X, I could make the mistake of starting by saying, 'the fungus is characterized by this, and that is not what we are looking for.' We are looking for the percentage of discoloration that this fungus can provide. Many times, these kinds of things are confused when they are written. (Student interviewed_5, discussion group, May, 2018)
>
> Well, we say that we have to base ourselves primarily on how we should handle everything in the laboratory. In fact, a professor told me that there was no use for a microbiologist who had good knowledge if he did not know how to apply it in the laboratory. Precisely for that reason, we focus on how you work in the laboratory... because you can learn a lot of theory, but if you get to a laboratory and you know how to do complex calculation, but you arrive and do not know how to prepare a culture. You can know many complex things, but when it comes to applying them everything is different. (Student interviewed_7, discussion group, May, 2018)
>
> There are many processes that need precision. Then, it's up to you to practice in order to gain experience. That way you know you are doing things well. (Student interviewed_2, discussion group, May, 2018)
>
> The most important thing in a lab session is technique. You can know the theory, but when you are working in such an environment there are things that even the theory does not tell you. By analysis, or because the professors give you some little tips that can influence the technique, well then, you already know. You have to follow the conditions that the technique tells you to the letter and you cannot change anything. The professors sometimes do it because they have experience and they know what happens if they change this or that, but one who is a novice cannot experiment with what happens if you remove a minute from the technique. (Student interviewed_5, discussion group, May, 2018)

These perceptions show that reading research articles provides students with a model of how to write their reports (3 and 4), i.e., they study and evaluate literature that is useful for their performance in the laboratory. There are also recognized norms and standards for the writing of reports (5). It has also been said that the problems in these texts are mainly in the Results, Discussion and Conclusion sections (6). For example, discussion is often confused with the theoretical framework (7). On the other hand, the importance of the technical component of the laboratory performance (8, 9 and 10) is recognized. Hence, students recognize the need to have skills to manipulate devices and use materials when conducting their experiments. In fact, the laboratory is constituted as a scenario where students acquire skills for assembling and monitoring bioprocesses. Therefore, they acquire theoretical foundations and the competence to apply quantitative techniques that allows them evaluating production parameters.

The issues raised by the students show that working in the laboratory promotes scientific education, including the understanding of scientific concepts (Domin, 2007), practical scientific skills and problem solving skills (Reid and Shah, 2007), scientific mental habits and understanding the nature of science (Vhurumuku, 2011). Likewise, it involves getting involved in research and scientific writing practices that they use to communicate and report the procedures, understandings and scientific findings in an objective way, which, in turn, enables to assess how valid their approaches are. That is, learning to develop and share a research context —the laboratory— from the theoretical and the empirical involved in the writing practices (Kelly et al., 2008; Saul, 2004).

Next section looks at writing problems related to the Results, Discussion and Conclusion sections, the most critical from a professor's point of view. In fact, college students do not always have experience in writing a report. One study (Kalaskas, 2013) revealed that less than a half of the college respondents expressed not to know how to make a report since they did not learned it at high school. They had feelings of frustration and were "unsure of what a lab report is, how and why it is organized the way it is, and why it matters in science in the first place" (p.115).

