Student Assessment Of Laboratory In Introductory Physics Courses: A Q-sort Approach

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Abstract. This paper will introduce a previously developed Q-sort instrument, called the Laboratory Program Variables Inventory (LPVI). We will also report on a case study using a modified version of the LPVI to investigate students' perceptions about the implementation of a new lab type and further to compare characteristics of the new lab with those perceived by students in other PER-based learning environments. Our preliminary results show that the LPVI is a valuable instrument for assessing hands-on learning environments and related curriculum development and implementation in PER.

INTRODUCTION

Q-sort instruments have been commonly used in social, and clinical contexts, and in personality psychology to obtain *descriptive* information on various topics, since Q-methodology was first introduced by William Stephenson [1,2]. A Q-sort instrument is usually composed of a set of statements, pictures, or other items printed on separate cards. Subjects are asked to rank the cards according to some single criterion. Subjects are instructed to force the rankings into a quasi-normal distribution. This process is referred to as Q-sorting. The resulting data can be analyzed by a number of statistical methods. Compared to other common methods used to obtain descriptive information, such as field observations, subject interviews, and questionnaires, a Q-sort instrument has its own rationales: it can get first-hand data from large numbers of students with less time than other methods, and objective and statistical data analysis can be applied to the data [3].

While some Q-sort instruments have been developed and used in other educational fields [e.g., 3-6], the authors are unaware of any Q-sort instrument yet reported in PER (except for some papers previously presented by the authors at the AAPT and PER conferences [7-9]). Based on our previous work, this paper will introduce a Q-sort instrument, called the Laboratory Program Variables Inventory (LPVI) [3], to the PER community. In addition, we will report on our preliminary results of a case study using a modified version of the LPVI to investigate students' perceptions

about the implementation of a new lab type and further to compare characteristics of the new lab with other PER-based learning environments.

The LPVI [3] is a Q-sort instrument originally developed for assessing three different types of college general chemistry labs: traditional verification, guided inquiry, and open/inquiry labs. It is useful for obtaining descriptive information about teaching methods and curriculum materials used in those labs. The LPVI contains 25 statements that are characteristic of most hands-on lab environments; the statements describe common lab activities (see these statements in the appendix). In order to adapt the LPVI, the original statements were modified as follows: the word 'chemistry' was replaced by 'physics', and the word 'report' was replaced by 'manual'. This second change is reflective of the fact that many hands-on introductory physics courses (and all at the Ohio State University (OSU)) have in-class activities instead of take-home lab reports commonly found in chemistry.

Two important points should be noted. First, the LPVI is not an attitude survey. Students are not asked how they think or feel about the classroom activities. Rather, they are to give agreement or disagreement with subjective statements about the activities. This is a measure of what actually happens in the classroom, or more specifically, what the students feel are the most salient features of the classroom activities. Second, the statements in the LPVI are very general, and are applicable to all the lab types tested in this study. For example, a statement such as "The instructor is concerned with the correctness of the data" applies to all

lab types, but will be more strongly emphasized in some than others.

THE CASE STUDY

Motivation For The Use Of LPVI

ISLE, the Investigative Science Learning Environment [10,11] was developed and tested at Rutgers and California State University, Chico (CSUC) and later adapted and implemented at OSU. These include innovative laboratory activities such as different types of student design tasks intended to help students develop scientific abilities. To assess the *ISLE*, among a series of research questions, these two have been asked: (1) Does the *ISLE* labs work as designed? How do students perceive *ISLE* labs and what are important descriptive characteristics of *ISLE* labs from the point of view of the students? (2) Are *ISLE* labs different from *Physics by Inquiry* (PbI) [12] and from other PER-based introductory labs? If so, what are the differences?

To investigate these two questions, we have carefully searched for assessment instruments and found that the LPVI seems to serve our needs. It not only provides descriptive information about teaching methods and curriculum materials, but was also developed for assessing activity-based classrooms, such as labs and inquiry-based courses. In these classrooms a surface glance may reveal many similarities: students use equipment to probe physics concepts, students work in groups, instructors talk to the groups rather than give general lectures, and so on. However, due to the different goals of these classrooms, more careful observation would show distinct differences. For example, one classroom may have instructors circulating in order to check student responses, while other classrooms may have students checking their own results. The LPVI can distinguish these differences, as well as assess the course by giving a view of whether the goals of the course are strongly perceived by the students.

