行政院國家科學委員會專題研究計劃期中(進度)報告

教師科學認識觀與實施建構主義取向教學之相關性

計劃編號:NSC90-2511-S009-001

執行期限:90 年 8 月 1 日至 93 年 7 月 31 日

主持人:蔡今中 交通大學教育研究所暨教育學程中心

Abstract

Laboratory work is often viewed as a part of the practice of constructivism, if it is used appropriately. The purpose of this study was to explore the differences between science students' and teachers' perceptions toward laboratory environments. Through surveying more than one thousand junior high school students and their science teachers, this study revealed the following findings. The students showed much dissatisfaction with the approaches of actual laboratory activities than their teachers, and they preferred a much more student-cohesive, open-ended, integrated and rule-clear laboratory environment than what their teachers expected or preferred. However, these teachers showed higher preferences for better equipment and material environments for laboratory work than their students did. With some follow-up interviews from participant teachers, this study suggested that the epistemological views about science might be one of the most important factors that caused the differences of the perceptions toward laboratory learning environments between students and teachers.

Introduction

Laboratory work is often viewed as a part of the practice of constructivism, if it is used appropriately. In recent years, laboratory work and practical work[1] has gained renewed interest in the field of science education (e.g., Leach & Paulsen, 1999; Wellington, 1998), although the importance of laboratory exercises on science instruction is not a new idea. Hodson (1996), for example, has well elaborated the purposes of the practical work in science education, including: (1) to help students learn science (acquiring conceptual and theoretical knowledge), (2) to help students learn about science (developing an understanding of the nature and methods of science), and (3) to enable students to do science (engaging in expertise in scientific inquiry). However, students may often focus on the "aims" of laboratory activities, but not their "purposes." In other words, students are trying to see or determine the expected results from the activities per se, but they are not pointing to much mental engagement or relating to other learning experiences during laboratory work (Hart, 2000). Consequently, studies on students' laboratory activities showed that many students gain little insight in school laboratory activities either about the involved major concepts or toward the process of knowledge construction (Novak, 1988), and that students tend to follow the cookbook type approach to experimentation and their purpose of laboratory activities is to match the truths presented in textbooks (Roth & Roychoudhury, 1994; Tsai, 1999; Watson, Prieto & Dillon, 1995).

A possible reason for this may come from the fact that teachers and students may have different perceptions about laboratory learning environments. For example, science teachers may hope that students can engage in more learning experiences, but students merely work toward the "aims" of laboratory activities. Or, an opposing situation may happen. That is, students may prefer to have a better understanding about the concepts and nature of science and scientific inquiry through laboratory work, but science teachers may not actually provide such laboratory environments or well perceive these purposes. Fisher and Fraser (1983), for example, found, in an Australian sample, students preferred a more favorable classroom environment that was perceived as being actually presented by science teachers and that teachers generally perceived the environment of their classes more favorably than did students in the same classrooms. This study hypothesized that there was a gap between science teachers' and students' perceptions toward laboratory environments. Through surveying a group of science teachers and students, this study explored the possible differences between science students' and teachers' perceptions toward laboratory environments.

Method

Instrument

Science Laboratory Environment Inventory (SLEI), developed and validated by Fraser, Giddings and McRobbie (1995), was administered to explore teachers' and students' perceptions of laboratory activities. SLEI originally has two forms: one is actual form, which investigates students' views about actual laboratory environments, and the other is preferred form, which assesses students' perceptions about ideal laboratory environments. In this study, the author changed the wording and created two corresponding forms for assessing teachers' perceptions of laboratory environments. Hence, a total of four forms of SLEI were used in this study, including student actual form, student preferred form, teacher actual form and teacher preferred form. Each form includes the following five different scales, and each scale consists of seven questions.

1. Student Cohesiveness Scale: extent to which students know, help, and are supportive of one another.
2. Open-Endedness Scale: extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation.
3. Integration Scale: extent to which the laboratory activities are integrated with nonlaboratory and theory classes.
4. Rule Clarity Scale: extent to which behavior in the laboratory is guided by formal rules.
5. Material Environment Scale: extent to which the laboratory equipment and materials are adequate.

