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What Defines Effective Chemistry Laboratory Instruction? Teaching Assistant and Student Perspectives

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The purpose of this study is to identify the qualities that students and teaching assistants (TAs) involved with an introductory chemistry laboratory course perceive to be important for effective laboratory instruction. To assess students' and TAs' perceptions a two-part questionnaire consisting of Likert-type statements and a free-response question was used. The research questions that guided this study are:

1. What do undergraduate students and TAs involved in the introductory chemistry laboratory consider to be important qualities for an effective laboratory TA?
2. How do these qualities differ between undergraduate students and TAs?

We feel that assessing students' and TAs' perceptions of effective laboratory instruction is important in expanding definitions of teaching effectiveness to encompass different types of instructional contexts. In addition, we believe that this is an important first step in addressing more long term goals of (i) developing more effective training programs for chemistry laboratory TAs and (ii) designing a more effective method for evaluating chemistry laboratory TAs. This article discusses our findings concerning students' and TAs' perceptions of the qualities that define effective laboratory instruction, some possible implications these findings have for TA training, and future work in this area.

Background and Significance

Laboratory instruction is a cornerstone of most science programs because it allows students to be actively involved in their learning. Many educators value the laboratory's instructional potential, but laboratory has also been the focus of considerable criticism concerning the lack of student learning in laboratory *(1–4)*. Therefore, there has been increased interest in alternative laboratory instruction styles, such as inquiry-based or problem-based laboratory experiments *(5)*. Domin suggests that the most popular, though most criticized form of laboratory instruction, the expository or "cookbook" style, has evolved into its present form from the need to minimize resources such as time, space, equipment, and personnel *(5)*. Certainly these factors are important in large introductory chemistry courses where hundreds or thousands of students must use the laboratory facilities every week. As such, it is likely to be difficult to move entirely away from the traditional expository style of laboratory instruction. Therefore, we must focus on effective teaching under these constraints.

Researchers have studied both the factors that contribute to teaching effectiveness and the evaluation of teaching effectiveness. Although this research has not provided one clear-cut definition of an effective teacher, many researchers have developed their own working definitions of teaching effectiveness. Though these working definitions differ from one another in some ways, most definitions show a substantial overlap *(6)*. The majority of research concerning teaching effectiveness, however, has focused on traditional classroom instruction *(7, 8)*. There is very little research that focuses on teaching effectiveness in the laboratory.

Despite the lack of research concerning effective laboratory instruction, the laboratory instructor is considered an important factor in student learning in laboratory. In their review of laboratory instruction research, Lazarowitz and Tamir state there are many factors that may affect student learning in the laboratory, but the most important factor is the instructor *(9)*. Pickering also argues that the lack of progress in laboratory teaching is our failure to consider the laboratory instructor *(10)*.

Examining teaching effectiveness in laboratory instruction is important because the laboratory is a different instructional context from classroom instruction. First, laboratory instruction often tends to be more interactive and one-on-one than traditional classroom instruction. Second, the function of the instructor in the laboratory is to help students come to an explanation that is consistent with the data, not to impose an explanation *(10)*. Third, the activities effective laboratory instructors employ differ from those used by effective classroom instructors. Thus, effective instruction in the laboratory is different from effective classroom instruction.

Definition of Teaching Effectiveness

There are a number of different ways in which teaching effectiveness has been defined. Marsh *(11–13)*, Feldman *(14, 15)*, Abrami *(8, 16)*, and Young and Shaw *(17)* used different sets of characteristics to define or evaluate teaching effectiveness. One possible reason for the various definitions of teaching effectiveness is the multidimensional nature of the construct. Given this complexity, it is not surprising that no one definition effectively encompasses teaching effectiveness. However, the overlapping definitions suggest the existence of common factors.

Abrami et al. indicate three possible definitions of teaching effectiveness: the product definition, the process definition, and the process–product definition *(8)*. The product definition focuses on positive changes produced in students; the process definition focuses on the activities of the instructor. The process–product definition seeks to determine what activities differentiate good instructors from poor ones in promoting positive changes in students.

In this study we examined the qualities perceived to be important for an effective laboratory TA using the process–product definition. As such we looked at (i) what constitutes particular qualities of an effective laboratory TA and (ii) how particular qualities are perceived to help students in the laboratory. Based on the teaching effectiveness literature, the process–product definition of teaching effectiveness, and data from our study we have developed a working definition of teaching effectiveness. Within the contexts of this study, we define teaching effectiveness as the qualities that effective laboratory TAs should possess, the characteristics, activities or behaviors of TAs that demonstrate those qualities, and the positive effects that are perceived to result from these characteristics, actions, or behaviors.

Study Design

Participants

The participants in the study were (i) students enrolled in the first half of an introductory chemistry course for science and engineering majors at a large Midwestern university during the spring 2001 term and (ii) TAs responsible for the laboratory and recitation sections of this course. The student population in the spring is generally slightly more diverse than in the fall section of the course.

