Improving scientific Practice Skills in a Virtual Chemistry Lab Course

Patricia Morales Bueno[1], Rosario Santos Rodas[2]

Pontificia Universidad Católica del Perú PUCP, Perú[1,2]

Abstract

The laboratory has long been considered the best setting for science teaching and learning for many reasons ranging from the opportunity to develop skills in handling materials and equipment, to achieving the goal of familiarizing students with scientific reasoning and the way science is done. From the perspective of scientific competences development, the capacities that should be highlighted in the teaching of experimental science are more clearly identified, such as the pertinent application of scientific knowledge, involvement in research to address problems, as well as proposing, developing and sustain solutions to them. The usual practice in teaching laboratories is mainly focused on following established procedures that lead to concrete results that allow the student to be assigned a grade. However, this way of working provides very few opportunities for the development of scientific skills in students. The current situation of health emergency has caused unavoidable changes in the way experimental science is taught and, with this, a wide variety of alternatives has been opened that can promote the development of the scientific capacities of students. This work reports the result of monitoring the development of skills for scientific practice, without considering manual skills, in a virtual laboratory course in general chemistry for first-year students at a Peruvian university. These skills were evaluated by means of a rubric that considers the progress achieved in four levels. The results were compared with those obtained by students from a previous cohort who had the same course under the standard modality. Chi square statistic was used, and it was verified that there were significant differences in the achievements obtained by both groups, being these favourable for the group of students that followed the virtual modality.

Keywords: Scientific skills, science education, instructional design, assessment

1. Introduction

The current situation of global health emergency has revealed a series of critical aspects related to organization of society and governments, the relationship between people, environment, and education, among the most important. In this last aspect, scientific education undoubtedly assumes a truly relevant role, since it is necessary that people make use of a set of abilities related to the knowledge of some aspects of science and the way it is developed to understand the problem in its real dimension, the preventive actions that are necessary, and the control proposals of the competent organization. In that sense, for several years scientific education has sought to contribute to the development of abilities to assess the quality of scientific information; describe, explain, and predict natural phenomena; identify the scientific issues that determine political decisions and assume informed positions related to various situations that involve science and technology [1], [2]. This concept of scientific literacy is closely related to that of scientific competence, which includes both scientific knowledge and the use made of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions on matters related to science and its social impact [3], [4]. That is, scientific competence implies abilities linked to knowledge, the practice of science and the individual's attitudes towards it.

Regarding the practice of science, the related capacities involve the abilities to deduce the objective of a determined scientific experience, identify the variables that can be controlled or measured in an experience, pose problems, formulate hypotheses, propose research strategies, collect, and process information. In addition, it includes the skills to elaborate, communicate and support conclusions based on scientific evidence; assume, and support a position related to them; and reflect on the social impact of the advancement of science and technology [3], [4].

The laboratory has long been considered the natural context for science teaching. If the activities to be developed in the laboratory are designed with clear objectives and with an adequate assessment scheme, high levels of achievement can be achieved in the development of abilities for inquiry, reasoning, problem solving, as well as skills for the correct handling of materials and equipment. Additionally, opportunities for the development of skills for collaborative work and communication are promoted [5].

However, in the specific case of chemistry laboratories, reports have been made that indicate that it is frequent that the goals of experimental teaching are not aligned with the results regarding the learning achieved. The organization of the laboratory session usually implies that the students follow an established procedure and record the results obtained in a format structured by the teacher. There is a greater emphasis on learning hands-on techniques and few opportunities for the development of critical thinking, analysis and discussion of results, development and integration of concepts, and development of communication skills [6], [7], [8].
The changes that have been made in the way experimental chemistry is taught in the context of the health emergency have opened a series of alternatives that can help to promote the capacities that make up scientific practice and that go beyond technical skill. This paper reports the results of the comparison of two groups of first-year students from a general chemistry laboratory at a Peruvian university. The comparison variable was the level of achievement in the development of abilities for scientific practice, without considering hands-on techniques skills, between a virtual laboratory course and another developed in traditional mode.

2. Methodology

2.1 Participants

The participants in this study were two cohorts of first year students of Science and Engineering from a Peruvian university. They were enrolled in a General Chemistry Laboratory course.
Traditional cohort: 39 students who took the traditional course. They were aged 17 – 20 years, 84,62% was male and 15,38% was female.
Virtual cohort: 42 students who took the virtual course. They were aged 17 – 20 years, 78,57% was male and 21,43% was female.