(Insert Table 1 about here)

Table 1 shows sample SLEI items for each form used in this study. The translation of SLEI was validated by two Chinese-speaking researchers with specialization in science education. Students' and teachers' responses on SLEI were scored as follows. For the positive-stated items, a "very often" response was assigned 5 and a "almost never" response was assigned a score of 1. Items stated in a reverse manner were scored in a reverse manner. Therefore, students or teachers perceiving or preferring their laboratory environments which were student cohesive, open-ended, integrated with theory classes, and had clear rules as well as adequate materials would have higher total scores on responding scale (full score on each scale is 35).

Fraser, Giddings and McRobbie (1995) reported that the reliability coefficients (Cronbach Alpha) of SLEI were .78, .71, .86, .74, and .76 on each scale for the (student) actual form, while the coefficients were .73, .70, .84, .68, and .73 on each scale for the (student) preferred form. The same coefficients calculated from the student sample of this study (described later) were.76, .60, .83, .75, and .72 on each scale for the (student) actual form, and .75, .61, .87, .73, and .74 on each scale of the (student) preferred form. A pilot study evaluating the reliability of teacher's SLEI forms was conducted with 68 science teachers. The alpha coefficients for the actual form were .75, .68, .86, .77, and .76 on each scale, while for the preferred form were .77, .65, .88, .75 and .79 on each scale.

In order to avoid contamination of responses across these two instruments, the administration of the two forms of SLEI was conducted separately, for once each of the instruments. The order of administering SLEI actual form first, then SLEI preferred form later. The period between the administration of two instruments was about one to two weeks for all subjects (including teachers and students).

Subjects

The student subjects involved in this study initially included 1211 eighth and ninth graders in Taiwan. The population was stratified into three demographic areas, Northern, Central and Southern Taiwan. Six high schools from Northern Taiwan, four schools from Central Taiwan and four schools from Southern Taiwan were selected. The school number ratio selected roughly corresponds to the actual high school number ratio across these three areas. For each selected school, one or two classes, depending on the size of the school, were chosen. At a result, these students came from 24 classes in 14 junior high schools. Although this sample could not be viewed as a national sample, the selected Taiwanese eighth and ninth graders were across various academic background, demographic areas and social-economy levels, and they may then, to a certain extent, have represented Taiwanese junior high school students. Because some students failed to complete both of the questionnaires used in this study or they had missing data in the questionnaire(s), their results were excluded from final analyses of this study. Consequently, the final sample for this study included 1012 students and 46% of them are females.

Moreover, the selected students' science teachers (a total of 24) were also asked to respond to the SLEI questionnaire. In other words, the selected students were under the instruction of one of the selected teachers at the time of conducting this study. These students had been under one of the surveyed teachers' science instruction for at least eight months. And these students at least had conducted seven sessions of laboratory under the teacher's guidance. These sample teachers had an average of 9.8 years of science teaching.

Results

Actual versus Preferred Scores

Students' scores on the actual form and preferred form of SLEI were reported in Table 2. A series of the paired t-tests on comparing students' scores of the actual form with those of the preferred form indicated that students' preferred form scores were significantly higher than those of the actual form ($p<0.001$). That is, students tended to perceive their actual laboratory environments as less student-cohesive, less open-ended, less integrated with theory class, and less rule clarity than what they preferred. Also, they showed dissatisfaction with the material support provided by actual laboratory environments. A similar comparison on teachers' scores between actual form and preferred form was also conducted in Table 3. Teachers' scores on the student cohesive, open-ended, integration, and rule clarity scales were not significantly different between actual form and preferred form. However, teachers tended to complain the material environment in actual school laboratory, while they preferred a much better material support ($p<0.001$).
(Insert Table 2 and Table 3)

