An Assessment of Faculty Perceptions of Secondary School Laboratory Instruction

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Abstract

Reported here are the results of a pilot study of secondary school instructor attitudes and perceptions of the school laboratory experience. A new instrument, *Attitudes Toward and Perceptions of Laboratory Instruction (ATPLI)* was employed to gather these views. ATPLI contains five sections providing demographic details along with questions regarding goals and perceptions and preferences with respect to the laboratory experience. The final section asks teachers to gauge their actual and ideal use of a variety of research-based recommendations for particular laboratory practices. Twenty percent (N = 82) of the four hundred randomly selected secondary science teachers receiving the survey by mail responded.

This survey has revealed much about what the average secondary school teacher thinks about laboratory work, how they apply such instruction in the classroom and how they feel about a range of suggestions for enhancement of the laboratory instructional experience. Data from this survey provide a much more complete picture of the laboratory instructional landscape than has been available up to this point. The results also provide indications of those suggestions for enhancement that are more or less likely to be accepted by instructors as innovations to science teaching and learning.

INTRODUCTION

The vast majority of secondary science courses include a laboratory component. The Horizon Research (2002) survey of 5000 science teachers shows that the laboratory and/or hands-on teaching is used at least twice a month by 35% of teachers and once a week by 36% more. This is a relatively high rate of application of a single teaching technique – more than once per week for at least a third of all U.S. secondary teachers.

Blosser (1981), who conducted the most extensive review of research in the use of the instructional laboratory to date, states that "[s]cience educators are not able to provide a large amount of evidence in support of the continuation that laboratory work should continue in science classes . . . " (Blosser, 1988, p. 126). Gallagher (1987) looked at sixteen more recent studies focusing on laboratory teaching and agrees with Blosser when he says "[g]iven its important place in the education of youth it is surprising that we know so little about its functioning and effects" (p. 351). In spite of this issue of impact, the vast majority of both secondary and undergraduate science courses to include a laboratory component which instructors typically defend, perhaps on faith or tradition, and which students tacitly accept as a part of science instruction.

Investigations into the practice of laboratory instruction and its impact as a science education tool are difficult. The laboratory environment itself is highly complex with scores of important physical, personal and psychosocial variables that can potentially affect student achievement (McComas, 1997). Such variables include the nature of the written instructions, the role of the teacher in the laboratory, prior conceptions and attitudes of the learners and the relationship of the laboratory to the lecture component of the course. Therefore, it is difficult if not impossible to design a study that totally separates the laboratory element from anything else that might contribute to science learning. Further complicating the issue of the role of the laboratory in enhancing science instruction is the undeniable fact that not all laboratory experiences are the same in their potential effect on learning. It is clear that not all laboratory work is the same and may range from a "dry lab" worksheet to a full inquiry into some aspect of the natural world. A wide variety of research studies have demonstrated that some laboratory teaching strategies, techniques and teacher behaviors are more effective than others in helping students gain from their experience.

To shed more light on the role and potential for the laboratory in science instruction, the study reported here was initiated to gain baseline information about instructor perceptions of the laboratory both from the perspective of traditional goals for such instruction and from the perspective of what research says about exemplary practice in laboratory instruction. This study required the development of a new survey instrument based on these perspectives accompanied by demographic and other information that might likely be correlated with specific patterns of response.

RESEARCH QUESTIONS

The central research questions involved the elucidation of opinions from secondary school instructors regarding the laboratory experience in general, the perceptions of the purpose and nature of the laboratory, desired changes in the laboratory, and the actual and desired occurrence of particular elements representing exemplary practice in laboratory teaching. The results of this study will provide guidance in redesigning certain aspects of the laboratory and in anticipating the reaction of students and instructors to particular recommended enhancements. Questions guiding this endeavor are listed below:

1) What is the average state of laboratory teaching in the secondary school environment?

2) What goals do secondary school instructors have for the laboratory experience?

3) What changes would secondary school teachers report with respect to the laboratory?

4) What is the actual occurrence of particular exemplary elements in laboratory instruction as expressed by instructors?

5) What is the desired occurrence of particular exemplary elements in laboratory instruction as expressed by instructors?

METHODOLOGY

To address the research questions, we designed, tested, and administered a new survey *Attitudes Toward and Perceptions of Laboratory Instruction (ATPLI)* of the nature of the school laboratory experience. The survey instrument consists of 64 items (some two-part) arranged into the following groups: demographics (11 items of a check list response format), general practices and attitudes (11 Likert items), perceptions of the goals of school laboratory instruction (9 Likert items), desired changes in the laboratory (16 Likert items) and actual and preferred aspects of the laboratory experience (17 two-part Likert items). This instrument was modified from one used earlier in a study of college instructors' perceptions of laboratory teaching (McComas and Wang, 1997).

