OPEN ACCESS
EURASIA Journal of Mathematics Science and Technology Education
ISSN: 1305-8223 (online) 1305-8215 (print)
2017 13(6):2069-2083
DOI 10.12973/eurasia.2017.01214a

The Interest of the Diversity of Perspectives and Methodologies in Evaluating the Science Laboratory Learning Environment

Pedro Membiela
University of Vigo, Facultade Ciencias Educacion, SPAIN
Manuel Vidal
University of Vigo, Facultade Ciencias Educacion, SPAIN

Received 22 December 2015 ▪ Revised 4 October 2016 ▪ Accepted 14 October 2016

ABSTRACT
The importance of researching the opinions of students and teachers has been pointed out concerning the improvement of teaching and learning in laboratory environments. In this regard, a study of the laboratory environment was carried out from a diversity of perspectives and methodologies. By means of a questionnaire it was learned that the perception of the actual laboratory environment was clearly positive, with clear similarities but also some differences among participants. While the retrospective narrative has helped explain some of these differences, such as a less positive assessment by the teacher of the material environment as regards the large number of students for the limited laboratory space, the students' assessment is highly homogeneous and does not appear to be influenced by these conditions. The use of a fast and simple quantitative tool has provided the participants' general outlook, complemented by the qualitative depth of the retrospective account provided by the teacher.
Keywords: participant perspectives, mixed methods, learning environment assessment, science laboratory

INTRODUCTION

As noted by several authors (Fraser, 1994, 2007; Kijkosol, 2005) the origin of research on learning environments dates back to the 1930s, when Lewin (1936) established the well-known formula B = f (P, E), where human behavior (B) is determined by the personal characteristics of the individuals (P) and their interaction with the surrounding environment (E). Walberg developed the "Learning Environment Inventory" (LEI) as part of the research and evaluation of a Physics project of at Harvard (Walberg & Anderson, 1968), and Moos began to develop the first of his social climate scales leading to the "Classroom Environment Scale" (CES) (Moss & Trickett, 1987). Both are considered the starting point of much research and different kinds of tools, representing consistent, validated, and easy to apply questionnaires that have been used to assess the perceptions of students and/ or teachers

Correspondence: Pedro Membiela, *University of Vigo, Facultade Ciencias Educacion, 32004 Orense, Spain y.*
membiela@uvigo.es

State of the literature

- Due to the high cost of laboratory teaching and the doubts expressed about its effectiveness, it is important to investigate the opinions held by students and teachers, as regards the impact of the various laboratory environments on teaching and learning, thus providing a foundation to guide the systematic attempts to improve these learning environments.
- Research on learning environment in Europe or the Spanish-speaking world is still limited; there is considerable scope for developing new methods and wider use of the methods established in qualitative research. We are still far from the inclusion of learning environment ideas in the initial and in-service training programs.
- To find out the students' and/or teachers' perceptions of the environment, have recommended a combination of quantitative and qualitative methods, because the complementary nature added richness to the whole and the resulting models are more consistent.

Contribution of this paper to the literature

- The assessment of the actual laboratory environment has clearly been positive by both future teachers and their educator. There are clear similarities beyond certain differences between participants, who show a very homogeneous assessment over time.
- The teacher perceived as major problems relating to the large number of students in the laboratory sessions and the limited space available. Students do not show such changes in their perceptions of the material environment.
- The strategy followed has proved productive, consisting in the use of a fast and simple quantitative tool provides an overall view of participants, complemented with the depth provided qualitatively by the teacher.

regarding the classroom learning environment at different educational levels (Fraser, 2007, 2014).

Practical work in the laboratory is one of the most characteristic elements of science education. As noted by Hofstein and Mamlok-Naaman (2007), practical laboratory activities have always played a distinctive and central role in the science curriculum and educators have suggested that many benefits accrue, engaging students in science laboratory activities (Hodson, 1993; Hofstein, 2004; Hofstein & Lunetta, 1982, 2004; Lazarowitz & Tamir, 1994; Lunetta, 1998; Tobin, 1990). In a recent review of the teaching and learning of science in the school laboratory, Lunetta, Hofstein and Clough (2007) suggested that the science lab is a unique resource that can enhance students' interest and knowledge of science concepts and procedures, and which also provides important tools and skills that can in turn develop new scientific knowledge. They also note that laboratory experiments can help give students insights about the nature of science that are crucial to the understanding of scientific knowledge.

However, as noted some time ago (Fraser, Giddings & McRobbie, 1992), due to the high cost of education in the laboratory and the doubts expressed about its effectiveness (Abrahams & Millar, 2008; Hodson, 1991; Osborne, 1993, Wellington, 1998), it is important to investigate the opinions held by students and teachers about their laboratory classes, as regards the impact of the various laboratory environments on teaching and learning, thus providing a foundation to guide the systematic attempts to improve these learning environments.