Samples And Data Collection

The LPVI was given to five different learning environments: introductory calculus-based *ISLE* labs at Rutgers, CSUC, and OSU, respectively, PBI at OSU, and a regular introductory calculus-based lab (OSU 131) using PER-based materials at OSU. Although there exist differences in the detailed contents of each *ISLE* lab at each university, the goal of all *ISLE* labs is to help students develop scientific abilities. The PbI course for pre-service teacher and non-science major students uses *Physics by Inquiry*

[12] developed by Lillian McDermott and the PER group at the University of Washington. Students in OSU 131 lab work in groups of 3~4 during 2-hour weekly labs and the lab manual was developed including PER components, in particular, with an emphasis on conceptual understanding.

In each course above, the LPVI was used only as a post-test. Each student was given a packet of 25 statements(see the appendix), each printed on a separate small slip of paper. Students were given approximately 15 minutes to sort the 25 statements into 5 groups. These groupings are defined to be quasi-normal, students can only put 2 statements in the category labeled "Group I: most descriptive", and 2 in the category "Group V: least descriptive". 9 statements can be placed in the central category (Group III), and in the remaining two groups (II and IV) students can place 6 statements. Students then recorded their rankings on a form with the labeled groups as described above. Students were asked to double check that they had used each statement once and only once before submitting them.

Data Analysis and Results

Once the statements have been ranked, they can be weighted depending on which group they are in. Group I (most descriptive) statements are weighted with +2, Group II is weighted with +1, and so on until Group V (least descriptive) with -2. These weights represent how strongly the students felt the statements described (or did not describe) their class. It remains unclear if statements ranked as Group III are statements students are neutral toward or statements that do not apply to that lab. Since in this study we only pay attention to the most and least descriptive statements, we are not going to focus on this issue.

Based on this scale, the weighted average for each statement from each class is calculated. Table 1 shows the results of the top five most descriptive statements from each course. Table 1 clearly shows that all the *ISLE* students have perceived that student-designed experiments are a significant characteristic of the *ISLE* lab. In addition, the *ISLE* students at Rutgers and CSUC both indicated that they were asked to "explain why certain things happen," but this is not clear from the *ISLE* students at OSU. However, the OSU *ISLE* students did feel that their assumptions and conclusions must be justified based on discussions with the instructor. Since it was the first time to adapt and implement the *ISLE* labs at OSU, the results here tell us that in the future we need to make students' lab manuals and lab instructors *more explicitly* require students to give their explanations based on experimental evidence. In addition, the results in Table

1 also show that the *ISLE* labs possess important features of an open/guided inquiry lab [3].

The PbI results in Table 1 fairly describe what happens in a typical PbI course, which is consistent with our perceptions as instructors. The results from the regular OSU 131 lab indicate that this lab still runs more in a traditional format but with PER developed lab materials that emphasize students' conceptual understanding.

TABLE 1. Top five most descriptive statements from each course based on the weighted average of each course

ISLE Lab (N = 156, Rutgers, Au 04)	11	7	5	13	16
ISLE Lab (N = 70, OSU, Au 04)	7	11	25	23	5
ISLE Lab (N = 36, CSUC, Sp04)	7	2	17	15	16
ISLE Lab (N = 44, CSUC, Sp 02)	5	7	16	13	11
PbI course (N = 84, OSU, Sp 04)	17	1	5	23	22
Regular 131 (N = 203, OSU, Au 04)	1	17	22	11	5

Furthermore, to study any differences between the different types of labs, two of the authors independently developed a series of subgroups for the statements. One of these series separated 12 of the statements (statements 7, 17, 21, 19; 1, 3, 14, 8; 4, 22, 10, 12) into three groups: student-directed, instructor-directed, and in between. We then came to a consensus before forming the final categories. For example, consider statements 3, 17, and 22. Each of these statements relates to the correctness of the experimental results. Statement 17, "Students discuss their data and conclusions with each other" was placed in the student-directed group. Statement 3, "The instructor is concerned with the correctness of the data" is considered instructor-directed. Statement 22, "During laboratory students check the correctness of their work with the instructor" is in between, because the students still consider the instructor the judge for correctness, but the role of the instructor is more passive, while the role of the students is more active as compared to statement 3. These categories can then be analyzed based on the weighted rankings of their statements by students in each classroom. In Fig. 1 below, we report on student-directed and instructor-directed results as averages for all the five different courses at different universities.

