Learning environment in the undergraduate chemistry laboratory courses in Beirut

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Abstract

The undergraduate chemistry laboratory is an ideal place for meaningful learning to occur, and the laboratory work is considered as an integral part of most chemistry courses; however, a significant proportion of laboratory experiments remain highly prescriptive and fail to challenge undergraduate students. This study investigated the chemistry laboratory environment among 170 undergraduate students at a private university in Beirut, Lebanon. Data were collected using the Chemistry Laboratory Environment Inventory with its both versions: Actual Chemistry Laboratory Environment Inventory and Preferred Chemistry Laboratory Environment Inventory. The findings of this study showed that the students prefer a chemistry learning environment with greater levels of integration and material environment, but less level of open-endedness. Suggestions for improving chemistry laboratory learning environments are provided.

Keywords: Chemistry, laboratory, undergraduate courses, learning environment.

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1. Introduction

Laboratory work is a core component of university chemistry courses across the world. The introduction of practical work into university science courses started in Germany in the early 19th century and was spread to Scotland, America and England by mid to late 19th century (Boud, Dunn & Hegarty-Hazel, 1986). Practical work is now well established, but there are considerable variations in the amount of practical work that contributes to different science programmes throughout the higher education sector. Laboratory work is one of the main forms of teaching used in all undergraduate chemistry courses, and most chemistry educators agree that laboratory work has an essential role in chemistry education. In addition, the chemistry laboratory is a unique mode of learning, instruction and assessment. Chemistry laboratories have long been recognised for their importance and unique form in science education. The original reasons for its development lay in the need to produce skilled technicians for industry and highly competent workers for research laboratories (Morrell, 1972). Today, many first degree chemistry graduates are not employed as bench chemists in industry (Statistics of Chemistry Education, 2007), and the needs of research have inevitably become much more specialised as chemical knowledge has expanded.

2. Classroom learning environment

The importance of the classroom environment has been increasingly recognised over the past 50 years. In the past, common means of measuring the learning environment was through the use of perceptions, which led to insights into the learning environment through the eyes of the participants, rather than through an external observer. The current field of learning environments has been shaped by several powerful figures over the years. As cited in Hofstein (2004) and Lewin (1936) initiated the idea that personal behaviour is a result of the interaction between the individual and his/her environment, and Murray (1938) expanded upon this idea by considering additional effects within the system, namely, that an individual's behaviour is affected internally by the characteristics of personality and externally by the environment itself. The individual's interaction with the environment relates to the personal needs of the individual. To enable the classification and sorting of various components of an environment, Moos (1974) developed a scheme for classifying human environments into three dimensions: relationship, personal development and system maintenance and system change. These three basic dimensions assist in explaining the characteristics of human behaviour:

i. *The relationship dimension*: assesses the nature and intensity of personal relationships within the environment and the extent to which people are involved in the environment and support one another.
ii. The personal development dimension: assesses the extent of personal growth and self-enhancement.
iii. The system maintenance and system change dimension: assess the responsiveness, orderliness, level of expectation and control of the environment.

Past research which investigated the determinants of classroom environment has revealed reliable differences in the perceptions of classroom environment held by students and their teachers (Fraser, 1984). A strong theme in past classroom learning environment research has involved investigations into associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial characteristics of their classroom environments (McRobbie & Fraser, 1993; Wong, Young & Fraser, 1997).

Hofstein and Lunetta (1982) pointed out the importance of examining the uniqueness of the science laboratory learning environment in research. They wrote: 'Since creating a healthy learning environment is an important goal for many contemporary science educators, there is a need for

further research that will assess how the time spent in laboratory activities and how the nature of students' activities in the laboratory affect the learning environment'.

Hofstein, Nahum and Shore (2001) analysed the learning environment of inquiry-type laboratories in high school chemistry classes. They used the Science Laboratory Environment Inventory. Statistical comparison of the inquiry and control groups revealed significant differences between them regarding their actual perceptions. Moreover, it was found that the differences between the actual and preferred laboratory learning environment were significantly smaller for the inquiry group than for the control group.

Quek, Wong and Fraser (2005) investigated the chemistry laboratory classroom environment, teacher–student interactions and student attitudes towards chemistry among 497 gifted and non-gifted secondary school students in Singapore. The data were collected using three questionnaires: the Chemistry Laboratory Environment Inventory (CLEI), the questionnaire on teacher interaction and the questionnaire on chemistry-related attitudes. Some statistically significant associations of modest magnitude were found between students' attitudes towards chemistry and both the laboratory classroom environment and the interpersonal behaviour of chemistry teachers.