Student versus Teacher Scores

Table 4 lists a series of comparisons between students’ and teachers’ scores on each SLEI scale. For the scales of student cohesiveness, open-endedness, integration, and rule clarity on the actual form, teachers’ scores were significantly higher than students’ scores. For the same scales on the preferred form, teachers’ scores on the preferred form were significantly lower than those of students. Students showed much dissatisfaction with the approaches of actual laboratory activities than their teachers, and they preferred a much more student-cohesive, open-ended, integrated and rule-clear laboratory environment than what their teachers preferred and expected. However, the scores on the material environment scale showed an opposite result. Teachers’ scores on the scale of the actual form were significantly lower than those of students; however, teachers’ scores on the same scale of the preferred form were significantly higher than those of students. These indicated that teachers showed much preference for better equipment and material support for laboratory than their students.
(Insert Table 4)

The results derived from this study implied that students tended to be more concerned with the ways of conducting laboratory activities, for example, student cooperation, the extent of open-endedness, the integration between laboratory and theory classes, and the rule-clarity of conducting laboratory work. However, teachers may pay more attention to the material environment of the laboratory activities. These findings suggested that students and teachers may have had different foci and purposes about the laboratory activities, which may be related to their epistemological views of science. (This will be elaborated more details later in this paper). Hence, this study called these differences as an "epistemological gap." Science teachers need to recognize these differences and to narrow the gap by paying more attention to provide more student-cohesive, open-ended and integrated laboratory activities for students. It follows that students are expected to have more meaningful knowledge construction in laboratory activities.

Follow-up study--Interview with some selected teachers

As this study revealed that teachers had different perceptions toward laboratory learning environments than their students, a potential approach to explore this issue further was to conduct in-depth interviews. Consequently, eight teachers were randomly selected to work on this part of interview. In order to acquire more research insights and evidence directly related to this study, these teachers were asked to reflect on the findings of this study and then possibly to give some perspectives or reasons. (Hence, students may not be appropriate to have similar interviews, as they did not have adequate background knowledge to understand the findings). These teachers were interviewed individually. Their views about the teachers' and students' differences toward laboratory learning environments were summarized below.

Student-cohesive---

Concerning the difference in the student cohesiveness scale, many interviewed teachers thought that they tried to create more opportunities for student cooperation, but some management concerns may have hindered such opportunities. For example,

> Teacher A: I always encourage their discussion, group work and argumentation in the lab activities. But I often found that they were talking something unrelated to lab activities. So, I may need to keep an eye on their discussion or group work, and they may not feel very comfortable for discussion or argumentation under my close monitoring. Therefore, they may think that I could provide more favorable environments for student cooperation.
>
> Teacher D: I agree that ideally lab activities require a high degree of student cooperation. But, in realty, I feel hesitated to let them do this, as this causes a lot of problems of management. For example, many things that you are not expecting may happen.

These teachers' views concurred with the problem of management in argumentation activities raised by Newton *et al.* (1999). Teachers may need more knowledge or skills to be more confident to create laboratory learning environments with high degree of student cooperation. Moreover, some teachers' conceptions about the purposes of laboratory activities may impede the teachers' incentive for students' cooperation.

> Teacher B: Although working in groups in lab activities is important, I think to follow the experimental procedures and examine how the scientific knowledge works is more important in lab. That is the main task of doing lab. I think I have provided enough opportunities for student cooperation, but they did not well perform the experiments. They always just talked to each other, but did not have final or certain results derived from the lab activities.
>
> Teacher H: I often saw that students worked together but finally got nothing at the end of laboratory activities. I think that an emphasis on student cooperation may not guarantee an effective way of making the experiments well done by students. Sometimes, students who worked alone, but carefully followed the experimental procedures could quickly get more accurate laboratory results.