2.2 Context of the study

The students were organized in permanent groups of three members. The design of the laboratory course considered three stages:
a. Pre-laboratory stage: individual preparation stage that consisted of developing some short activities, such as reviewing some concepts related to the work session, looking for some physical properties of the substances to be used in the laboratory, analyze a video related to the experience, as well as to do some simple calculations.
b. Development of the experimental session: In the traditional group the students developed the laboratory experience following general guidelines for the hands-on activities, data collection and processing. The teacher was a facilitator during this stage and, promoted the academic discussion of what was being worked on.
In the virtual group the students worked with simulators available online. These resources offer the possibility for the students to intervene in the manipulation of experimental conditions and verify the result in a short time for analysis and processing. In some cases, they can visualize the phenomenon at the molecular level. The student maintains an active role throughout the process and the teacher can monitor his work, the interaction with his group mates, the quality of the discussion and analysis, through the platform used.
c. Report preparation: The working groups prepared their work report after the end of the laboratory session. This should be sent for review a week later.

2.3 Instrument

A rubric to assess abilities for scientific practice was applied during the semester in all the practical sessions. Figure 1 shows the rubric in detail.

RUBRIC TO ASSESS ABILITIES FOR SCIENTIFIC PRACTICE

ACCOMPLISHED	PARTIAL ACHIEVEMENT	WITH DIFFICULTY	UNACHIEVED
• The student is on time for the session and is ready to start work. • The student works in an organized manner with his fellow group members. • The student performs observations, data collection, calculations, and interpretations in a correct and autonomous way with his groupmates.	• The student is on time for the session and is partially ready to start work. • The student works in an organized manner with his fellow group members. • The student makes correct observations, data collection, calculations, and interpretations with his fellow group members, but requires guidance.	• The student is on time for the session but is not ready to start work. • The student's work with his group mates has organizational problems. • The student makes observations, data collection, calculations, and interpretations with his fellow group members, but with frequent errors.	• Student is on time for the session sometimes and not ready to start work. • The student's work with his group mates has serious organizational problems. • The student makes observations, data collection, calculations, and interpretations with his fellow group members, incompletely or with serious errors.
• The student presents his results in an organized and coherent way with the objectives of the experiment, the methodology and procedures followed. • The student correctly analyzes the results relating and supporting them with the corresponding theory. He discusses possible sources of error, comments on the similarities and differences of his results with those of the other work groups and makes suggestions to improve the experiment. • The student integrates the results obtained with the concept or scientific principle involved. He mentions the level of achievement for each of the objectives initially raised, relating to the theory and possible sources of error. Report difficulties or unexpected events indicating the way in which they were solved.	• The student presents his results in an organized and coherent way with the objectives of the experiment, the methodology and procedures followed. • The student correctly analyzes the results relating and supporting them with the corresponding theory and discusses possible sources of error. • The student integrates the results obtained with the concept or scientific principle involved. He mentions the level of achievement for each of the objectives initially raised, relating to the theory and possible sources of error.	• The student presents his results in a partially organized and coherent way with the objectives of the experiment, the methodology and procedures followed. • The student analyzes the results relating and supporting the corresponding theory, but with some confusion. • The student integrates the results obtained with the concept or scientific principle involved.	• The student presents some results, but with a lack of organization and coherence with the objectives of the experiment, the methodology and procedures followed. • The student analyzes the results poorly, with serious confusion in the application of the theoretical concepts related to the experiment.

Figure 1. Rubric to assess abilities for scientific practice

2.4 Analysis of data

The data were analyzed using Statistical Package for the Social Sciences (SPSS) 23 software ®. Level alpha was established a priori in 0,05. Chi square statistic was used to verified if there were significant differences in the achievements obtained by both groups.

3. Results

Figures 2 and 3 show the frequency at each level of achievement for each laboratory session of the traditional group and the virtual group, respectively.