Conceptual Framework of the Survey

The validity of the survey is based on its design; it is based on an extensive literature review and the application and subsequent modification of the survey in several previous studies.

The literature review revealed that many goals are associated with the instructional laboratory. In the most extensive set of such goals (Lee, 1978) found more than 120 different objectives linked to the laboratory. This highly specific taxonomy is unwieldy for research purposes so the more encompassing set of broad categories proposed by Tamir (1976) was used. Tamir has suggested that each of the goals for laboratory investigations could be grouped into one of five broad categories including manipulation of equipment, experience with the processes of science, an understanding of the nature of science, knowledge development and the formation of positive attitudes about science. Each of these goals has been represented by items on the ATPLI survey.

Two of the survey sections, perceptions of the goals of laboratory instruction and student/instructor feelings about the actual and preferred frequencies of particular laboratory teaching strategies, are based on both a review of the literature and the conclusions of a study of exemplary laboratory teaching practice (McComas, 1991, 1996). These studies have shown that there are at least fifteen research-based suggestions linked with exemplary laboratory teaching practice (see Appendix A). In the survey, each of the recommended practices is assessed first by asking if such a technique is commonly in use and then by a question asking if respondents would like such a practice to occur. In this fashion, we can measure both perceptions and preferences of these recommended issues.

Survey Method

We secured the addresses of 400 randomly chosen secondary school science teachers from the *National Registry* of all such teachers maintained by the National Science Teachers Association. Teachers were mailed the survey along with a stamped envelop which they were requested to use to return the survey. In order to maintain anonymity we did not track respondents and so could not send follow up reminder notices. This lack of follow up may have hampered the goal of achieving a more robust response set.

Approximately 20% (N=82) of the science teachers contacted responded. The survey data were analyzed using SPSS software to produce both descriptive and inferential results. The relatively low response rate does recommend that the results presented here might best be considered those of a pilot study.

RESULTS and DISCUSSION

The General State of Affairs

As shown in Table 1, the majority of the respondents have either earned an MA/MS degree (21%) or a master degree with additional college credits (49%). Slightly less than half (41%) of these teachers report themselves primarily as biology instructors with another 36% reporting chemistry as their primary teaching assignment. The remainder of the respondents are teachers of the other high school science subjects.

These teachers report an average of 25.25 students in a typical laboratory class, but when factoring in the standard deviation of 7.73. At one standard deviation, therefore, this represents a range of 18 to 33 students for the majority of teaching situations. Most would not criticize a laboratory teaching situation of 18 students, but 32 seems inordinately high. The average teacher responding to this survey indicates using about 28 different laboratory activities in a school year (slightly less than one activity per week). The standard deviation for this statistic is 17.5 revealing a wide range in the number of different activities.

More than half of these teachers (52%) use a laboratory approach at least one day per week with 38% engaging students in laboratory investigations as much as two days per week. Teachers report using an average of 28 different laboratory investigations per year (s.d. 17.5). One individual surveyed reports using a laboratory teaching approach every day!

The typical teacher indicated that they consult a wide variety of sources for laboratory investigations. Such sources include textbooks and lab manuals, their fellow teachers, workshops and conferences, science teacher journals and those investigations that are self-designed. It was hard to see any particular pattern in the data, but as an example 15% of the teachers design about 25% of the labs personally, 14% say that 25% come from textbooks and lab manuals, 15% report that about 25% of their labs were acquired from colleagues. Surprisingly, a relatively small percentage of labs come from workshops and conferences and an even smaller number of teachers 5% suggestion that science teacher journals provide them with a source of laboratory investigations.

Table 1 provides teachers' responses to a variety of questions about the laboratory teaching experience including teachers' views about student confidence, the relationship of lab to lecture and questions about what might be necessary for teachers to engage in more laboratory work.

Table 1. Average responses to questions about student and instructor opinions about the college laboratory experience. The scale ranged from "Strongly Disagree" (Value = 1) to "Strongly Agree" (Value = 5). The percentages provided here are the totals of those selecting either of the top two categories.