The above teachers clearly exemplified how their views about the purposes of laboratory activities guided their perceptions or practice about school laboratory activities. Their purposes of laboratory activities were more oriented to the "aims" of laboratory exercises, as defined by Hart (2000). That is, the expected results or a series of confirmed facts were central to the school laboratory. These views may be related to their epistemological beliefs about science. A final-form view of science or a simple positivist position about the epistemology of science may have reinforced their ideas as well as actual behaviors when conducting and guiding school laboratory activities for students. However, the survey data revealed earlier in this study showed that students might prefer a more student supportive laboratory environment, likely suggesting a more social constructivist perspective about the epistemology of science. This epistemological discrepancy may somewhat explain the differences between students' and teachers' perceptions about the degree of student cooperation in actual and preferred laboratory environments.

Open-ended—
In regard to the difference in the open-ended scale between students and teachers, most teachers believed that students lacked knowledge and relevant skills sufficient to conduct open-ended laboratory activities. For instance,

> Teacher B: Students lack adequate knowledge to do that. When they get in college or even graduate schools, they will do that.
>
> Teacher C: I once tried an open-ended approach to do the lab, but it did not work well. Students always asked me what to do next. Or, they asked me to just tell them the expected results or answers
>
> Teacher D: Students need more knowledge and reasoning skills to do that. They also need to plan the details of conducting open-ended activities. I doubt whether they can do that. In regular lab, they have difficulties of following the step-by-step lab processes provided by the textbooks, so I can not imagine how they can finish the lab if it is more open-ended.

In sum, as these teachers believed that these students did not have adequate knowledge and skills of conducting open-ended inquiry, they may have asked their students to merely follow the codified procedures to complete the laboratory activities. This view may be one of the major reasons why much laboratory work in the secondary science education level is situated in a cookbook type of instruction.

Integration—
Concerning the differences in the integration scale, many teachers thought that the time constraints may have caused the difficulties or problems of integration between theory and laboratory classes.

> Teacher E: I just did not have time to do that. Always, the laboratory activities were completed in a rush manner. I did not have enough time to explain the relationships between the theory class and laboratory activities. And, the laboratory was not often available when I needed it. As a result, there may be some mismatch between theory and lab classes.
>
> Teacher D: This is a time issue. Usually, we have just 45 minutes to finish one to two lab activities. Therefore, it is actually no time for me in the lab to clarify the connections between theory class and lab activities. The main task for me in the lab is to make sure that students complete the lab and get a final result. Also, they safely work with all apparatus or equipment.

Although time was a central factor in which teachers may not have well connected the theories with laboratory activities, teachers' epistemological views may also have influenced their thoughts about the issue of integration. For instance, Teacher H claimed that "Theory and lab are different sides of science, so the integration between these two is not a big issue." This, again, implies that teachers' epistemological views about science may shape their perceptions about the nature of school laboratory activities.

Rule clarity—
In regard to the differences in the rule clarity scale, some teachers believed that a large class

size caused the difficulties of providing a laboratory environment with clear rules. For instance,

> Teacher A: I think I have clear rules for guiding their lab activities. But, I have more than forty students in a class, so it is not possible for me to promptly respond to every student's question or to carefully monitor whether they follow the rules I set.

Some teachers also pointed out a dilemma between rule clarity and open-endedness. For example,

> Teacher F: For me, this part of research results was strange. Students, on the one hand, ask for more freedom or open-endedness of conducting lab activities; they, however, on the other hand, ask me to set up more clear rules for them to be followed. How can I do this?
>
> Teacher G: I try to figure out this part of findings, but can not quite understand. The rule clarity may inhibit the degree of open-endedness. So, I can not comment on this.

Practicing teachers may feel a tension between the use of open-ended laboratory activities and the need of clear rules in the laboratory requested by students. They may need more thoughts to resolve this tension. However, these two parts are not necessarily conflicting. For example, students may need clear rules in the laboratory *in general*, but they may not mean that teachers need to provide comprehensive guides or rules when conducting any specific laboratory activity. It is also practically possible that science teachers can design open-ended activities with few but very clear guidelines for students.