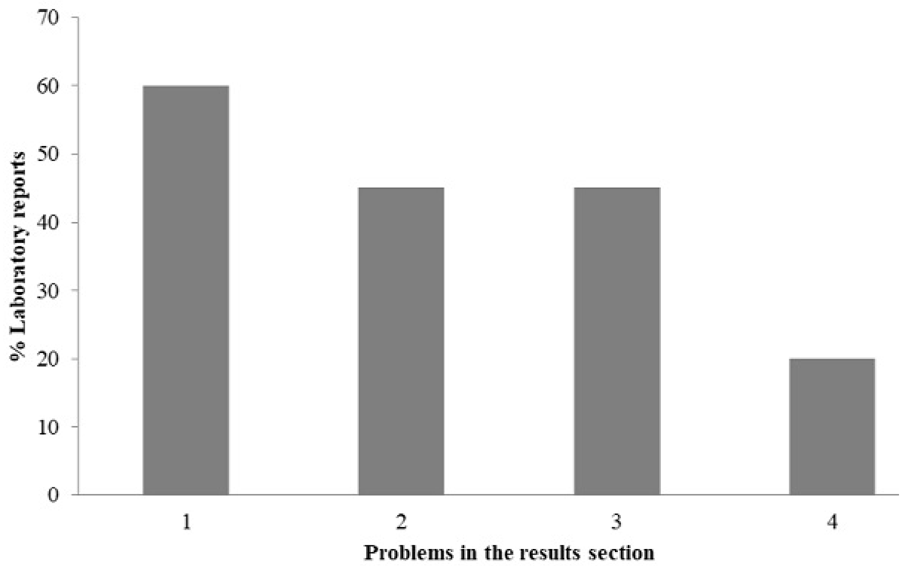
Most frequent writing problems and possible interventions

Fifty percent of writing problems are related laboratory practices. Some are related to the chemical techniques used to track the case results within a discipline such as growth curves of microorganisms of industrial interest. Students in the laboratory not only seek to acquire skills for processing samples under sterile conditions and obtain accurate data, but also to learn how to write a report intended to express results, provide documentation and discuss them. The Results, Discussion and Conclusion sections are specifically addressed since the most frequent writing problems occur within them.

Results

This section must present data in tables, graphs and figures. In addition, it must include calculation of basic statistics such as averages, standard deviations, and coefficients of variation of sequential replicates. The latter is intended to detect experimental errors. Replicas are then discarded to produce a final table with reliable values.

The most recurrent problems are shown in Figure 3. It shows that Type 1 problems account for the largest percentage of laboratory report errors. This occurs because authors sometimes fail to take into account that text in figures and tables must be short and clear, and the reader expects to understand the figure or table without referring to the text. Type 3 problems are important because these errors lead to incorrect analyses that negatively affect the discussion of results.



Key	Type of problem in results section
1	Difficulty assigning correct and appropriate titles to tables and figures
2	Tables and figures are not presented or described in the text of the report
3	Errors calculating response variables
4	Partial omissions of results

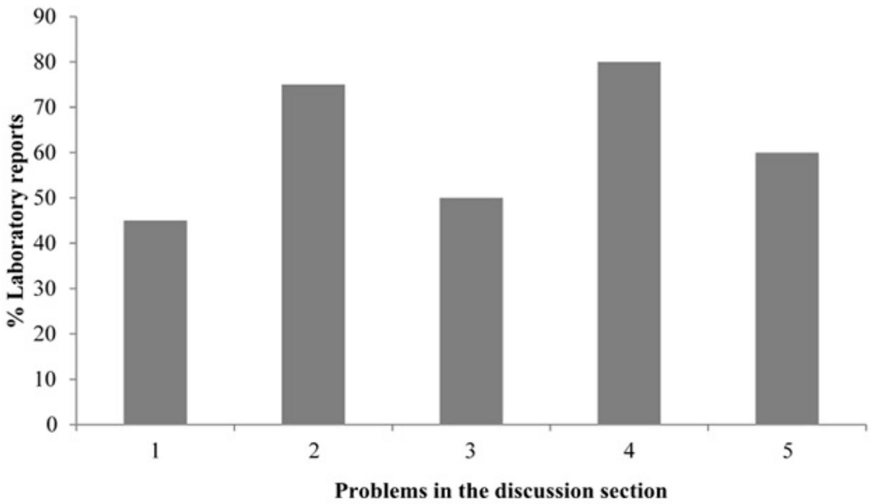
FIGURE 3.
Distribution according to Type of Problem found in the Results section of laboratory reports (n = 20)
Source: own source

The Results section reports data collected during the experiment. It requires that the information be clearly presented in graphs, figures and/or tables according to the rules/standards typical to the discipline. It also requires to provide calculations allowing reliable evaluation of results with respect to the hypothesis.