The research on learning environments has greatly contributed to the growth and international expansion of the knowledge base (Fraser, 2014). First, it has stimulated greater awareness of the fact that, since the measures of learning outcomes cannot provide a complete picture of the educational process, researchers, evaluators and professionals should pay more attention to learning environments. Second, it has developed and validated a number of robust, affordable instruments, which are widely used worldwide to evaluate such environments. Third, it has contributed to basic knowledge on how to improve the academic performance of students by creating positive environments. Fourth, evaluation studies have often shown the importance of including the learning environment dimensions as process efficiency criteria in the evaluation of educational programs, innovations and teaching methods.

However, much remains to be done (Fraser, 2014) and research on environment in Europe or the Spanish-speaking world is still limited; there is considerable scope for developing new methods and wider use of the methods established in qualitative research. We are still far from the use by teachers of ideas and learning environment questionnaires or the inclusion of learning environment ideas in the initial and in-service training programs.

The aim was to investigate, within the context of early childhood science teacher training, the use of laboratory learning environment assessment using a mixed approach that combines quantitative and qualitative methods to understand the perspectives of different groups of participants regarding the following questions:

How did the participants perceive the actual laboratory environment? What differences exist between the participants? What could they be due to?

Theoretical framework

Given the large number of hours that students and teachers spend at school, their perception of their experiences in the classroom is very important. However, despite this, research has tended to fundamentally (and sometimes exclusively) evaluate academic achievement and other outcomes of learning. Although their value is indisputable, they alone cannot give a complete overview of the educational process (Fraser 1994). The classroom environment should also be evaluated and studied, despite being a subtle concept. Thus, there have been many studies of how teachers and students perceive the environment in which they operate, and remarkable progress has been made in the conceptualization, evaluation and research of the classroom environment (Fraser, 2007, 2014).

One of the tools described is known as SLEI (Science Laboratory Environment Inventory), developed in the 1990s (Fraser, McRobbie & Giddings, 1993; Fraser & McRobbie, 1995; Fraser, Giddings & McRobbie, 1995) as a sign of the importance of the laboratory in science education and the remarkable interest in evaluating the laboratory learning environment in high school and higher education. Research in various countries on the environment of science classes carried out in the laboratory indicates that they are dominated by closed activities, that women generally perceive the environment slightly more favorably than men, and that there are associations between the students' attitudes and the learning environment dimensions in the laboratory (Fraser et al., 1993). In this regard, Fisher, Harrison, Henderson and Hofstein (1998) noted that physics laboratory classes were perceived as more open than chemistry or biology ones, with the perception of greater clarity of rules in chemistry laboratory classes than in physics or biology.

To find out the students' and/or teachers' perceptions of the environment, many authors have recommended a combination of quantitative and qualitative methods (Cook & Reichart, 1979; Smith & Fraser, 1980; Fraser, 1986, 1994, 2007; Firestone, 1987; Howe, 1988). Fraser (1986, 1994) identified several reasons for the combination of the two methods: (a) the complementary nature of qualitative observation data and quantitative classroom environment data gives added richness to the whole; (b) the use of classroom environment surveys provides an important source of information concerning how students view their classes; and (c) through triangulation of qualitative and quantitative information on the classroom, the credibility of the results is reinforced since, by using various data collection methods, the resulting models are more consistent.

Context

The research was carried out in the mandatory course subject "Knowledge of the Natural, Social and Cultural Environment" (2008-2009 and 2009-2010), subsequently renamed "Learning of the Sciences of Nature" (2010-2011 and 2011-2012) under the new curriculum. In both subjects practical laboratory activities play a fundamental role in introducing science in the initial training of early childhood education teachers in a life-oriented, participatory and active way. Thus, in addition to more traditional science topics (e.g. the water cycle), others of social and personal relevance (e.g. making bread) have been included, with the use of household materials in the laboratory (baking scales or kitchen jars) to connect with the life experience.

Subject to certain variations, according to the academic year, seven practical activities were carried out in small groups in the science lab: the water cycle, density, germination, combustion, bread making and making fresh cheese, together with an activity chosen by the students, also carried out in small groups and presented to their peers. The first lab session each year is an introductory day in which each subgroup chooses its own participants (2-4 students) and a detailed explanation is given of the timetable for the different activities, the work and safety rules for the laboratory and the structure of the report to be handed in at the end of the course, in which a teacher's guide and student guide for each practice activity performed is included. The teacher's guide includes the objectives to be achieved with the proposed activity, the materials needed to carry out the procedure, the problem situation posed by the teacher, the hypotheses or predictions formulated by each subgroup, monitoring of the activity and the final conclusions. The student guides reflect by means of drawings or images the materials required, as well as an outline of the most representative features of the activity. Having reviewed the reports on practical activities submitted by the students at the end of each course, the teacher marks and returns them indicating any possible improvements as appropriate. Each laboratory practical session begins with a brief PowerPoint presentation by the teacher divided into four sections. The first one (What should we know?) is a theoretical introduction to the practical activity to be performed. This is followed by a description of the materials needed to carry it out (What do we need?) and an outline of the procedure to be followed (How to do it?). Finally, according to the practical activity to be carried out, a problem situation is presented, on the basis of which each small group discusses and formulates different hypotheses for resolving the problem issue. There follows the experimental development of the practical activity, which is closely monitored. At the end of the laboratory session, the teacher shares his views with the entire laboratory class, where the results are discussed and conclusions for each activity carried out are established.