This study aimed to: assess students' perception of the actual and preferred undergraduate chemistry laboratory learning environment. The research question investigated in this study was: are there any relationships between the students' perceptions of their actual chemistry laboratory learning environment and preferred chemistry laboratory learning environment in the undergraduate chemistry laboratory courses in Beirut?

3. Methodology

In this study, the researcher used the quantitative method to collect data related to the chemistry laboratory learning environment.

3.1. Sampling

This study took place at a large private university in Beirut during the spring 2014 semester which is for 4 months and covered a sample of six chemistry laboratory courses. A total of 170 undergraduate students who were enrolled in these six lab courses participated in this study. The students were informed that this study had no impact on their grades and all the names of the instructors and rooms were represented by pseudonyms. Most of the respondents came from urban areas in a percentage of 89.04%; whereas a small subset (10.96%) of the students enrolled in the practical chemistry courses were from rural areas. The highest percentage of responses (85.53%) that completed the questionnaires was in the age range of 18–20 years and 65.56% were females. Ninety percent of the respondents have completed their high school at private academic institutions, and 76.97% of the students were Lebanese. Most of the respondents have finished one to two chemistry practical (laboratory) courses and one to three regular chemistry courses. The majority of the students were at the junior level (47.55%). The distribution of majors was as follow: biology (45.03%), nutrition (24.5%), chemistry (11.92 %), pharmacy (4.64%) and other fields or undecided (13.91%). Almost half of the students (51.02%) have a high GPA (between three and four); whereas only 3.4% of them have a GPA below two.

3.2. Data collection tools

For this study and to answer the research question, the researcher used two questionnaires to collect data:

i. *Actual Chemistry Laboratory Environment Inventory (ACLEI)*: to assess students' perceptions of their actual learning environment (see Appendix A)

ii. *Preferred Chemistry Laboratory Environment Inventory (PCLEI)*: to assess students' perceptions of their ideal (preferred) learning environment (see Appendix B)

The researcher and the instructors of the lab courses have collected data using the questionnaires mentioned above. Respondents were given clear instruction about completing each questionnaire and given approximately 10 minutes to complete each questionnaire. All data were collected anonymously and without individual identification.

3.3. Descriptive information for the Chemistry Laboratory Environment Inventory (CLEI) –ACLEI and PCLEI

Each questionnaire consists of 35 items and these items are divided into five scales, where each scale was containing seven items (see Table 1).

Table 1. Descriptive information of CLEI

Scale name- five scales	Description of scale	Sample items	Scales classified according to Moos' scheme	Format
Student cohesiveness (SC)	The degree to which students know, help and are supportive of one another.	I get on well with students in this chemistry laboratory class (+)	Relationship dimensions	5-point Likert (Almost never/very often)
Open-endedness (OE)	The degree to which the laboratory activities emphasise on open-ended and divergent approach to experimentation.	There is the opportunity for me to pursue my chemistry interests in this chemistry laboratory class (+)	Personal development dimensions	
Integration (IN)	The degree to which the laboratory activities are integrated with non-laboratory and theory classes.	What I do in our regular chemistry class is unrelated to my chemistry laboratory work (-)	Personal development dimensions	
Rule clarity (RC)	The degree to which behaviour in the laboratory is guided by formal rules.	My chemistry laboratory class has clear rules to guide my activities (+)	System maintenance and change dimensions	
Material environment (ME)	The degree to which the laboratory equipment and materials are adequate.	I find that the chemistry laboratory is crowded when I am doing experiments (-)	System maintenance and change dimensions	

3.4. Data gathering procedure

Before the beginning of the spring 2014 semester, an e-mail was sent by the researcher to the chairperson of the Natural Sciences Department of the University to take permission to conduct the study, and it was approved. In his turn, the chairperson informed all the instructors in the department to participate in this study by helping in collecting the data.

3.5. Data analysis

The quantitative data were analysed by using the SPSS20 software. Descriptive statistics (mean, mode, min, max, standard deviation, CV, etc.) and inferential statistics (ANOVA, *t*-test, *p*-value, regression, significance, etc.) were calculated for the questionnaires.