Lab is a vital part of school science	100%
Students feel confident working in the laboratory	60%
Laboratory and lecture are well related	93.9%
I would include more lab work if I had a higher budget	59.7%
I would use more lab work if I had more time (class periods)	79.2%

Discussion of the General State of Affairs

In general, instructors have similar attitudes toward laboratory work. Not surprisingly, all agree or strongly agree that the laboratory is a vital part of school science, laboratory and that the lecture parts of the course are well related (93.9%). Teachers suggest that they would include more laboratory work if they had more class periods (79.2%). The question was asked to ask that if more time were available for instruction generally, would teachers use it for more content or more laboratory work. Few teachers would complain if additional funds were available to support laboratory work, but only about half (59.7%) suggest that a budget increase alone would cause them to conduct more hands-on investigations. This is interesting because it seems to suggest that the limiting factor is related to time not finances. Teachers feel that the laboratory and the lecture parts of the course are well related (93.9%). In the absence of additional information it is difficult to question this statistic, but one of the deficiencies of a survey is that one does not know how teachers interpreted this question. Many science educators would argue that the laboratory and lecture are typically disjointed in the way they support learning. Finally, we see that teachers report only a modest amount of confidence on the part of students as they work in the laboratory teaching situation.

The Goals of Laboratory Work

This next section of the survey questioned teachers about their goals for laboratory investigations based on the goal clusters provided by Tamir (1976). Table 2 summarizes the findings of this set of questions.

Table 2. Responses to questions about student and instructor opinions about the goals of the laboratory experience. The scale ranged from ANot a Goal@ (Value = 1) to AMajor Goal@ (Value = 4). The percent-tages provided here are the totals of those selecting either of the top two categories. The number in parentheses is the rank of the goals in terms of its popularity. The goal marked (1) is the most commonly held.

The goal of the laboratory experience is to:	Important Goal	Major Goal		Total (Rank)	
Increase students= interest or excitement		31.3%	66.6% (2)		97.9%
Reveal what students already know	48.1%	16.5%		64.6% (9)	
Prove or verify scientific ideas	46.3%	30.0%		76.3% (8)	
Teach laboratory-related skills	45%	42.5%		87.5% (6)	
Help students understand how science works in the real world	27.2%	66.7%		90.9% (5)	
Test ideas, hypotheses or theories	43.0%	50.6%		93.6% (4)	
Apply concepts / ideas discussed in the lecture or the textbook	26.3%	71.3%		97.6% (3)	
Help students understand what is discussed in the lecture or textbook	34.1%	65.9%		100% (1)	
Show how the course content is related to students= lives	46.3%	37.8%		84.1% (7)	

Discussion of Goals of the Laboratory

Instructors agreed that many of the stated goals are important rationales for laboratory instruction. These included the teaching of laboratory related skills, expansion and application of concepts and ideas presented in the textbook, increase students' interest and excitement in science, and help students understand how science works in the real world. It is not surprising that teachers use the laboratory to help students understand the content discussed in the textbook. As a close second we see that teachers use the laboratory to increase students' interests. It is intriguing that these two top goals each represent a distinct psychological domain – one linked to cognition and the other linked to the affective realm. The least held goal is that of using the laboratory to revel what students already know. The implication here is that the laboratory may assist students in visualizing their own conceptions or misconceptions of the underlying phenomenon in a constructivist fashion. It may be that the implications of the goal as stated in the survey were not well understood by teachers or that they do not see how the laboratory can play a constructivist role.

Potential Changes to the Existing Laboratory Teaching Routine

Table 3 summarized the results of a series of questions about what teachers would like to change regarding laboratory teaching. Teachers could indicate that they are satisfied with their current laboratory teaching practice in a particular area by selecting the middle value of the range.

Table 3. Average responses to questions about proposed changes in the laboratory experience. The scale ranged from "Strongly Disagree" (Value = 1) to "Strongly Agree" (Value = 5) with a notation that if teachers are satisfied with laboratory practice in a particular domain they should choose Value = 3. The rank, shown in parenthesis, is based on the number selecting either agree or strongly agree with the highest such value given a rank of one.

	Satisfied	Agree/ S Agree	Rank
Make the activities more interesting	38.3%	53%	(5)
Make the activities more challenging	42.5%	51.2%	(6)
Make the activities more practical (useful)	33.3%	58%	(3)
Increase the relationship between laboratory and the lecture parts of the course	44.4%	51.8%	(7)
Improve the physical setting	24.7%	67.9%	(1)
Use more state-of-the-art equipment	28.4%	66.6%	(2)
Make the activities *less* step-by-step	40.7%	40.7%	(8)
Include more group work	40.7%	54.3%	(4)

Provide clearer instructions	56.3%	33.8%	(9)