Material environment—
Finally, the students' and teachers' different perceptions toward the material environment scale were also explained in the teachers' interviews. As previously revealed, the findings derived from the material environment scale were opposed to those from the other four scales. In this scale, teachers had higher scores on the preferred form than their students in the same form, while teachers tended to show more dissatisfaction with the material support offered by actual laboratory environments than their students. Many teachers believed that better material support would help students have more accurate scientific knowledge.

> Teacher B: Science needs to be accurate, so the equipment and materials need to be good. Therefore, I have high standards about the material environments.
>
> Teacher E: If we do not have better material support, students can not conduct proper experiments and then can not get a certain result that confirms the scientific knowledge. That is, they can not see what they are expecting to see. Then, what is the purpose of lab?
>
> Teacher H: There are several reasons for requesting a better material support. First, good material or equipment will facilitate the lab processes, so students will not waste their time. They will quickly get the results or products of the experiments, which is the main task of the laboratory work. Second, with the assistance of better and more precise equipment, it will help students more accurately portray the rules of the nature. Finally, if we have better material supported lab environments, students, and even me, will feel more comfortable and show more willing in doing lab, as they can always get something useful or confirmed in the lab.

These views, again, were related to teachers' views about the purposes of laboratory activities. Many teachers involved in this study believed that laboratory was used to get some accurate or nearly certain results to confirm established scientific knowledge; therefore, they stressed the need of better material and equipment. These ideas, again, may also imply that their epistemological views about science were more oriented to positivism and empiricism, which guided their perceptions toward the school laboratory activities. Research literature has well documented that many teachers had positivist or empiricist views about the epistemology of science (Gallagher, 1991; King, 1991; Lederman, 1992, Tsai, in press). For example, Tsai (in press) found that twenty-one among 37 Taiwan science teachers interviewed in the study held a positivist-empiricist view about the nature of science. Similar findings were revealed about teachers' views about teaching science. For instance, an half of the student-teachers in Aguirre, Haggerty and Linder's (1990) study viewed science teaching as "a matter of knowledge transfer from the teacher's head and textbooks to the 'empty' minds of children" (p.388); therefore, the teacher was simply a presenter of the factual content of scientific knowledge. Further, the role of creativity and imagination on students' science learning was not appreciated by the group of teachers. Gustafson and Rowell (1995) also found that the majority of preservice teachers in their research held a tabula rasa view of children's minds and they mainly viewed learning simply as gaining information. Tsai's (in press) study on practicing teachers showed a similar finding. As well, many teachers in this study may have believed that the main task for student laboratory work was to gain scientific fact or truth with a blank mind.

Although this study did not have comparable data gathered from the students, with some interview evidence from teachers, it hypothesized that the epistemological views about science and teaching science may be one of the most important factors contributing to the differences of the perceptions toward laboratory learning environments between students and teachers. That is, the so-called epistemological gap causes these differences.

Discussion and Conclusions

Through surveying more than one thousand junior high school science students in Taiwan, this study revealed that students, compared to actual laboratory learning environments, preferred those where they could have more student cooperation, conduct more open-ended inquiry, explore more deeply about the connections between theory and laboratory work, and have clearer rules for guidance and better material support. Nevertheless, their teachers did not express a similar gap between their perceptions of actual laboratory learning environments and those of preferred learning environments, except the aspect of material support. They emphasized that the actual material environment in school laboratory should be greatly improved.

Students' and teachers' responses on the survey also found that students showed much dissatisfaction with the approaches of actual laboratory activities than their teachers, and they preferred a much more student-cohesive, open-ended, integrated and rule-clear laboratory environment than what their teachers expected or preferred.

However, these teachers showed preferences for better equipment and material environments for laboratory work than their students did. Interview with selected teachers also revealed that teachers may have focused on the aims or the products derived from the laboratory; consequently, they did not place student cooperation or even the open-endedness or integration with theories as high-priority features for student learning in laboratory activities. As a result, they claimed that the material support was important as it was directly related to aims and products of laboratory work. This study further asserted that these views were possibly shaped by their epistemological views about science, and these teachers might have positivist or empiricist-oriented views about the nature of science. Although this study did not gather in-depth information about students' and teachers' epistemological views about science, it believed that these could potentially be one of the major factors related to science students' and teachers' perception differences toward laboratory learning environments. Hence, this study called these differences as an "epistemological gap."