4. Results

In this section, we are looking to compare the difference between the items of ACLEI and PCLEI questionnaires. To study this effect, the independent sample test (*t*-test) was used. It's a parametric test used to compare the results between two groups. For the interpretation, we compare the degree of significance (Sig) with error ratio (α = 5%, i.e., 0.05). If Sig > α, we consider the difference insignificant and vice versa.

Results in Table 2 show the average item means for each factor in the actual and preferred version of the student form of the CLEI; in an attempt to show the differences between scores on pairs of forms of each CLEI scale, statistically significant differences ($p < 0.05$) was clearly observed in IN (Sig = 0.015) and ME (Sig = 0.001). But insignificant differences were observed in SC (Sig = 0.420), OE (Sig = 0.379) and RC (Sig = 0.439).

Table 2. Mean and degree of significance for the actual and preferred versions of CLEI

Scale	No. of items	Mean		Sig.
		Actual	Preferred	
SC	7	3.90	3.96	0.420
OE	7	3.14	3.07	0.379
IN	7	3.33	3.56	0.015*
RC	7	3.88	3.93	0.439
ME	7	3.23	3.65	0.000**

*Significant at the 0.05 level.
**Significant at the 0.01 level.

The average item means were plotted (see Figure 1) instead of the scale means, since the average item means provided a fair basis for comparison between the different scales. The response alternatives of the CLEI instrument corresponding to the value intervals on the average item mean axis in Figure 1 are as follows: 1 = 'Never', 2 = 'Seldom', 3 = 'Sometimes', 4 = 'Often' and 5 = 'Very Often'. This simplified plot gave us a clear vision of the comparison between the actual and preferred perceptions of the chemistry laboratory classroom environment of students. An interesting pattern emerged from this part of this study. It was found that students tended to have similar perceptions of the levels of SC, OE and RC existing in their laboratory classes. However, a significantly higher level of IN and ME were perceived. With regards to their preferred perceptions, students would prefer an environment with greater levels of IN and ME. Moreover, students also preferred a learning environment with more SC and RC but with less OE.
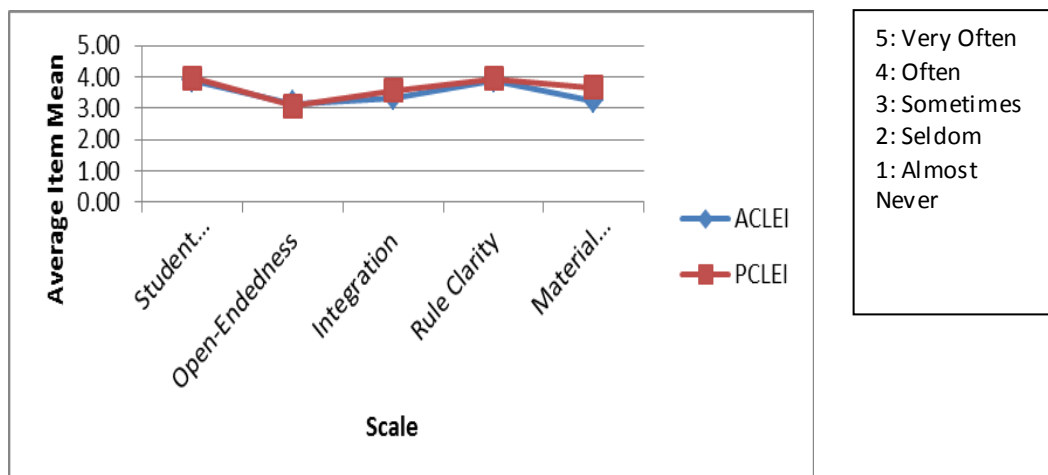
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Figure 1. Simplified plot of significant differences between student (actual) and student (preferred) CLEI scores

In summary, the results showed that students prefer a chemistry learning environment with greater levels of IN and ME, but with less level of OE.