METHODOLOGY

General framework

A mixed methods research design is a procedure to collect, analyze and combine quantitative and qualitative methods in a single study to understand a research problem (Creswell, 2012). It is used because together they provide a better understanding of the research problem, or when one type of research is not enough to address the research problem or when it is intended to provide an alternative perspective on a trial, such as when qualitative data afford a deeper understanding of how it actually worked than just the quantitative study. In our case the mixed methods used (Creswell, 2012) consisted in a design and process analysis and interpretation of explanatory data, with two aims: 1) Follow up outliers or extreme cases in quantitative data and compile qualitative data to explore the features of these cases; and 2) Explain the quantitative results to identify groups in relation to variables, thanks to qualitative data to explore the reasons for these differences. In our case, combining multiple methods, perspectives and observers in the same study mainly aims to add rigor and depth to the study (Denzin & Lincoln, 1994; Flick, 1992).

Data collection and analysis

Relatively simple methods have been used to assess the learning environment in the laboratory, allowing an overview based on the responses of students and teachers to a questionnaire. Apart from the use of the SLEI questionnaire as a quantitative tool to understand the perceptions of the actual personal learning environment in the laboratory, we have collected other qualitative information, such as teacher observation reports on their perception of the environment at the end of each academic year. This has allowed us to provide depth, nuances, and hear the opinion of participants - future primary education teachers and their teacher - about the context of the implementation of the curriculum including education innovations.

To find out about the perceptions of students and teacher regarding the learning environment in the science lab, a Science Laboratory Environment Inventory (SLEI) questionnaire has been used (Fraser et al., 1995, Fraser & McRobbie, 1995) consisting of a questionnaire of 35 items grouped into five scales with five possible answers (“hardly ever”, “rarely”, “sometimes”, “often” and “very often”). The different scales, their equivalence according to the Moos scale (1974), a description and an example of the items are shown in **Table 1**.

Table 1. Descriptive information of each sample scale and item of the Science Laboratory Environment Inventory (SLEI)

Scale	Moos dimension	Description	Sample item
Student Cohesiveness	Relationship	Extent to which students know, help and are supportive of one another.	Students in this laboratory class get along well as a group. (+)
Open-Endedness	Personal Development	Extent to which the laboratory activities emphasize an open ended, divergent approach to experimentation.	In our laboratory sessions, the instructor decides the best way to carry out the laboratory experiments. (-)
Integration	Personal Development	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.	We use the theory from our regular science class sessions during laboratory activities. (+)
Rule Clarity	System Maintenance and System Change	Extent to which behavior in the laboratory is guided by formal rules.	There is a recognized way of doing things safely in this laboratory. (+)
Material Environment	System Maintenance and System Change	Extent to which the laboratory equipment and materials are adequate.	The laboratory is too crowded when we are doing experiments. (-)

Note. Items designated (+) are scored for the responses *almost never* (1), *seldom* (2), *sometimes* (3), *often* (4), and *very often* (5). Items designated (-) are scored in the reverse manner. Omitted or invalid responses are scored 3. Adapted from “Evolution and validation of a personal form of an instrument for assessing science laboratory classroom environments,” by B.J. Fraser, G.J. Giddings, and C.J. McRobbie, 1995, *Journal of Research in Science Teaching, 32*, p. 404.

The SLEI has been adapted and written in Spanish, the process of reform and adjustment was conducted by the research team, who acted as an expert panel and, based on the items of the SLEI, carried out a process of selection and adaptation to adapt the questionnaire to the Spanish education system and our innovative educational practices.

Apart from the use of the SLEI questionnaire as a quantitative tool to understand the perceptions of the actual personal learning environment in the laboratory, we have collected other qualitative data (teacher observation reports on their perception of the environment at the end of each academic year) that allowed us to triangulate data and information, as recommended by different authors (Cook & Reichart, 1979; Fraser, 1986, 1994; Smith & Fraser, 1980). However, triangulation has not been used as a validation strategy, but rather as an alternative to validation (Denzin, 1989a, 1989b; Denzin & Lincoln, 1994; Fielding & Fielding, 1986; Flick, 1992).