Research literature in science education has showed that teachers’ epistemological views of science are often considered as an important factor that frames their teaching beliefs, and these views may be related to instructional practice (Abd-El-Khalick, & Lederman, 2000; Brickhouse, 1989; Lederman, 1992; Mellado, 1997; Tsai, 2002). This study may further suggest that teachers' epistemological views of science may shape their views about the purposes of laboratory and then influence their actual implementation about laboratory activities. A more careful analysis about science teachers' epistemological views and their perceptions about laboratory work is necessary to clarify this research issue.

References

Abd-El-Khalick, F., & Lederman, N.G. (2000). Improving science teachers’ conceptions of nature of science: a critical review of the literature. *International Journal of Science Education, 22*, 665-701.

Aguirre, J.M., Haggerty, S.M., & Linder, C.J. (1990). Student-teachers' conceptions of science, teaching and learning: a case study in preservice science education. *International Journal of Science Education, 12*, 381-390.

Brickhouse, N.W. (1989). The teaching of the philosophy of science in secondary classrooms: Case studies of teachers' personal theories. *International Journal of Science Education*, *11*, 437-449.

Fisher, D.L., & Fraser, B.J. (1983). A comparison of actual and preferred classroom environments as perceived by science teachers and students. *Journal of Research in Science Teaching, 20,* 55-61.

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.

Gallagher, J.J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education, 75*, 121-133.

Gustafson, B.F., & Rowell, P.M. (1995). Elementary preservice teachers: constructing conceptions about learning science, teaching science and the nature of science. *International Journal of Science Education*, *17*, 589-605.

Hart, C., Mulhall, P., Berry, A., & Gunstone, R. (2000). What is the purpose of this experiment? Or can students learn something from doing experiments? *Journal of Research in Science Teaching, 37,* 655-675.

Hodson, D. (1996). Practical work in school science: exploring some directions for change. *International Journal of Science Education, 18,* 755-760.

King, B.B. (1991). Beginning teachers' knowledge of and attitudes toward history and philosophy of science. *Science Education*, *75*, 135-141.

Leach, J., & Paulsen, A. (1999). (Eds.) *Practical work in science education.* (Dordrecht, Netherlands: Kluwer).

Lederman, N.G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331-359.

Mellado, V. (1997). Preservice teachers’ classroom practice and their conceptions of the nature of science. *Science & Education, 6,* 331-354.

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education, 21,* 553-576.

Novak, J.D. (1988). Learning science and the science of learning. *Studies in Science Education, 15*, 77-101.

Roth, W.-M., & Roychoudhury, A. (1994). Physics students' epistemologies and views about knowing and learning. *Journal of Research in Science Teaching, 31*, 5-30.

Tsai, C.-C. (1999). “Laboratory exercises help me memorize the scientific truths”: A study of eighth graders’ scientific epistemological views and learning in laboratory activities. *Science Education, 83,* 654-674.

Tsai, C.-C. (2002). A science teacher’s reflections and knowledge growth about STS instruction after actual implementation. *Science Education, 86*, 23-41.

Tsai, C.-C. (in press). Nested epistemologies: Science teachers’ beliefs of teaching, learning and science. *International Journal of Science Education.*

Watson, R., Prieto, T, & Dillon, J.S. (1995). The effect of practical work on students’ understanding of combustion. *Journal of Research in Science Teaching, 32,* 487-502.

Wellington, J. (1998). (Ed.) *Practical work in school science.* (London: Routledge).