-Discussion

The first task of the Discussion section is to analyze the behavior of the results. Then, it must explain them on the basis of concepts and theoretical issues prepared in advance for the experiment. The second task is to look for results in recent scientific articles that can be compared to the results obtained. Since results found in the literature are not always obtained under the same conditions as in the current laboratory experience, this section must explain the differences and provide references. In short, the discussion section supports the reasoning for the results obtained and cites the bibliographic reference consulted. It should avoid a narrative description of the results already presented and also avoid presenting the theoretical framework.

The most recurrent problems are shown in Figure 4. It indicates that Types 2 and 4 account for the highest percentages, probably because it is necessary to study this mode of analysis intensely from the beginning of the college program in order to acquire the ability to discuss results.



Key	Type of discussion section problem
1	A theoretical framework rather than a discussion is presented
2	Difficulty discussing results
3	Omission of analysis fundamental to explanation of the phenomenon
4	Difficulty comparing results with those found in scientific articles
5	Problems of order, coherence, and grammar

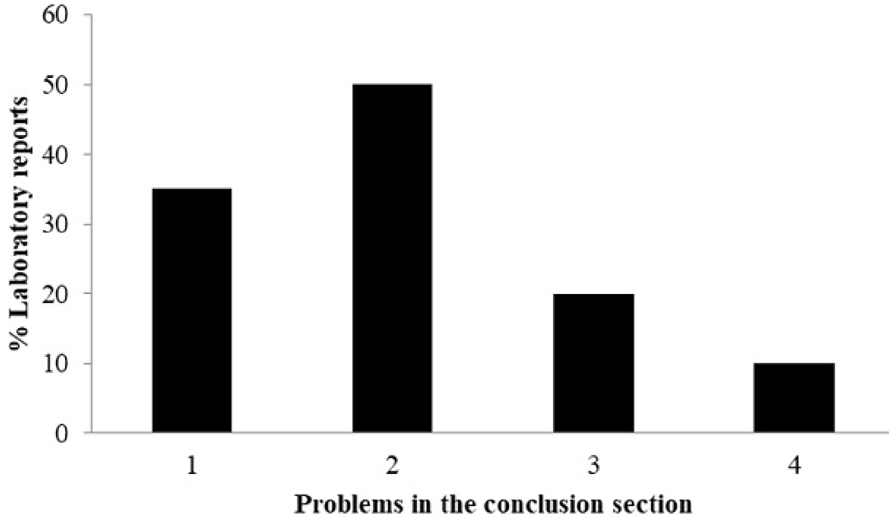
FIGURE 4.
Distribution according to Type of Problem found in the Discussion section of laboratory reports (n = 20)
Source: own source.

The Discussion section must provide a general view of the experiment significant findings in the light of previous studies. Likewise, it implies that students learning science must develop their own argumentation skills and learn how to develop a chain of reasoning typical to the scientific research practices. This includes analyzing and understanding scientific questions, making and supporting claims with evidence from data, and relating the evidence to established or new explanations (Kuhn, 1993; Newton et al., 1999; Driver et al., 2000; Jiménez-Aleixandre et al., 2000).

- Conclusions

The Conclusion section provides a summary of how the experiment contributes to the understanding of the subject dealt with and responds to any initial objectives. A conclusion can also ascertain something previously described in the theory. Affirmations must be supported by evidence, and must be clear, concise and consistent. They should be based on the results obtained rather than on what other researchers have found. It is important to not confuse the conclusions with the presentation of results. They can only be reached on the basis of the results obtained from the ongoing experiment and must take into account the objectives set out in it. Conclusions must be concrete and clear.

Figure 5 shows the most important problems found in the conclusions of laboratory reports. Type 2 problems occurred most frequently because writing concretely and clearly is difficult for the students due to their lack of experience in scientific writing. On the other hand, as they do review articles related to the subject of the laboratory, students tend to write the conclusions found in those studies even though they did no experiments in the laboratory allowing drawing the same conclusions. Type 1 problems occurs because conclusions must be based only on results related to the phenomenon being studied.