5. Conclusion and discussion

Universities have in the recent years faced new challenges as the new generations of students enter the old institutions. Many of the incomers belong to the so-called digital natives who use various digital applications and mobile devices as integrated parts in their everyday lives, their knowledge seeking and knowledge sharing activities are different from the previous generations (Sandstrom, Ketonen & Lonka, 2014). Now the very context of higher education is radically changing, where team work and collaboration are emphasised, as the new 21st century skills. The social and cultural changes are also infiltrating the practices in higher education and different learning organisations. Learning takes place in both formal and informal environments, locally and globally, both virtually and socially and in successive cycles of personal and collaborative learning efforts (Sandstrom et al., 2014). Nowadays, it is a must to develop new ways of learning that are both intellectually activating and make students enjoy going to an educational institution, and it is important to make the efficient use of and develop those physical environments and tools that each university has (Sandstrom et al., 2014). By previous research, Sandstrom et al. (2014) believe that the perceptions reported by the chemistry students can provide us with important insights, also, into how higher educational facilities and curricula could be better organised to support the new generation of learners and emerging knowledge practices.

It is well known that the learning environment is an important aspect of the education process. It influences both the students' outcomes and teacher performances. Using CLEI instrument at the higher education level helps instructors to evaluate their learning environments in the chemistry laboratory to improve their education process and performance. Furthermore, the information from CLEI could be useful as a guide to enhance the effectiveness of chemistry laboratory. These instruments provide the information about students' perceptions of actual and preferred laboratory learning environments in addition to the instructor interpersonal behaviour. The effectiveness in chemistry laboratory is very important because the practical work is of high cost and time-consuming. Therefore, evaluation of the chemistry laboratory teaching is important for improving and developing students' learning achievement successfully.

Responses on items of OE factor based on using the ACLEI were interesting in this study. Students made it clear that they almost never get a chance to design their experiment, decide the best way to

proceed during laboratory experiments, or allow to go beyond the regular laboratory exercise and to do some experimenting of their own; this finding agrees with the chemistry laboratory manuals' evaluation.

Moreover, the findings based on using the PCLEI showed a preference by the students for a less OE (to pursue their own chemistry interests in the lab, to design their own experiments, or solve a given problem, collecting different data for the same problem, go beyond the regular laboratory exercise and do experimenting of their own, different students performing different experiments, deciding the best way to carry out the laboratory experiments and deciding the best way to proceed during laboratory experiments), but a greater level of IN of content between information presented in the lecture and the experiments carried out in the laboratory portion of the course (regular chemistry class must be related to the laboratory work, use the theory from the regular chemistry classes sessions during laboratory activities, the topics covered in regular chemistry class work will not be different from the topics dealt with in laboratory sessions, the laboratory sessions must help them to understand more the theory covered in the regular chemistry classes and laboratory work and regular class work would be more related) and a better level of ME (better equipped laboratory, less crowded, better appearance and working order, with fresh air and ventilation, cool climate, attractive place to work in and spacious lab). It seems that students at this level prefer an easy lab course (with low-inquiry level), so that they can guarantee an 'A' in the course at the end of the semester because they consider that the chemistry practical courses are less important than the theoretical courses and they need fewer efforts to receive an easy 'A'. Moreover, it is important to mention that the assessment of students' practical knowledge and abilities and the purposes of laboratory inquiry tend to be seriously neglected even by high-stakes tests that support to assess chemistry standards. Thus, many students do not perceive laboratory experiences to be particularly important in their learning.

In general, the CLEI indicated that there was little congruence between the actual and preferred chemistry laboratory learning environment; thus, indicating that students would prefer for there to be more SC, less OE, greater IN, more RC and better laboratory facilities. Students had a greater score in the preferred column in each of the scales except for the OE, which could indicate a variety of preferences. These students could prefer more self-initiated activities and greater cohesiveness as found by Byrne, Hafde and Fraser (1986) in a similar study. If greater cohesiveness is desired, students may prefer a more positive classroom environment (positivity is associated with the relationships between student–instructor and student–student), which is a common request of students as found by Dorman (2008). In addition to the desire for a more cohesive classroom, this study also found that this laboratory classroom was dominated by close-ended activities (e.g., laboratory activities guided by exact procedures and prescribed laboratory experiments with no room for deviation). Fraser, Giddings and McRobbie (1995) also found this when evaluating the science laboratory classroom. But students in this study would prefer for there to be less OE than what they are currently experiencing (e.g., the opportunity to design students' experiment and procedures). However, this desire for less OE is similar to the work of McRobbie and Fraser (1993), as those researchers found that the students did not desire more open-ended activities.