Table 1: Sample items in four forms of SLEI

Scale	Sample items -- Students' version	Sample items -- Teachers' version
Student Cohesiveness	I get on well with students in this laboratory class. (actual form) I would get on well with students in this laboratory class. (preferred form)	My students get on well with other students in this laboratory class. (actual form) My students would get on well with other students in this laboratory class. (preferred form)
Open-Endedness	I am allowed to go beyond the regular laboratory exercise and so some experimenting of my own. (actual form) I would be allowed to go beyond the regular laboratory exercise and so some experimenting of my own. (preferred form)	My students are allowed to go beyond the regular laboratory exercise and so some experimenting of their own. (actual form) My students would be allowed to go beyond the regular laboratory exercise and so some experimenting of their own. (preferred form)
Integration	What I do in our regular class is unrelated to my laboratory work.* (actual form) What I do in our regular class would be unrelated to my laboratory work.* (preferred form)	What my students do in my regular class is unrelated to their laboratory work.* (actual form) What my students do in my regular class would be unrelated to their laboratory work.* (preferred form)
Rule Clarity	My laboratory class has clear rules to guide my activities. (actual form) My laboratory class would have clear rules to guide my activities. (preferred form)	My students' laboratory class has clear rules to guide their activities. (actual form) My students' laboratory class would have clear rules to guide their activities. (preferred form)
Material Environment	The laboratory equipment which I use is in poor working order.* (actual form) The laboratory equipment which I use would be in poor working order.* (preferred form)	The laboratory equipment which my students use is in poor working order.* (actual form) The laboratory equipment which my students use would be in poor working order.* (preferred form)

* Scored in a reverse manner.

Table 2: Student perceptions of laboratory learning environments as assessed by SLEI actual and preferred forms (n=1012)

	Actual		*Preferred*		*Paired t-test between actual and preferred scores*
Scale	**Mean**	**S.D.**	**Mean**	**S.D.**	**t-value**
Student Cohesiveness	24.27	3.55	29.23	3.55	-31.04***
Open-Endedness	16.63	3.62	22.03	4.15	-30.85***
Integration	23.50	4.06	29.44	3.29	-36.18***
Rule Clarity	25.50	4.06	29.04	3.16	-22.07***
Material Environment	24.91	4.19	28.85	3.03	-23.50***

*** p<0.001

Table 3: Teacher perceptions of laboratory learning environments as assessed by SLEI actual and preferred forms (n=24)

	Actual		*Preferred*		*Paired t-test between actual And preferred scores*
Scale	**Mean**	**S.D.**	**Mean**	**S.D.**	**t-value**
Student Cohesiveness	28.08	1.98	28.46	1.50	-1.44
Open-Endedness	19.21	2.54	19.67	1.99	-1.66
Integration	27.25	2.17	27.54	1.44	-1.23
Rule Clarity	27.63	1.81	27.88	1.42	-0.90
Material Environment	23.08	2.50	32.29	1.63	-12.84***

*** $p<0.001$

Table 4: The differences between students' and teachers' perceptions toward laboratory learning environments

	Student		*Teacher*		*t-test*
Scale	**Mean**	**S.D.**	**Mean**	**S.D.**	**t[a]**
Student Cohesiveness (actual)	24.27	3.55	28.08	1.98	-9.10***
Open-Endedness (actual)	16.63	3.62	19.21	2.54	-4.87***
Integration (actual)	23.50	4.06	27.25	2.17	-8.13***
Rule Clarity (actual)	25.50	4.06	27.63	1.81	-5.42***
Material Environment (actual)	24.91	4.19	23.08	2.50	3.46**
Student Cohesiveness (preferred)	29.23	3.55	28.46	1.50	2.38*
Open-Endedness (preferred)	22.03	4.15	19.67	1.99	5.54***
Integration (preferred)	29.44	3.29	27.54	1.44	6.08***
Rule Clarity (preferred)	29.04	3.16	27.88	1.42	3.80**
Material Environment (preferred)	28.85	3.03	32.29	1.63	-9.97***

*** $p<0.001$, **$p<0.01$, * $p<0.05$

a: Levene's test for equality of variances indicates that these two samples are not assumed to have statistically equal variances for each variable in the Table.

Note

[1] In current stage, most practical work in school science is referred to laboratory-based experiences.