Key	Type of conclusion section problem
1	Results presented rather than conclusions
2	Conclusions are not clear and concrete or do not correspond to the work done
3	Conclusions have conceptual errors
4	Discussion presented rather than conclusions

FIGURE 5.
Distribution according to Type of Problem found in the Conclusion section of laboratory reports (n = 20)
Source: own source.

In addition to the coherence, cohesion, spelling and grammar issues, difficulties when developing the sections primarily involve problems of rhetoric, organization and their communicative purpose. The writing problems detected in these laboratory reports are evidenced by their overall quality as shown in Figure 6. Only 10% obtained *excellent* grades and 25% obtained *unsatisfactory* grades.

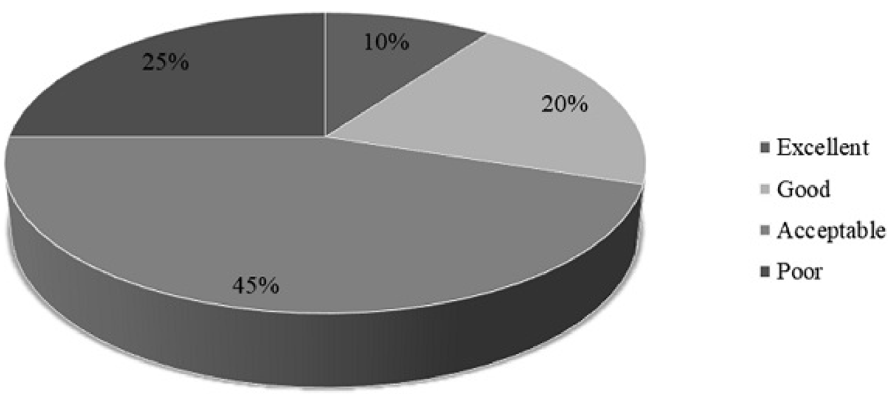


FIGURE 6.
Distribution of laboratory report quality (n = 20)
Source: own source.

Throughout a BP course, students have opportunities to observe and describe various phenomena, establish relationships between variables under study, explore possible explanations and use theory to interpret the data. Nevertheless, this is not often reflected in their laboratory reports as shown in Figure 4. Most of the laboratory reports showed types of problem 2 and 4, indicating that students have difficulty explaining complex biological phenomena. For example, students are able to establish differences such as indicating that a fungus discolors more than another, but they do not usually explain why.

This is a starting point for reflecting on how to solve these problems. Table 1 contains recommendations that can be used as guidelines to help students write their laboratory reports. In addition, professors of other subjects should be encouraged to promote argumentation in the laboratory to help students develop the ability to construct arguments, reason and think critically in a scientific context. This, in turn, shows the need for laboratory research that requires argumentation (Katchevich et al., 2013).

TABLE 1.
Recommendations for preparing BP laboratory reports

Report Section	Activities and Tasks	Goal
Results (Document and interpret data)	Activity 1: Take data from all work groups Activity 2: Calculate response variables according to a mathematical formula or transformation with conversion factors. Activity 3: Choose data for analysis of results. Activity 4: Verify that all tables and figures have appropriate titles. Tasks: Create graphs and tables with data.	Present data in in an organized manner Choose data using descriptive statistics.
Discussion (Discussion of results)	Activity 1: Study related concepts and additional topics needed to understand results prior to laboratory activities. Activity 2: Ask questions to help find the explanation of the results, e.g. Why did the pH increase? Activity 3: Choose scientific articles related to the subject under study. Activity 4: Propose guidelines for interpretation of literature, divide them into main findings and use them to construct arguments. Task: Analyze and explain the behavior of laboratory results. Compare the results obtained with those found in the literature. Consult doubts, peer review.	Understand and interpret the results obtained. Discuss criteria for analyzing results with lab partner. Read scientific literature and use key findings to discuss results. Produce a properly written laboratory report which uses appropriate vocabulary.
Conclusions	Activity 1: Read the objectives of the experiment. Activity 2: Verify that the results are logical according to the theory. Activity 3: Find the relationships between variables. Task: Write conclusions without confusing them with presentation of results.	Write conclusions

Source: own source.