Students in this study would prefer better laboratory facilities, which can result in an enriched learning environment, which includes a setting that results in greater involvement in purposeful activity (Ainley, 1990). Purposeful activity promotes greater student learning, which can be accomplished through science laboratory facilities if they are operated in a manner that is exciting and encouraging for students (Freedman, 1997). Exciting and encouraging environments can promote more positive attitudes toward science (Freedman, 1997). Fraser et al. (1995) found that greater student achievement occurred when there was greater congruence between the actual and preferred classroom environment, as evaluated by students. Results in this study indicated that students would prefer for greater congruence between the actual and preferred classroom, in four scales of the CLEI out of five; therefore, the student achievement could have been low due to the lack of congruence between each scale.

The IN scale was evaluated to determine if there was adequate IN between lecture and laboratory portions of the course. The data indicated that there was a significant difference between the actual and preferred level of IN; thus, showing that students would prefer for there to be more IN between the laboratory class and the lecture or theory portion of the class. IN may be the most important aspect of the laboratory environment that was evaluated concerning student learning. Research (Bliuc, Ellis, Goodyear & Piggott, 2009) has shown that IN of knowledge is imperative to student learning. If the information is not integrated, students can perceive material as unrelated and not important to the overall learning goal (Bliuc et al., 2009).

Finally, instructors must facilitate activities that promote a positive learning environment and creating activities that allow students more freedom to explore their interests, while still accomplishing the same learning goals. To create activities that allow an extension of thinking, but are not entirely open-ended, instructors may try directing the focus of students by offering potential areas to explore or experiments to perform, but giving students the freedom to choose within the guidelines.

6. Recommendations

According to the findings of the study and the previous researches related to the chemistry laboratory learning environment, following suggestions can be offered: first, based on students' perceptions, the findings related to the chemistry laboratory learning environment are particularly useful to the administrators and instructors and could help instructors to reflect on the various aspects of the chemistry laboratory and their interactions with students; second, chemistry classroom learning environment is an important predictor to understand students' attitude toward chemistry and their motivational beliefs. For this reason, classroom environments should be developed according to students' need and their interest; third, instructors and administrators in the science department must pay particular attention to the low score in the OE (degree to which the laboratory activities emphasise an open-ended divergent approach to experimentation) and ME (degree to which the laboratory equipment and materials are adequate) dimensions of the laboratory learning environment. This indicates areas where improvement can be made in the teaching and learning of chemistry; fourth, the OE learning environment could be beneficial in establishing a unique and enjoyable learning environment for the students. The practical implication of this finding is that teachers might attempt to adopt more open-ended approaches in their teaching and improve the quality of the ME in the chemistry; fifth, the CLEI could be used by the instructors as one part of action research intended to examine the effects of a new laboratory teaching approach or strategy and as a part of improving instruction. Even researchers can also use this instrument for more summative type studies in which they examine effects of different kinds of teaching in the laboratory on students' perceptions of the learning environment; sixth, seminars, workshops and conferences should be organised occasionally for chemistry instructors. This will help the instructors to refresh their knowledge especially on modern strategies of teaching and learning which could enhance the teaching and learning of chemistry and to improve the chemistry laboratory learning environment; finally, we must redesign our chemistry curriculum by customising instruction to meet the learning needs of learners, incorporating more lively and practical approaches and infusing scientific inquiry, creative and critical thinking skills into both the theoretical and the laboratory work.

In the future, this study should be replicated with a larger sample and in different subject areas. Both hard science laboratory courses (e.g., chemistry, physics, etc.) as well as applied science laboratory classes should be evaluated. The researcher should obtain achievement scores at the semester end to determine if student achievement is affected by the perception of differences in the actual and preferred classroom environment. To more adequately evaluate the IN scale, information should be obtained from the instructor for each lecture course. Further information about the curriculum can provide insight into the presentation order of material as well as the depth to which each topic is covered.

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Appendix A

Actual Chemistry Laboratory Environment Inventory (ACLEI)