Data analysis

The perceptions of 289 students, during the academic years 2008-2009 (95 students), 2009-2010 (64 students), 2010-2011 (64 students) and 2011-2012 (66 students) are analyzed. For the statistical treatment of actual personal perceptions of the learning environment in the science laboratory we have processed the data obtained with the SPSS Statistics 20 statistical package. In an initial analysis a test of normality of the data has been carried out, and to this end the Kolmogoroff-Smirnoff normality test was applied, obtaining a significance of 0.183 ($\alpha > 0.05$), allowing us to accept that the data follow a normal distribution. Subsequently an item-test correlation was carried out, a statistical method to study both the internal consistency of the items (reliability of the scale) and the discrimination against them, and to determine the reliability of the SLEI questionnaire supported by Cronbach's alpha calculation method. In our research is 0.704 for all 35 items analyzed, which means, according to George and Mallery (2003), that our result indicates an acceptable level of reliability (alpha coefficient > 0.7). Said α value has also been calculated for each of the 35 items as if each was eliminated. Thus, the degree of internal consistency of the questionnaire if a particular item is removed is also high, with alpha values ranging between 0.752 and 0.793, indicating that each item measures a proportion of the feature we want to study and therefore that the SLEI questionnaire is reliable. Finally, we have also analyzed the correlation between SLEI subscales to measure the degree of relationship between them. As shown in **Table 2**, the correlation values obtained between the SLEI subscales fall within a range of values between 0.008 and 0.416 and indicating a weak correlation, i.e., each scale behaves in a relatively independent manner. Then a comparison was made between the students' and teacher's assessments reflected in their responses to the SLEI and the teacher's qualitative assessment of his experience.

Table 2. Correlation coefficient values between SLEI scales

	Student Cohesiveness	**Material Environment**	**Open-Endedness**	**Rule Clarity**	**Integration**
Student Cohesiveness	-	.360	-.041	.416	.266
Material Environment	.360	-	.008	.408	.313
Open- Endedness	-.041	.008	-	-.105	.020
Rule Clarity	.416	.408	-.105	-	.331
Integration	.266	.313	.200	.331	-

Note. N=289

RESULTS

Students' and teacher's assessment

Figure 1 shows the results obtained by scales of learning environment perceptions of the students and their teacher in the set of four academic courses studied. Coincidence can be seen in an assessment of the scale of Cohesion, as participants perceive a good relationship among students, helping and supporting each other. The Open-Endedness and Rule Clarity scales show similar values, though with a better valuation by teacher. The greatest differences were seen in the Material Environment and Integration scales, both of which were better valued by the students that by their teacher, with a perception of greater integration of activities carried out in the laboratory with the remaining activities and the adequacy of the equipment, materials and infrastructure.

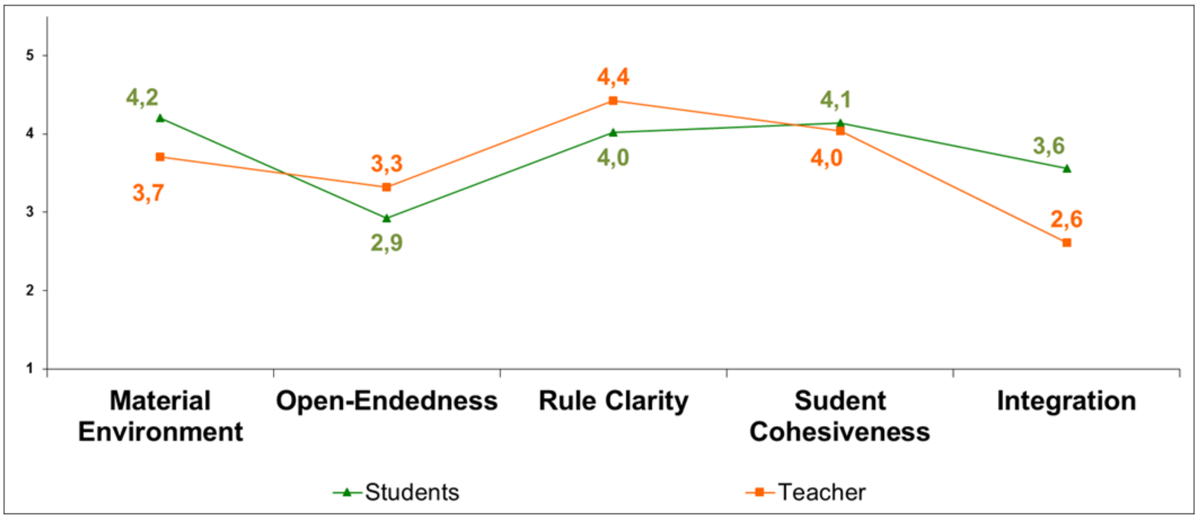

Figure 1. Overall assessment by scale of actual learning environment laboratory perceived by students and teacher (N = 289)

The students' perception of the actual science lab environment (**Figure 2**) shows a similar assessment, especially in the Material Environment and Integration scales, during the academic years in which the study was conducted. There is a clear coincidence in giving a relatively low rating to opening activities. The best-rated scales are Material Environment (equipment and materials) and Student Cohesiveness (degree to which students know and help each other).