Peer reviews using an evaluation rubric are recommended for student's works. Feedback on this type of process is essential for enculturation of students in literacy and scientific epistemologies (Hyland, 2009).

Discussion

Although the idea of a radical change in the writing of laboratory reports based on recommendations or assistance courses has not been proposed so far, some changes should be introduced. These include practices, tasks, activities and instruments such as rubrics that can significantly contribute to reduce prolems that students showed when writing the specific laboratory report sections chosen herein. Starting by the recognition of problems, improvement strategies can be generated that allow rethinking the time and space management both in the laboratory and the classroom. This should allow writing examples to be used, students should learn to write through multiple drafts as well as learning the value of the feedback and the importance of developing guidelines for reading scientific literature. These measures can make possible to understand how scientists present their results and how they use them to construct arguments. In turn, this will allow students becoming aware of what textually and discursively characterizes each section of a laboratory report. It will also allow them understanding that the laboratory space gives them the opportunity to understand the physical world, write texts and internalize scientific thought.

According to Winsor (1990), language influences the very nature of activity and the way individuals interact around objects of the physical world. In this case, the objects are associated with discolorations and transformations of substrates into products such as acids, biomasses, and amino acids. Along the same lines, Gee (1999) proposed that the language in use provides support and structure to any human activity while supporting associations and connections among individuals, social groups and institutions within a culture. In the case of BP, different codes, conventions, norms and standards are used together with other symbolic systems to create epistemic and scientiAc elaborations around particular contexts, especially within the framework of industry.

Similarly, students are iteratively involved in reading, writing and solving problems from graphs. For these students, this represents being acquainted with the conventions and what Barquero et al. (2000) called "visuospatial conAgurations of graphic elements". Æis is the combination of knowledge and certain cognitive abilities for interpreting the constituent elements of graphs, which allows for internal and thematic consistency of the information displayed. Nevertheless, as previously indicated, the Results section in a laboratory report poses a difficulty that requires the professor's support. In addition to the use of graphics as arguments in the context of the discussion of results, graphs are constituted as inscription instruments (Latour and Woolgar, 1986). Æey are semiotic systems that serve the construction and representation of the order of the world by a sicientist, while providing structure and support for the interaction of students and professors within the framework of the laboratory. Æe possibilities for transforming material substances into a Agure or external representation system are established through graphs, tables, diagrams, conceptual maps, equations, and statistical data.

The laboratory is then constituted as a context explicitly intended to teach technical, scientific, and professional practices where six skills are put into play according to Jeffrey (1967, cited by Hofstein and Lunetta, 1982):

1. Communication: identification of laboratory equipment and operations
2. Observation: recording of observations and detection of errors in techniques
3. Investigation: accurate recording of measurable properties of an unknown substance
4. Reporting: maintenance of a suitable laboratory record
5. Manipulation: skills for working with laboratory equipment
6. Discipline: maintenance of an orderly laboratory and observation of safety procedures (p. 209).

Literature about situated learning and writing genres in different academic disciplines has suggested that as students begin to learn skills within a discipline, they are also learning to become members of a rhetorical and situated discursive community (Kirschner and Meester, 1988; Dannels, 2000). In the case studied here, skills include designing experiments to test or verify hypotheses and performance of activities that allow students understanding the scientific method. Students learn not only content, but also standards and expectations in that particular area of specialization. This learning generally occurs through experiencing genres of writing in a particular discipline, engaging in research in that discipline, reporting and interpreting data from experiments, applying knowledge from and about solving problems, and interpreting texts from the discipline (Berkenkotter et al. 1988; Blakeslee, 1997). However, as this article evinces, the construction of scientific knowledge is observable and verifiable and builds, in turn, social and rhetorical knowledge.This is true because spaces like laboratories confront the students with decisions and activities that put their identity within an academic discipline and their values as scientists at stake, and they fulfill rhetorical purposes according to the genres the students read and write.

