Student Perceptions of Three Different Physics by Inquiry Classes using the Laboratory Program Variables Inventory

Gordon J. Aubrecht, II

The Ohio State University Marion Campus

Abstract. Students from different versions of Physics by Inquiry courses (properties of matter, electric circuits, and astronomy by sight and optics) determined most and least characteristic aspects of their classes using the Laboratory Program Variables Inventory (LPVI), a Q-sort instrument. Students generally described these separate courses similarly, but with certain differences. We also compare student rankings with instructor rankings.

Keywords: Physics by Inquiry, Q-sort instrument, laboratory survey, physics education research
PACS: 01.40.Di, 01.40.Fk, 01.50.Qb

INTRODUCTION

The setting of Physics by Inquiry (PbI) classes at the Ohio State University (OSU) is the laboratory. Students do experiments as suggested by the text as well as creating their own experiments to test predictions they have made about nature's behavior.

Evaluation of laboratory classes often has been performed in a disorganized fashion and not been useful. Formative evaluation can be accomplished utilizing a form of Q-sort assessment that eschews affective information.

The Q-sort mechanism, devised by William Stephenson in 1935,[1] consists in organizing the statements or pictures into a ranking scheme. The assessment forces students to categorize the extent to which they think twenty-five descriptive statements characterize their laboratory class experience. They sort the statements from most to least characteristic of the course into boxes in bins of successive size 2, 6, 9, 6, 2 (forcing a "normal" distribution).

We have described our version of the instrument, the Laboratory Program Variables Inventory (LPVI), elsewhere. [2,3] This work presents a new example of the utility of instructor use of the LPVI, for comparing different groups' responses. Q-sort instruments can get first-hand data from large numbers of students in a short time; statements describe common lab activities. The LPVI measures what individual students think are the most and least characteristic features of classroom activities, not what they most like or most dislike about the course or the instructor. PbI uses guided inquiry, and students assessment of PbI classes reflect some important aspects of inquiry as conceived by instructors, while not supporting others

METHOD

Students in the Ohio State Physics by Inquiry (PbI) course were instructed to sort the 25 statements of the modified LPVI into five groups. Group I is considered most descriptive of the course; Group V is least descriptive. Students are forced to rank the statements into groups of size 2, 6, 9, 6, 2 by writing statement numbers into pre-designated boxes, forming a quasi-normal distribution. While the instructions imply that the statements are organized in groups, many students carefully sort and weigh each statement against the others before entering into boxes. We examine here the most descriptive and least descriptive statements as ranked by students in three different versions of the inquiry class—properties of matter (V.1 [4]), electric circuits (V. 2 [5]), and optics and astronomy by sight (V.1 and V.2 [4,5]). Data have been gathered on student rankings in these OSU PbI classes since Autumn 2004. The sample consists of responses of N = 174 students in properties of matter, N = 239 in electric circuits, and N = 53 in optics and astronomy (this class has fewer students overall, and I misplaced a large number of responses). In addition, 18 PbI instructors filled out the LPVI during this time period.

With these large numbers of students, nearly all statements are significant at the 99.99% level using chi-square. Only statements 2 and 3 in optics and astronomy in our sample are not significant at the 95% level (i.e., by convention indistinguishable from chance). For the instructors, statements 3 and 4 are not significantly different from chance, but all others are significant above the 99.99% confidence level.

Filling the 25 statements by the five groups a matrix is created for each class; it is normalized by dividing by the appropriate N; the null result is extracted to give a matrix of variations (if student choices were random, all elements would be zero).

I also calculated an average "position" for each statement. For example, if each student chose the same statement as most descriptive, its position would be 1; if each chose one statement as least descriptive, its position would be 25. While "position" is not an exact measure, because not all students order the statements with painstaking precision, it is a proxy for the most and least descriptive statements (there is clearly no discriminatory power for the middle statements).

RANKING OF STATEMENTS

Do all three PbI classes' students see the courses (all taught the same way) as acting identically?

We adopted three different methods to determine the most descriptive and least descriptive statements. One, described above, is the average position; a second, denoted average score, was discussed in Ref. [3] and is formed by weighting groups I and V by 2 and II and IV by 1 ($2M_I + M_{II} - M_{IV} - 2M_V$); and the third, with equal weighting is denoted the matrix score ($M_I + M_{II} - M_{IV} - M_V$). The matrix score can be between 1 and -1, the average score between 2 and -2, and the position between 1 and 25. Tables 1 through 4 show the results for each group.