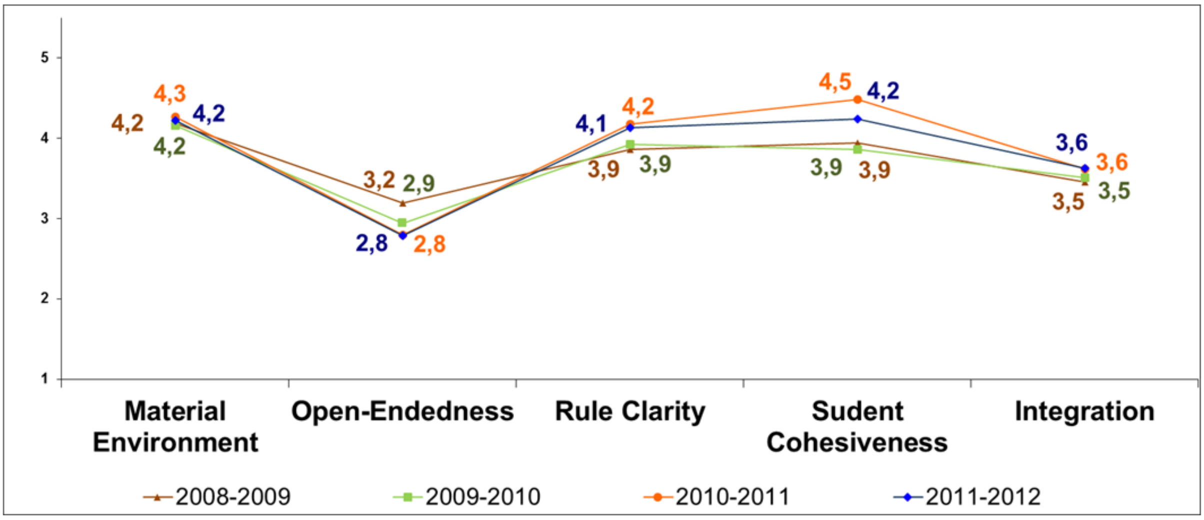

Figure 2. Assessment per academic year and scale of actual laboratory learning environment perceived by students (N = 289)

As for the teacher, it is worth noting that his assessment is very similar throughout the four academic years studied (**Figure 3**) except for the Material Environment scale, with a clearly lower rating in the first two years. Teacher perceptions indicate a high assessment and consistency of Rule Clarity, which means that, in the teacher's view, students have a clear perception of the existence of standards of work and behavior in the laboratory and showed a remarkable level of cooperation and assistance among them when conducting the practical activities proposed. Moreover, low values can also be seen regarding the cohesion of activities, indicating, according to the teacher, a disconnect between the activities undertaken in the laboratory and the other science classes.