All students and TAs involved with the course were asked to participate in this study; however, participation was voluntary. A questionnaire was given to students and TAs during the midpoint of the term. Students returned 538/800 questionnaires (67% response rate). The free-response portion of the questionnaire was completed in 405/538 questionnaires. TAs returned 14/19 questionnaires (74% response rate), and 10/19 completed the free-response portion. Although a greater response rate is desirable, participation was constrained by the University's Committee on the Use of Human Subjects regulations, which required that students and TAs complete the questionnaire outside the laboratory period. In light of this constraint, the response rate was considered adequate.

Of the students who participated in this study, 50% were engineering majors, 15% were preprofessional majors, 13% were biology or health sciences, 13% were other sciences, 4% were in management, and 5% were in arts or undecided. In addition, 85% of the student participants were freshmen and 64% of them were male. This sample is representative of students enrolled in the course as a whole.

All of the 14 TAs who participated in the study were graduate students, 11 were in chemistry, one was in business, one was in management, and the other did not list a major. Owing to the large number of students in these courses, the department must occasionally hire graduate students from other departments who have some chemistry background. All of the teaching assistants had at least one term of TA experience, with seven of the TAs indicating three or more years of teaching experience. Four of the TAs were female.

During the course students completed 11 experiments covering a variety of introductory chemistry topics such as acid–base chemistry, stoichiometry, and thermochemistry. Most of these experiments were traditional verification experiments. The laboratory period was 3 hours in length and each student was expected to individually complete the experiment within that 3-hour period. Each student completed an individual lab report for each experiment, due at the beginning of the next laboratory period. Laboratory sections

Table 1. Frequency Distribution of Student Responses to the Statements in the Questionnaire

Statement: An Effective Lab TA…	Scale				
	5	4	3	2	1
Grades lab reports correctly and fairly	78.3	16.8	3.6	1.1	0.2
Is well prepared for lab	77.1	20.5	1.9	0.6	0.0
Thoroughly understands the lab exercise	76.7	20.1	2.6	0.4	0.2
Is able to help students understand what is going on in the lab	71.8	24.7	2.2	0.6	0.7
Explains and demonstrates the necessary lab techniques	64.4	28.2	6.0	1.5	0.0
Shows respect for students	64.2	30.2	5.0	0.4	0.2
Listens carefully and tries to understand students' problems	59.7	31.9	7.1	0.9	0.4
Gives feedback on lab reports that is helpful	52.4	35.6	9.9	1.9	0.2
Is available for help outside the lab	50.8	33.6	12.1	2.6	0.7
Is genuinely concerned with students' progress in the lab	47.6	40.5	10.1	0.9	0.9
Makes students aware of safety issues	42.3	35.0	16.3	5.4	0.9
Is warm and friendly	42.2	36.1	17.4	3.2	1.1
Is enthusiastic about teaching the lab	39.9	36.6	19.2	3.0	1.3
Motivates students to do their best in the lab	38.8	35.6	21.6	3.0	0.9
Asks students questions to help them solve their own problems rather than doing it all for them	37.9	39.7	16.2	4.1	2.1
Has a good sense of humor	34.5	30.4	26.5	6.2	2.4
Encourages students to ask questions or express opinions	32.8	37.1	23.5	5.2	1.3

NOTE: Frequency distributions are in percents. The scale ranges from 5, very important, to 1, not at all important.

consisted of no more than 24 students and one TA. TAs were responsible for all aspects of running the laboratory sessions. These duties included: providing students with prelaboratory instructions, making sure that students followed the appropriate safety procedures, helping students with equipment and any problems they encountered with the experiments, and collecting and grading the laboratory assignments.

Questionnaire Design

Likert statements were generated from a review of the literature on effective teaching and student evaluations *(6, 13, 14, 17)*, and from some statements that were specific to laboratory instruction *(18, 19)*. Two selection criteria were used: (i) the statements represented effective teaching factors that were common to a number of different definitions of teaching effectiveness or (ii) the statements related to the laboratory instruction role of the TA. Most of the statements used were similar to statements found on commonly used teaching evaluation forms but were reworded to be more consistent with laboratory instruction. Other statements such as "makes students aware of safety issues" and "explains and demonstrates the necessary lab techniques" were more specific to the laboratory context. Several experienced educators who had also been laboratory TAs reviewed the statements to determine whether there were other statements that should be included or whether some statements should be removed.

The questionnaire consisted of demographic data, Likert statements, and a free-response question. The demographic data included major, gender, year of study or teaching experience, and required or elective course. The next part of the questionnaire consisted of 17 statements rated on a 5-point Likert-type scale. Students and TAs rated each statement as a number 1 through 5, with 5 being very important, 3 neutral, and 1 not at all important. It was stressed to the students and TAs that this questionnaire was not an evaluation of the TAs, that we were interested in what made a TA an effective laboratory instructor. The third part of the questionnaire was a free-response question that asked students and TAs to describe, in their own words, the qualities that were important for an effective laboratory TA. This question was designed to identify any important qualities that had not been included in the Likert statements and to provide a check of the Likert statement ratings.

Data Analysis

Likert Data

Frequency distributions were calculated for each statement (Tables 1 and 2). Only minor differences were found when student responses were compared on the basis of major, gender, year of study, or required course.[1] Therefore, the student data as a whole were used for comparison purposes.