Each method results in very similar most and least descriptive statements in each table. It should be noted that the smallest position difference between statements listed and the closest lower statement is 1.16, 0.81, 0.45, and 1.06 for Tables 1 to 4, respectively, and 0.80, 0.89, 0.53, and 1.22, for Tables 1 to 4, respectively, for the least descriptive statements.

Taking averages for each category in Tables 1 to 4, we compare the four groups' responses in Table 5.

Table 5 shows a great deal of agreement among the groups. Statement 17 ("Students discuss their data and conclusions with each other."), statement 23 ("In discussion with the instructor, assumptions are challenged and conclusions must be justified."), and statement 13 ("The instructor or laboratory manual requires that students explain why certain things happen.") are perceived as strongly characteristic and statement 6 ("The instructor lectures to the whole class."), statement 24 ("Students usually know the general outcome of an experiment before doing the experiment."), and statement 7 ("Students are asked to design their own experiments.") are perceived as strongly uncharacteristic.

There is somewhat less importance attributed to statement 1 ("Students follow the step-by-step instructions in the laboratory manual.") and statement 5 ("Laboratory activities are used to develop concepts.") on the characteristic side and statement 21 ("Students identify problems to be investigated."), statement 14 ("Laboratory is used to investigate a problem that comes up in class."), and statement 4 ("Students are allowed to go beyond regular laboratory exercises and do experiments on their own.") on the uncharacteristic side.

Statements 16 ("Questions in the laboratory manual require that students use evidence to back up their conclusions.") and 22 ("During laboratory students check the correctness of their work with the instructor.") are interesting because of the difference between the groups. Instructors, electric circuit students, and optics and astronomy students believe that evidence is important, but properties of matter students rate it as less important than other aspects of the course.

TABLE 1. Properties of matter (N = 174)

	Statement	Matrix score	Statement	Average Score	Statement	Position
Most Charact-teristic	13	0.52	13	0.7	13	8.49
	23	0.46	23	0.63	23	8.99
	17	0.43	17	0.61	1	9.07
	5	0.41	1, 5	0.55	17	9.17
	1	0.38	22	0.47	5	9.22
	. . .	. . .	. . .	. . .	. . .	. . .
Least Charact-teristic	21	-0.35	14	-0.53	14	16.8
	14, 24	-0.46	24	-0.57	24	17.1
	4	-0.52	4	-0.72	4	17.6
	7	-0.6	7	-0.83	7	18.4
	6	-0.79	6	-1.41	6	21.3

TABLE 2. Electric circuits (N = 237)

	Statement	Matrix score	Statement	Average Score	Statement	Position
Most Charact-teristic	17	0.46	17	0.66	17	8.68
	13	0.44	23	0.63	13	9.05
	23	0.41	13	0.61	23	9.1
	16, 22	0.36	1, 16	0.48	1	9.76
	5	0.35	22	0.47	16, 22, 5	10.1
	. . .	. . .	. . .	. . .	. . .	. . .
Least Charact-teristic	14	-0.33	21	-0.42	14	15.9
	21	-0.35	14	-0.46	21	16
	7	-0.56	7	-0.76	7	18
	24	-0.61	24	-0.78	24	18.4
	6	-0.89	6	-1.69	6	22.8

TABLE 3. Optics and astronomy (N = 53)

	Statement	Matrix score	Statement	Average Score	Statement	Position
Most Charact-teristic	17	0.7	17	1.08	17	6.26
	23	0.68	23	0.92	13	7.38
	13	0.66	13	0.87	23	7.51
	16	0.55	16	0.68	16	8.4
	22	0.45	22	0.64	1, 22	9.55, 9.58
	. . .	. . .	. . .	. . .	. . .	. . .
Least Charact-teristic	4	-0.4	4	-0.42	21	16.3
	14, 21	-0.43	14, 21	-0.47	14	16.5
	7	-0.53	24	-0.64	24	17.9
	24	-0.55	7	-0.81	7	17.9
	6	-0.87	6	-1.7	6	22.9

TABLE 4. PbI instructors (N = 18)