Discussion of Desired Changes

Potential changes to laboratory teaching practices were gauged through this set of questions and it is clear that in almost every case, teachers do believe that some changes are warranted. Only in terms of the nature of the instructions do more than half (56.3%) of the teachers report satisfaction with the current situation. Teachers clearly indicate that the physical setting of the laboratory should be improved and perhaps related, that more advanced equipment be available. Teachers would like the activities to be more useful (58%) but it is not clear whether tat means useful generally or useful in terms of instruction. As we proceed down the list we can see that teachers would like more cooperative or group work (54.3%) although almost half are satisfied with almost the same percentage reporting a desire that the activities be more interesting (53%) and challenging (51.2%). Finally, we see that these teachers are split in their desire that laboratory activities become less step-by-step. 41% are satisfied with the current state of explicitness in the instructions and 41% would like the activities to be less prescriptive. The results of this item might represent an opportunity for future study to investigate what teachers think are the advantages and disadvantages of stepwise instructions in laboratory teaching.

Exemplary Practices in Laboratory Instruction: Actual vs. Ideal Responses

The final section of the survey was designed to assess how frequently teachers used each of a number of practices deemed exemplary practices (see Appendix A). These items were presented in pairs with respondents asked how frequently a particular strategy is used and then asked how much they would like to use such a strategy. The “almost always” and “always” responses on a five point Likert scale were grouped for each of the actual and ideal states. The difference in percentage points and the level of significance of this difference were then calculated. Differences that are not significant would imply that teachers are generally satisfied with their practice while those differences that are significant indicate the teachers would like to do more – or less – of a particular strategy.

Table 4. Responses to questions about student and instructor opinions about the secondary school laboratory experience. The scale ranged from “Never” (Value = 1) to “Always” (Value = 5). The percentages provided here are the totals of those selecting either of the top two categories. Significant differences between actual and ideal responses are indicated in the final column.

	Actual	Ideal	Difference	ρ
Student engage in cooperative work	73.8%	81.5%	7.7	nsd
Investigations occur outside the school (zoos)	4.9%	48.2%	43.3	.001

Laboratory investigations require several days	23.5%	44.5%	21.0	.001
Laboratory investigations are the proper difficulty level	58.8%	83.9%	25.1	.001
The laboratory teaches students how science operates in the real world	41.0%	81.7%	40.7	.001
Procedures provided are step-by-step instructions	53.1%	49.4%	-3.7	nsd
Students make choices about how to conduct the lab	14.6%	67.1%	52.5	.001
Student lab work is assessed with paper and pencil tests	28.1%	24.4%	-3.7	nsd
Students are assessed with hands-on measures	37.8%	66.3%	28.5	.001
I answer students= lab questions directly	32.9%	26.7%	-6.2	.001
I answer students= lab questions indirectly	62.9%	75.4%	12.5	.05
I interact with small groups of students frequently but briefly	92.6%	93.9%	1.3	.05
I am well prepared with materials etc. for lab instruction	76.8%	97.5%	20.7	.001
Lab activity comes before related lecture	16.0%	28.4%	12.4	.001
Pre lab discussions are short, post lab longer	70.4%	76.8%	6.4	.001
I share my own laboratory experiences with students	48.2%	56.3%	8.1	.05
I look at many sources for laboratory ideas	79.3%	96.3%	17	.001

Discussion of Actual versus Ideal Perceptions

It might be profitable first to examine those three items that showed no statistically significant difference from actual state to idea. These are questions about cooperative work (ideal 81.5%), step-by-step instructions (49.5%) and the assessment of students in the laboratory with paper and pencil tests (24.4%). In all three cases, it is reasonable to assume that teachers are satisfied with their current practice whether it is high in the case of engaging students in cooperative work or low in the case of the assessment question, although many (66.3%) would like to use more authentic measures. One might be pleased that teachers value and use cooperative learning in the laboratory and devalue paper and pencil tests of laboratory achievement, but as with the previous section, there is an odd situation when step-by-step instructions are considered. About half of the teachers provide such instructions and think that is a good practice. This still leaves the other half of the teachers who seem not to use or value such a practice. Clearly, an opportunity exists here for enhancement and further study.

Teachers seem to understand that answering student questions indirectly is useful and about 64% of instructors apply this practice. It is encouraging to note that three-quarters of teachers would like to engage in this technique. Related to questioning and interaction, we find that at a very high level (92.6%), teachers interact with small groups of students frequently but briefly and even more (93.9%) would like to so.