The writing of laboratory reports that include Results, Discussion and Conclusions sections is essential for students of Industrial Microbiology because it involves not only teaching how to write but also involves interpreting the literature, breaking it down into its main findings and using it to build an argument and support a discussion. According to this analysis of writing problems in laboratory reports, the Conclusions and Discussion sections were the most difficult for students to write. To overcome these deficiencies, writing needs to be intensified in the first semesters since writing skills are difficult to develop in only one semester. In addition, students require support from their professors, and feedback strategies must be implemented. These should include peer review. Assignment of scientific literature analysis should also be intensified to continue developing the critical thinking and understanding of science. Finally, it is important to motivate students in advanced subjects so that they will continue working on this kind of writing.

Conclusions

This article contributes to the discussions on written genres within an academic discipline and the learning based on the recognition of the laboratoru as a space where scientific thinking is strengthened, problems are identified, experimental methods are understood, data are organized and interpreted, the relationships of facts are situated within the solution of problems, experiments are designed to test hypotheses, and —upon this basis— generalizations and conjectures are provided. For all these reasons, it is fundamental that the rhetorical structure of this kind of genre be taught (Peacock, 2011). Although laboratory work and, by extension, the writing of reports are scenarios that enhance the development of knowledge, skills and the scientific way of thinking, it is necessary to identify the most frequent problems and look for pedagogical support strategies. The student's difficulties may be due to a lack of guidelines, other criteria to guide writing tasks, detailed description of structures, communicative purposes, discursive and rhetorical characteristics of a report, and evaluation criteria. As long as it is true, it is necessary to assume that writing is a process that includes planning, writing, reviewing and editing in specific genres, and that all of them can be supported by peer review, whereby students are also assumed to be evaluators.

Despite the contributions from this study, it is not exempt from limitations associated with a case study that does not represent all laboratories. Despite this, it does show practices typical to a microbiology laboratory as well as typical laboratory objectives, problems, strengths and weaknesses that are related to what it means to read, write, think and act as a scientist in a training environment. Therefore, a review of other spaces like this one is a pending work. There is a need to study other spaces where practices with these and other scientific disciplines are developed to enculturate scientists. This supposes to have the knowledge of norms, conventions, codes and standards, as well as a certain disciplinary identity. These should be studies of the specific conditions and strategies of laboratory work and their effects on the desired learning outcomes.

Finally, we believe that enhancing the scope and impact of these studies to improve the teaching of writing practices such as laboratory reporting requires the accompaniment by professors in the areas of science and language. In other words, we need to build bridges to foster the interdisciplinary understanding that not only supports the explanation of the scientific method itself but also supports textual and discursive issues specific to the writing of specific genres. The work of designing and executing experiments in the laboratory can create appropriate conditions for learning, interacting and discussing as scientists. In other words, this is the way to teach scenarios close to the reality of the industry.

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Notes

* Research Article.

1 This kind of bioprocesses integrate a set of techniques that use living organisms or their metabolites to obtain new products or modify pre-existing ones for beneficial purposes for the industrial, agricultural and environmental sectors ... it is necessary to understand the behavior of the microorganism, the product and the substrate as functions of time in order to standardize protocols, predict changes and optimize production processes thereby achieving the desired biological transformation in the shortest time possible. The fulfillment of this priority implies the use of quantitative techniques by the research laboratory for each parameter. These must be rigorously developed to obtain reproducible results in each production batch (Pedroza-Rodríguez et al., 2007).

2 Bioprocessing is an essential part of many food, chemical and pharmaceutical industries. Bioprocess operations make use of microbial, animal and plant cells and components of cells such as enzymes to manufacture new products and destroy harmful wastes. The use of microorganisms to transform biological materials for the production of fermented foods has its origins in the antiquity. Since then, bioprocesses have been developed for an enormous range of commercial products, from relatively cheap materials such as industrial alcohol and organic solvents, to expensive specialty chemicals such as antibiotics, therapeutic proteins and vaccines. Industrially-useful enzymes and living cells such as baker's and brewer's yeast are also commercial products of bioprocessing (Doran, 1995, p. 3).

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