Fig. 1 indicates that all the *ISLE* labs are student-directed, the regular 131 lab is instructor-directed, while PBI is in between. Another result obtained from Fig. 1 is addressing the implementation of *ISLE* labs at

OSU. A successful *ISLE* implementation should show students perceiving the labs as student-directed. In fact, the implementation at OSU was surprisingly successful since students had the highest weighted student-directed statements at that institution. We must be careful, however, as this could imply that students were not given enough help from the instructors - there could be frustration hidden in such high rankings from the students.
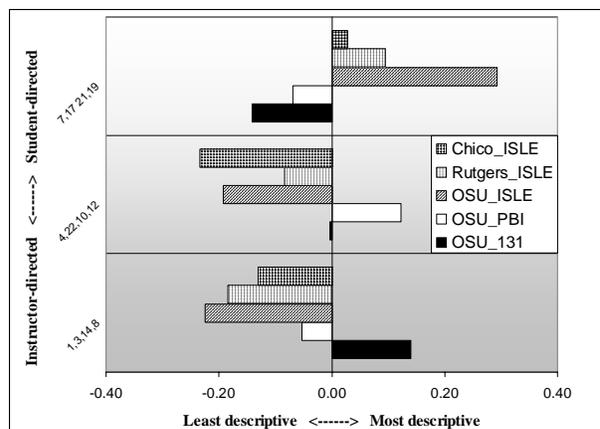

FIGURE 1. Results of the LPVI with the sub-groups

CONCLUSION

The LPVI is a Q-type instrument developed for assessing student perceptions of chemistry labs. With minor modifications it is suitable for use in physics courses. The authors feel that this is a valuable tool for use in PER, as it provides information about how students perceive the courses, which is not easy to determine by other methods. It also helps to understand what actually happens in a course without lengthy classroom observations. The LPVI was successfully used to assess the development of the *ISLE* lab and its implementation at OSU. It was found that students ranked statements in agreement with the course goals. It was also used to look at differences in course curricula in different hands-on learning environments. This data helps us understand the strengths and weaknesses of these courses, as well as the differences between the different labs. Other studies have been done by the authors, as well as more analysis for which there is no room in this paper. It is the hope of the authors that this paper will provide a foretaste of the usefulness of Q methodology to the PER community.

APPENDIX

Modified Laboratory Program Variables Inventory (LPVI) Statements:

1. Students follow the step-by-step instructions in the laboratory manual.
2. Questions in the laboratory manual require the interpretation of data.
3. The instructor is concerned with the correctness of the data.
4. Students are allowed to go beyond regular laboratory exercises and do experiments on their own.
5. Laboratory activities are used to develop concepts.
6. The instructor lectures to the whole class.
7. Students are asked to design their own experiments.
8. During laboratory students record information requested by the instructor or the laboratory manual.
9. Laboratory sessions raise new problems or result in data that cannot be immediately explained.
10. The instructor or laboratory manual identifies the problem to be investigated.
11. Laboratory activities require students to solve problems.
12. The laboratory manual requires that specific questions be answered.
13. The instructor or laboratory manual requires that students explain why certain things happen.
14. Laboratory is used to investigate a problem that comes up in class.
15. Laboratory experiments develop skill in the techniques or procedures of physics.
16. Questions in the laboratory manual require that students use evidence to back up their conclusions.
17. Students discuss their data and conclusions with each other.
18. The instructor or laboratory manual asks students to state alternative explanations of observed phenomenon.
19. During laboratory students record the information they feel is important.
20. Students propose their own explanations for observed phenomenon.
21. Students identify problems to be investigated.
22. During laboratory students check the correctness of their work with the instructor.
23. In discussion with the instructor, assumptions are challenged and conclusions must be justified.
24. Students usually know the general outcome of an experiment before doing the experiment.
25. The instructor gives information to individuals in small groups

ACKNOWLEDGMENTS

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