There are several exemplary practices that most in the science education community would like to see incorporated into laboratory instruction. These include the positioning of the laboratory *before* extensive discussion of the related content and the ability of students to make choices about how to conduct the lab. Here we have an interesting situation revealed by the data. Only a modest number of teachers (28.4%) ideally think that the laboratory should be placed before the lecture but 67.1% believe that students should make more personal choices in the conduct of the lab. In the case of the second notion, there is a large change between actual and ideal practice indicating that teachers are convinced that this practice is a good one. However, in the case of putting the laboratory before lecture we see only a modest change between what teachers do (16%) and what they think they should do (28.4%). It seems likely that innovation with respect to student decision-making is likely but a change in the timing of the laboratory is not.

With respect to some of the other recommended practices we see that fewer than half of the teachers believe that the laboratory teaches about how science functions in the real world, but 81.7% wish that it did. Just over half of the teachers believe that the activities are at the proper difficult level but 83.9% think that this issue could be more ideally addressed. Three quartered of teachers feel well prepared in terms of materials to deliver high quality lab instruction, but 97.5% ideally think this should be the case. One wonders why one hundred percent don't feel this way, however. Almost the same values appear in response to the question about looking at many sources for laboratory ideas.

Finally, there are two items about where investigations should take place and how long investigations should be. The actual situation reveals that investigations rarely take place beyond the classroom (4.9%) but 48.2% of teacher think they should. Almost one quarter of teachers employ activities that take longer than a single class period but twice that many (44.5%) think that they should. These two strategies are suggested so that students recognize that the laboratory as a research site does involve environments far removed from a single specific room and much work in science can not be completed in a discrete period of time. These suggestions for exemplary practice along with many of the others are designed to make investigation in school science look more like the real-world laboratory practice.

To complete the analysis of these data we conducted a cross tabulation based on the nature of the course taught by the respondents. Unfortunately, only responses from biology and chemistry teachers could be used for this purpose since surveys from teachers of other school sciences such as physics, physical science and earth and space science were few in number. A comparison of responses from biology and chemistry teachers revealed no significant differences in any of the major items indicating a high degree of homogeneity in views and teaching practices between instructors of these two secondary science disciplines.

Final Thoughts

This study provides a snapshot of the state of laboratory teaching and teachers' attitudes with respect to secondary school science instruction in the nations' schools. With more than one third of such teachers using laboratory instruction at least once a week, it is vital that the science education community have a firm grasp of what is occurring when teachers employ such a widely used instructional strategy.

Instruments such as ATPLI act as both a needs assessment and gauge of what interventions are most likely to succeed. Findings such as those revealed here can have profound implications for those who work to reform laboratory work. For instance, a review of the various data tables will show where typical practices are at odds with recommendations for enhancement. An analysis of the responses to the actual and ideal items likewise shows where we might focus our efforts and where it may be more or less likely that suggestions for enhancement will impact practice.

It is clear that the modest response rate and several questionable responses due to problems of interpretation should cause us to consider this report a pilot study. However, work will continue to refine this instrument as a tool for generating the kind of valid and reliable data that can be used to inform enhancement plans that will improve science teaching and learning.

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APPENDIX A:

REINVENTING THE LABORATORY EXPERIENCE: FIFTEEN WAYS TO ENHANCE HANDS-ON SCIENCE TEACHING

1) Use the laboratory to *introduce* or *discover* concepts not simply to verify things already known or implied by teachers and/or textbooks;

2) Engage students in the "challenge lab approach" by giving learners more responsibilities for choosing the problem, procedure and interpreting the results (i.e. increase the number and nature of personal choices made by students in the laboratory);

3) Structure the experience with short prelab discussions of procedure and more extensive postlab debriefing and negotiation sessions of results and questions;

4) Encourage investigations in venues beyond the classroom (i.e. nature centers, museums, zoos, etc.);

5) Use authentic assessment of laboratory experiences (perhaps by asking students to apply what they have learned by doing another investigation);

6) Where possible, give students opportunities to investigate questions of personal interest in the laboratory;

7) Encourage long term investigations (to simulate the work of real scientists);

8) Consult a wide variety of sources for laboratory activities (the danger in consulting a single source is that it may be written from a low-level perspective);

9) Apply a valid perspective of the philosophy (nature) of science in the design and facilitation of the laboratory experience (be particularly careful about the use of the terms experiment, investigation and activity);

10) Create a positive attitude for laboratory work by personally modeling an investigative perspective (perhaps carry out your own investigation alongside the students);

11) Give students opportunities to use actual instruments and techniques common to science;

12) Structure the laboratory using cooperative learning (for the work itself and in negotiating conclusions);

13) Engage small groups of students frequently buy briefly;

14) Respond to most student questions indirectly (by asking another question) rather than directly;

15) Support students by being available but not intruding into their thoughts and work