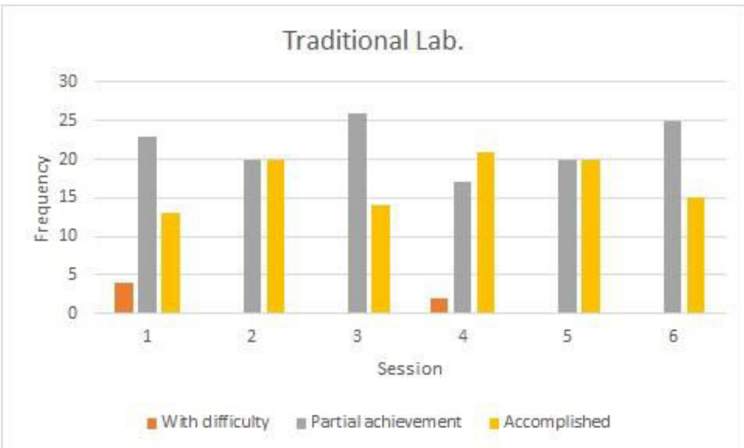

Figure 2. Level of achievement for each lab session of the traditional group

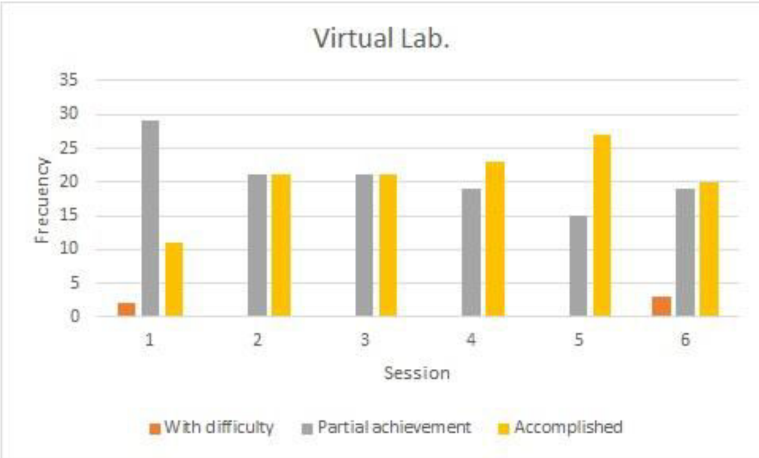

Figure 3. Level of achievement for each lab session of the virtual group

Figure 4 shows the average achievement level for the two participating groups.

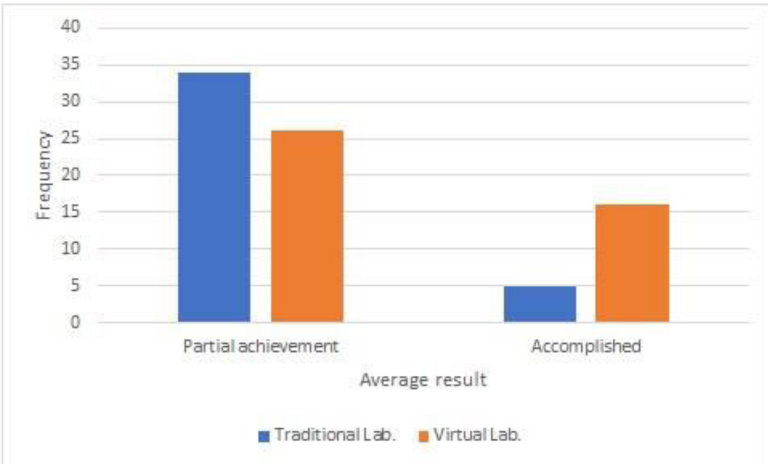

Figure 4. Average achievement level for the two participating groups

The results of the Chi-square test showed that 100% of the cases were valid. Table 1 corresponds to Level * Group crosstabulation.

Table 1. Level * Group Crosstabulation

		Group		
		traditional	virtual	Total
Scientific practice abilities	Partially achieved	34	26	60
	Accomplished	5	16	21
	Total	39	42	81

The value of the Continuity Correction statistic, since it is a 2 x 2 table, was 5.475 with one freedom degree and p value = 0.019. 0% of cells had an expected frequency lower than 5, the minimum expected frequency was 10.11. According to these results, it can be affirmed that there is significant evidence of association between the variables, that is, that the highest proportion of people who qualified at Accomplished level can be associated with the virtual group.

The results clearly show the effect of working using informatic resources, such as simulators, on the level of achievement achieved in developing skills related to scientific practice. Unlike traditional experimental work, the students of the virtual group showed greater engagement in the observation and study of the phenomenon or process studied, enriching the discussion and analysis of the data obtained. The exchange of ideas, the formulation of their own questions and the elaboration of conclusions had greater emphasis in the work of the virtual group. Additionally, the teacher's supervision of the students' work was carried out more efficiently through the platform, providing a greater opportunity for interaction and monitoring of the dynamics followed by the students. Additionally, the work carried out in the synchronous session contributed more significantly to the preparation of the final report, whose quality was notably higher in the virtual group.

4. Conclusions

The goals of science teaching in laboratories should involve skills for technical work and those that promote scientific reasoning, problem solving, critical thinking, and scientific communication. The results obtained provide evidence to consider alternatives to achieve these objectives. The challenge for educators is to develop pedagogical designs that take advantage of both direct experimental work and the use of computer resources, seeking a coherent alignment between educational goals, the design elaborated and the corresponding assessment system. The laboratory is still the best context for learning science, but the variety of resources that can enhance student learning achievements should not be lost sight of.

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