	Statement	Matrix score	Statement	Average Score	Statement	Position
Most Charact-teristic	17	0.72	17	1.06	5, 17	6.67
	5	0.61	5	0.89	8, 23	8.06
	16	0.56	13	0.72	1	8.11
	8, 23	0.5	1, 23	0.67	16	9.17
	1	0.44	23	0.67	13	9.44
	. . .	. . .	. . .	. . .	. . .	. . .
Least Charact-teristic	4	-0.33	4	-0.5	18, 7	17.2, 17.6
	18	-0.44	14	-0.72	14	18.4
	7, 14, 21	-0.61	7, 21	-0.78	24	18.7
	24	-0.67	24	-0.89	21	19.2
	6	-1	6	-1.78	6	23.2

Electric circuit students and optics and astronomy students choose checking with the instructor as important aspects of the course, while properties of matter students do not rank this in the top five.

Instructors do not rate alternate explanations as encouraged, as their choice of statement 18 (“The instructor or laboratory manual asks students to state alternative explanations of observed phenomenon.”) as uncharacteristic shows, but students do not recognize this aspect as strongly (it is also seen as uncharacteristic by students). As scientific consensus leads to just one explanation, it is not terribly surprising that the experiments lead to a single conclusion. Statement 8 ("During laboratory students record information requested by the instructor or the laboratory manual.") is also chosen among the top five only by instructors. Access to and reliance on these data is clearly more important to instructors than to students.

TABLE 5. Comparison of groups using their respective top five rankings (+: characteristic; -: uncharacteristic)..

Statement Number	PM N = 174	EC N = 237	OA N = 53	instructors N = 18
1	4+			3+
4	3-	5-		
5	5+			2+
6	1-	1-	1-	1-
7	2-	3-	3-	4-
8				4+
13	1+	2+	3+	5+
14	5-	5-	5-	4-
16		4+	4+	4+
17	3+	1+	1+	1+
18				5-
21		4-	5-	3-
22		5+	5+	
23	2+	3+	2+	2+
24	4-	2-	2-	2-

Table 5 presents only the top five among the ranked arithmetic averages of matrix score, average score, and position. To see how Table 5 is filled in, the averages for the top five PM characteristic statements (and corresponding rank) in the Table are first 13 (1.00), second 23 (2.00), third 17 (3.33), fourth 1 (4.00), and fifth 5 (4.33). The next highest-ranked average for PM students is statement 22 at an average of 5.67. The other entries in Table 5 are found in similar fashion. In EC, the next ranked statement after 22 (4.67) is 1 (5.00); in OA, the next ranked statement after 22 (5.00) is also 1 (6.33). The differences in PM and OA are quite large, while the difference in EC is quite small. The only other small difference is between OA uncharacteristic statements: the fifth least characteristic statement (14) averages 4.00, while unranked statement 4 averages 4.33, as small a difference as between statements 22 and 1 in EC.

There are many statements that are seen as strongly characteristic and strongly uncharacteristic that would likely please teachers like me who want students to see the utility of inquiry and to use inquiry in their own classes when they become teachers. Lectures don't happen. Conclusions are analyzed, justified, and explained by students. However, such teachers would probably want students to know they were able to do their own experiments extending what they are investigating. Ironically, in our OSU PbI courses, this sort of experimentation does happen, and often, but students apparently do not register it when it occurs. I have struggled with how to increase student recognition of their own experimentation but have not yet achieved it in my classes.

Because inquiry in PbI classes is guided, it is not surprising that students recognize that they are being led (by the teachers and the book) to the problems that are being investigated. The canonical understanding of nature is being sought, so students in PbI are led to that canonical explanation and alternate explanations, though essential to experimental science research, are not encouraged.

CONCLUSIONS

A benefit of Q-sort is that this can be used as a formative evaluation for the course (although because we give it at the end of the class, it is formative in the sense that future classes—not the current class—will benefit from any insights the instructor garners). The consonance between instructor goals and lab achievement in meeting these goals can be determined by comparing statements the instructor or instructors consider desirable and undesirable characteristics with student rankings. The choices of the student compared to those of the instructor could suggest ways to change the class so that students might converge to the instructor's choices.

This work supports the usefulness of Q-sort for assessing laboratory courses and shows that it can be used to provide instructors with formative assessment of their classes. The LVPI is a valuable tool for use because it gives instructors useful information about how students perceive what actually happened in a course without the need for lengthy classroom observations.

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