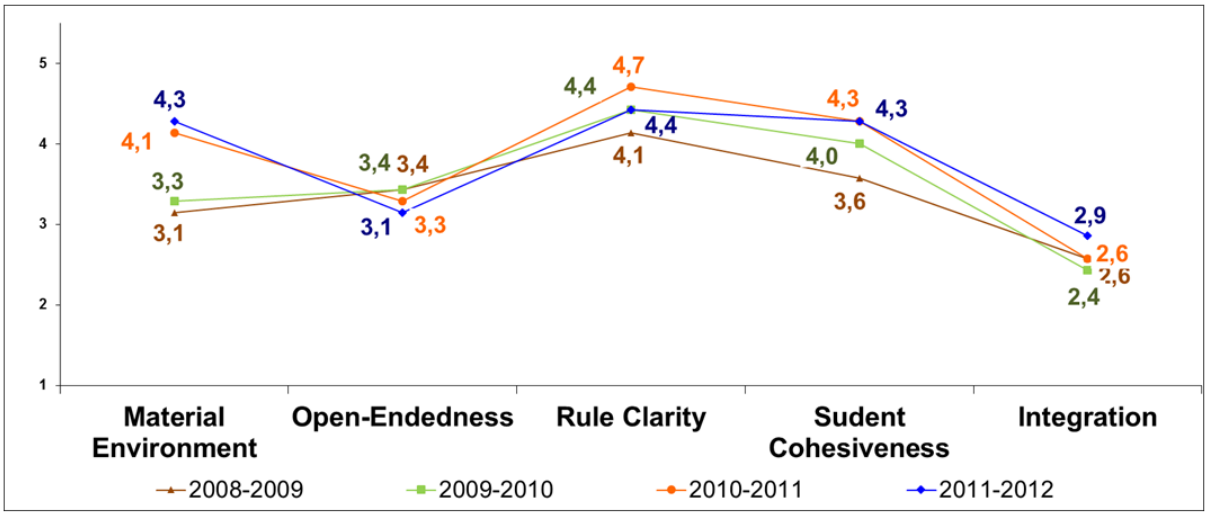

Figure 3. Assessment per academic year and scale of actual laboratory learning environment perceived by the teacher

On the Material Environment scale (See **Figures 2 and 3**), the perceptions of students are very similar across the courses studied, while teacher ratings differ, with the lower values for the first two courses due to the high number of students per lab session, reaching a maximum of 38 people, a situation that led to problems of space and availability of materials in the teacher's view. In the last two years, the implementation of a new curriculum led to a drastic reduction in the number of people in the lab, which clearly justified the higher rating by the teacher of the material laboratory environment. Moreover, and as indicated in **Figure 2**, it appears that such deficiencies related to material laboratory environment are not perceived, or are not considered as such by students.

DISCUSSION

The importance of an assessment of the actual laboratory environment by students and teacher

This work shows the need to collect the assessment of students because they have a different perception than their teacher. However, these differences detected are not in line with previous research showing a consistently higher valuation by teachers than by students. Thus, research conducted in USA (Moos, 1979), Israel (Hofstein & Lazarowitz, 1986; Raviv, Raviv & Reisel, 1990), the Netherlands (Wubbels, Berkelmans & Hooumayer, 1991), Australia (Fraser, 1982, 1986), and Spain (Suárez, Pías, Membiela & Dapía, 1998) showed how teachers saw the classroom environment in a more favorable light than their students, and in those cases where the magnitude of this difference is appreciable this can give the teacher a stimulus for change. In our case, the students' perceptions indicate a better assessment as regards the material environment and the integration of activities carried out in the laboratory with the other science classes, while the teacher makes a better assessment of the openness of the practical activities and the clarity of the rules established to work in the science lab.

The less favorable assessment of the material laboratory environment by the teacher is justified by his concern about the overcrowding of classes in the science lab, which coincides with the widespread belief that the number of students in a class affects the quality of the learning environment (Ehrenberg, Brewer, Gamoran & Willms, 2001; Cuseo 2007; Mulryan-Kyne, 2010). However, given the diversity of learning contexts and approaches that exist, a large class can be defined in different terms depending on the discipline and/ or educational needs, and so we should speak rather of environments where the number of students in class (Hornsby, Osman & de Matos, 2013) may adversely affect the quality of learning. The challenge is how to achieve high-quality education that promotes cognitive skills of a higher order can be achieved, such as problem solving and critical thinking, in a context or overcrowded classes not conducive to student participation, motivation or performance (Hornsby & Osman, 2014).

A mixed methodology allows deeper learning environment research

In our case the combination of the analysis of the responses of all participants to the SLEI questionnaire with the retrospective accounts by the teacher has allowed deeper understanding of the similarities, and above all of the differences in the perception of the learning environment in practical laboratory activities. The combination of multiple methods, perspectives and observers in the same study mainly aims to add rigor and depth to the study (Denzin & Lincoln, 1994; Flick, 1992), and has therefore not been used as a validation strategy, but rather as an alternative validation (Denzin, 1989a, 1989b; Denzin & Lincoln, 1994; Fielding & Fielding, 1986; Flick, 1992). Among the reasons that justify the combination of quantitative and qualitative methods (Fraser, 1986, 1994) it has been noted that the complementariness of quantitative and qualitative observational data from the classroom environment adds richness to the set and the credibility of the results is increased because, using a variety of data collection methods, the resulting models emerge in a more consistent way.

CONCLUSIONS

The assessment of the actual laboratory environment has clearly been positive by both future teachers and their teacher. There are clear similarities beyond certain differences between participants, who show a very homogeneous valuation, from the relatively low ratings given to Open-Endedness and Integration, to the relatively higher Rule clarity, Cohesion and Material Environment ratings. Thus, the teacher has a more favorable perception of the Open-Endedness of the activities and of Rule Clarity. The students' perceptions of are clearly better as regards the Integration of activities carried out in the laboratory with those of the other classes and, to a lesser extent, the degree of Cohesion among students.

The teacher perceived as major problems those identified in the first two academic years studied, relating to the large number of students in the laboratory sessions and the limited space available, indicating worse infrastructure, materials and resources used for the performance of the practical activities. His rating improved markedly in the two courses associated with new degree system, with a significantly reduction in the number of participants in each practical session. Students do not show such changes in their perceptions of the material environment; their valuations remain homogenous throughout the academic courses studied, and therefore independent of the number of participants in each session of laboratory practices.