Items #	**This questionnaire contains statements about practices which could take place in this laboratory class.** **You will be asked how often each practice actually takes place.**	Almost never	Seldom	Sometimes	Often	Very often
		1	2	3	4	5
1	Students in this laboratory class get along well as a group.					
2	There is opportunity for students to pursue their own chemistry interests in this laboratory class.					
3	What we do in our regular chemistry class is unrelated to our laboratory work.					
4	Our laboratory class has clear rules to guide student activities.					
5	The laboratory is crowded when we are doing experiments.					
6	Students have little chance to get to know each other in this laboratory class.					
7	In this laboratory class, we are required to design our own experiments to solve a given problem.					
8	The laboratory work is unrelated to the topics that we are studying in our chemistry class.					
9	This laboratory class is rather informal and few rules are imposed.					
10	The equipment and materials that students need for laboratory activities are readily available.					
11	Members of this laboratory class help one another.					
12	In our laboratory sessions, different students collect different data for the same problem.					
13	Our regular chemistry class work is integrated with laboratory activities.					
14	Students are required to follow certain rules in the laboratory					
15	Students are ashamed of the appearance of this laboratory.					
16	Students in this laboratory class get to know each other well.					
17	Students are allowed to go beyond the regular laboratory exercise and do some experimenting of their own.					
18	We use the theory from our regular chemistry class sessions during laboratory activities.					
19	There is a recognised way of doing things safely in this laboratory.					
20	Laboratory equipment is in poor working order.					
21	Students are able to depend on each other for help					

	during laboratory classes.
22	In our laboratory sessions, different students do different experiments.
23	The topics covered in regular chemistry class work are quite different from topics dealt with in laboratory sessions.
24	There are few fixed rules for students to follow in laboratory sessions.
25	The laboratory is hot and stuffy.
26	It takes a long time to get to know everybody by his/her first name in this laboratory class.
27	In our laboratory sessions, the teacher/instructor decides the best way to carry out the laboratory experiments.
28	What we do in laboratory sessions helps us to understand the theory covered in regular chemistry classes.
29	The instructor outlines safety precautions before laboratory sessions commence.
30	The laboratory is an attractive place in which to work.
31	Students work co-operatively in laboratory sessions.
32	Students decide the best way to proceed during laboratory experiments.
33	Laboratory work and regular chemistry class work are unrelated.
34	This laboratory class is run under clearer rules than other classes.
35	The laboratory has enough room for individual or group work.

Appendix B

Preferred Chemistry Laboratory Environment Inventory (PCLEI)

This questionnaire contains statements about practices which could take place in this laboratory class.
You will be asked how often you would prefer each practice to take place.

Items #		Almost never	Seldom	Sometimes	Often	Very often
		1	2	3	4	5
1	Students in this laboratory class would get along well as a group.					
2	There would be opportunity for students to pursue their own chemistry interests in this laboratory class.					
3	What we do in our regular chemistry class would be unrelated to our laboratory work.					
4	Our laboratory class would have clear rules to guide student activities.					

5   The laboratory would be crowded when we are doing experiments.

6   Students would have little chance to get to know each other in this laboratory class.

7   In this laboratory class, we would be required to design our own experiments to solve a given problem.

8   The laboratory work would be unrelated to the topics that we are studying in our chemistry class.

9   This laboratory class would be rather informal and few rules would be imposed.

10   The equipment and materials that students need for laboratory activities would be readily available.

11   Members of this laboratory class would help one another.

12   In our laboratory sessions, different students would collect different data for the same problem.

13   Our regular chemistry class work would be integrated with laboratory activities.

14   Students would be required to follow certain rules in the laboratory.

15   Students would be ashamed of the appearance of this laboratory.

16   Students in this laboratory class would get to know each other well.

17   Students would be allowed to go beyond the regular laboratory exercise and do some experimenting of their own.

18   We would use the theory from our regular chemistry class sessions during laboratory activities.

19   There would be a recognised way of doing things safely in this laboratory.

20   Laboratory equipment would be in poor working order.

21   Students would be able to depend on each other for help during laboratory classes.

22   In our laboratory sessions, different students would do different experiments.

23   The topics covered in regular chemistry class work would be quite different from topics dealt with in laboratory sessions.

24   There would be few fixed rules for students to follow in laboratory sessions.

25   The laboratory would be hot and stuffy.

26   It would take a long time to get to know everybody by his/her first name in this laboratory class.

27   In our laboratory sessions, the teacher/instructor would decide the best way to carry out the laboratory experiments.

28   What we do in laboratory sessions would help us to understand the theory covered regular chemistry

	classes.
29	The instructor would outline safety precautions before laboratory sessions commence.
30	The laboratory would be an attractive place in which to work.
31	Students would work co-operatively in laboratory sessions.
32	Students would decide the best way to proceed during laboratory experiments.
33	Laboratory work and regular chemistry class work would be unrelated.
34	This laboratory class would be run under clearer rules than other classes.
35	The laboratory would have enough room for individual or group work.