The strategy followed has proved productive, consisting in the use of a fast and simple tool to find out about the learning environment in the science lab, which provides an overall view of the perceptions of teachers and students with their similarities and differences, complemented with the depth provided by the perception of the environment qualitatively collected by the teacher.

Implications

Our research is unique in the field of science teaching and learning environments, as it has been carried out in one of its important but little studied scenarios, namely that of laboratories, following a mixed methodological approach, which combines quantitative and qualitative data in order to provide richness to the whole (Fraser, 1986, 1994, 2007).

The research on the educational experience focusing on practical science laboratory activities supports generalizations and, in particular, leads to implications for school improvement identified in research on learning environments (Fraser, 2007).

Thus, we have ascertained the importance of including the evaluation of the laboratory environment by different groups of participants, for assessment purposes and because teachers and students consistently have different perceptions (Fraser, 2007). It is also important, for the purposes of introducing educational improvements, to assess the laboratory as an actual teaching and learning environment different from the classroom, in which not only learning takes place, but also social relationships between students and the teacher, and because it can serve to raise awareness of the importance of the educational environment. Furthermore, in our case it is worth highlighting the importance of improving existing knowledge about future teachers' learning environments during their initial training (Martin-Dunlop & Fraser, 2012).

REFERENCES

Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education, 30*(14), 1945–1969.

Cook, T. D. & Reichart, C. S. (1979). *Qualitative and quantitative methods in evaluation* research (Vol. 1). Beverly Hills, CA: Sage publications.

Cuseo, J. (2007). The empirical case against large class size: Adverse effects on the teaching, learning, and retention of first-year students. *The Journal of Faculty Development, 21*(1), 5-21.

Creswell, J. W. (2012). *Educational research: planning, conducting, and evaluating quantitative and qualitative research*. 4th Ed. Boston, MA: Pearson.

Denzin, N. K. (1989a). *Interpretive interactionism*. Newbury Park, CA: Sage.

Denzin, N. K. (1989b). *The research act*. Englewood Cliffs, NJ: Prentice Hall.

Denzin, N. K., & Lincoln, Y. S. (1994). Introduction. Entering the Field of Qualitative Research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of Qualitative Research* (pp. 1-17). Thousand Oaks, CA: Sage.

Ehrenberg, R. G., Brewer, D. J., Gamoran, A., & Willms, J. D. (2001). Class size and student achievement. *Psychological Science in the Public Interest, 2*(1), 1–30.

Fielding, N. G., & Fielding, J. L. (1986). *Linking data: The articulation of qualitative and quantitative methods in social research.* Beverly Hills, CA: Sage.

Firestone, W. A. (1987). Meaning in Method: The Rethoric of Quantitative and Qualitative *Research. Educational Researcher, 16*(7), 16-21.

Fisher, D., Harrison, A., Henderson, D., & Hofstein, A. (1998). Laboratory learning environments and practical tasks in senior secondary science classes. *Research in Science Education, 28*(3), 353–363.

Flick. U. (1992). Triangulation revisited: Strategy of validation or alternative? *Journal for the Theory of Social Behavior, 22*(2), 175-197.

Fraser, B. J. (1982). Differences between student and teacher perceptions of actual and preferred classroom learning environment. *Educational Evaluation and Policy Analysis, 4*, 511-519.

Fraser, B. J. (1986). *Classroom Environment*. London: Croom Helm.

Fraser, B. J. (1994). Research on classroom and school climate. In D. Gabel (Ed.), *Handbook of Research on Science Teaching and Learning* (pp. 493-541). New York: MacMillan.

Fraser, B. J. (2007). Classroom learning environments. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 103–124). Mahwah, NJ: Lawrence Erlbaum.

Fraser, B. J. (2014). Classroom learning environments: Historical and Contemporary Perspectives. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 104–119). Mahwah, NJ: Lawrence Erlbaum.

Fraser, B. J., Giddings, G. J. & McRobbie, C. J. (1992). Assessment of the psychosocial environment of university science laboratory classrooms: A cross-national study. *Higher Education, 24*(4), 431-451.

Fraser, B. J., Giddings, G. J. & McRobbie, C. J. (1995). Evolution and validation of a personal form of an instrument for assessing science laboratory classroom environments. *Journal of Research in Science Teaching, 32*, 399-422.

Fraser, B. J., & McRobbie. C. J. (1995). Science laboratory classroom environments at schools and universities: A cross-national study. *Educational Research and Evaluation, 1*, 289-317.

Fraser, B. J., McRobbie, C. J. & Giddings, G. J. (1993). Development and cross-national validation of a laboratory classroom environment instrument for senior high school science. *Science Education, 77*(1), 1-24.

George, D. & Mallery, P. (2003). *SPSS for Windows step by step: A simple study guide and reference*. Boston, MA: Allyn y Bacon.

Hodson, D. (1991). Practical work in science: time for a reappraisal. *Studies in Science Education, 19*, 175-184.

Hodson, D. (1993). Re-thinking old ways: Towards a more critical approach to practical work in school science. *Studies in Science Education, 22*(1), 85–142.

Hofstein, A. (2004). The laboratory in chemistry education: thirty years of experience with developments, implementation and evaluation. *Chemistry Education Research and Practice, 5*, 247-264.

Hofstein, A., & Lazarowitz, R. (1986). A comparison of the actual and preferred classroom learning environment in biology and chemistry as perceived by high school students. *Journal of Research in Science Teaching, 23*, 189-199.

Hofstein, A. & Lunetta, V. N. (1982). The role of the laboratory in science teaching: neglected aspects of research. *Review of Educational Research, 52*, 201-217.

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*, 28-54.

Hofstein, A., & Mamlok-Naaman, R. (2007). The laboratory in science education: the state of the art. *Chemistry Education Research and Practice, 8*(2), 105-107.

Hornsby D. J., & Osman, R. (2014). Massification in Higher Education: Large Classes and Student Learning. *Higher Education, 67*(6), 711-719.

Hornsby, D. J., Osman, R., & De Matos, J. (2013). *Teaching large classes: Interdisciplinary perspectives for quality tertiary education*. Stellenbosch: SUN Media.

Howe, K. R. (1988). Against the quantitative-qualitative incompatibility thesis or dogmas die hard. *Educational Researcher, 17*, 10–16.

Kijkosol, D. (2005). Teacher-student interactions and laboratory learning environments in biology classes in Thailand. (Doctoral dissertation, Curtin University of Technology, Perth,). Retrieved from http://espace.library.curtin.edu.au

Lazarowitz, R. & Tamir, P. (1994). Research on using laboratory instruction in science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 94-130). New York: Macmillan.

Lewin, K. (1936). *Principles of topological psychology*. New York: McGraw-Hill.

Lunetta, V. N. (1998). The school science laboratory: Historical perspectives and centers for contemporary teaching. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education*. Dordrecht: Kluwer.

Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. In S. K. Abell and N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 393–441) Mahwah, NJ: Lawrence Erlbaum.

Martin-Dunlop, C. S., & Fraser, B. J. (2012). Using a learning environment perspective in evaluating an innovative science course for prospective elementary teachers. In B. J. Fraser, K. Tobin & C. McRobbie (Eds.), *Second Edition of the International Handbook of Science Education* (pp. 1305-1318). New York: Springer.

Moos, R. H. (1974). *The social climate scales: An overview*. Palo Alto, CA: Consulting Psychologists Press.

Moos, R. H. (1979). *Evaluating educational environments*. San Francisco: Jossey Bass.

Moos, R. H. & Trickett, E. J. (1987). *Classroom Environment Scale manual*. Palo Alto, CA: Consulting Psychologists Press.

Mulryan-Kyne, C. (2010). Teaching large classes at college and university level: Challenges and opportunities. *Teaching in Higher Education, 15*(2), 175–185.

Osborne, J. (1993). Alternatives to practical work. *School Science Review, 75*(271), 117–123.

Raviv, A., Raviv, A., & Reisel, E. (1990). Teacher and students: Two different perspectives? Measuring social climate in the classroom. *American Educational Research Journal, 27*, 141-157.

Smith, D. L. & Fraser, B. J. (1980). Towards a confluence of quantitative and qualitative approaches to curriculum evaluation. *Journal of Curriculum Studies, 12*, 367-370.

Suárez, M., Pías, R., Membiela, P. & Dapía, D. (1998). Classroom Environment in the Implementation of a Innovative Curriculum Project in Science Education. *Journal of Research in Science Teaching, 35*(6), 655-672.

Tobin, K. G. (1990). Research on science laboratory activities. In pursuit of better questions and answers to improve learning. *School Science and Mathematics, 90*, 403–418.

Walberg, H. J., & Anderson, G. J. (1968). The achievement-creativity dimension of classroom climate. *Journal of Creative Behavior, 2*, 281-291.

Wellington, J. (1998). Practical work in science. Time for a reappraisal. In J. Wellington (Ed.), *Practical work in school science: Which way now?* (pp. 3–15). London: Routledge.

Wubbels, Th., Berkelmans, M., & Hooumayer, H. (1991). Interpersonal teacher behavior in the classroom. In B. J. Fraser & H. J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 141-160). Oxford: Pergamon Press.

http://iserjournals.com/journals/eurasia