The first pattern found in the frequency distributions was that the majority of students and TAs rated all statements a 4 or a 5. This indicated that collectively students and TAs considered all 17 statements at least somewhat important. However, when the frequency distributions for each statement were examined, we found that some statements were collectively considered more important than others. Therefore, we chose to rank the statements according to the number of people that rated each item a 5 (very important).

Looking at the top eight statements for both students and TAs, we noted fairly good agreement between students and TAs, as six of the eight statements were common to both

Table 2. Frequency Distribution of Teaching Assistant Responses to the Statements in the Questionnaire

Statement: An Effective Lab TA…	Scale				
	5	4	3	2	1
Thoroughly understands the lab exercise	85.7	14.3	0.0	0.0	0.0
Is well prepared for lab	78.6	21.4	0.0	0.0	0.0
Makes students aware of safety issues	78.6	21.4	0.0	0.0	0.0
Listens carefully and tries to understand students' problems	64.3	35.7	0.0	0.0	0.0
Is able to help students understand what is going on in the lab	64.3	35.7	0.0	0.0	0.0
Shows respect for students	64.3	28.6	7.1	0.0	0.0
Encourages students to ask questions or express opinions	57.1	42.9	0.0	0.0	0.0
Explains and demonstrates the necessary lab techniques	57.1	28.6	14.3	0.0	0.0
Grades lab reports correctly and fairly	50.0	50.0	0.0	0.0	0.0
Asks students questions to help them solve their own problems rather than doing it all for them	50.0	50.0	0.0	0.0	0.0
Gives feedback on lab reports that is helpful	50.0	42.9	7.1	0.0	0.0
Motivates students to do their best in the lab	46.2	38.5	15.4	0.0	0.0
Is available for help outside the lab	35.7	64.3	0.0	0.0	0.0
Is genuinely concerned with students' progress in the lab	35.7	57.1	7.1	0.0	0.0
Is enthusiastic about teaching the lab	28.6	50.0	7.1	14.3	0.0
Is warm and friendly	28.6	42.9	14.3	14.3	0.0
Has a good sense of humor	21.4	28.6	35.7	7.1	2.9

NOTE: Frequency distributions are in percents. The scale ranges from 5, very important, to 1, not at all important.

groups. The common statements were "is well prepared for lab", "thoroughly understands the lab exercise", "is able to help students understand what is going on in lab", "explains and demonstrates necessary lab techniques", "shows respect for students", and "listens carefully and tries to understand students' problems". Another common element of these top-ranked statements is that, for the most part, fewer than 10% of the participants in each group rated these statements below 4.[2] This shows that there was not only agreement between students and TAs but also among the group of students or the group of TAs.

There were, however, some differences between the top-ranked student and TA statements. The two statements that were in the top eight ranked student statements but not in the top-ranked TA statements were both associated with laboratory reports: "grades lab reports correctly and fairly" and "gives feedback on lab reports that is helpful". The first of these statements was rated very important by 78% of students while only 50% of TAs rated the statement very important. On the other hand, both of the statements were rated a 4 or 5 by 90% or more of the TAs.

Statements ranked in the top eight by TAs but not by students were "makes students aware of safety issues", and "encourages students to ask questions or express opinions". It is not particularly surprising that TAs perceive safety issues as important, considering the safety training that chemistry TAs undergo. With regards to "encouraging students to ask questions", however, the difference is less clear. Literature indicates that international TAs are not as open to involving students owing to language difficulties and may not value student involvement as important, possibly owing to cultural differences *(20)*. Cultural differences, although beyond the scope of this study, do not appear to play a role here. The population of TAs for this course is typically much more culturally diverse than the student population, and a larger percentage of TAs rated this statement as important or very important. In addition, this limited sample does not appear to exhibit any link between "encouraging students to ask questions" and "years of teaching experience". Owing to the small TA sample size, however, we could not make any strong conclusions concerning this difference.

We then examined the statements that students and TAs ranked the lowest. In comparing the seven statements that the fewest students or TAs rated a 5, we noticed a moderate agreement between students and TAs, with four of the seven lowest-ranked statements being common to both groups. These common statements were: "has a good sense of humor", "is warm and friendly", "is enthusiastic about teaching the lab", and "motivates students to do their best in lab". An interesting pattern is that the first three of these common statements deal with some aspect of personality.

On the other hand, some of the statements that were among the lowest ranked by students were among the top eight ranked statements by TAs; the reverse case was also true. This demonstrates that though there is some agreement between students and TAs regarding the statements of lesser importance, that agreement is not as good as that for the statements considered most important. There was also less agreement among the group of students or group of TAs concerning the lower-ranked statements. Tables 1 and 2 clearly show that ratings of these statements are more widely distributed across the scale. Although the number of students or TAs who rated these items 1 or 2 are still quite low, the number of students or TAs that rated these items below 4 are often in the 20–30% range.

Free-Response Data

In describing an effective laboratory TA, students and TAs made statements that could generally be categorized into one of three themes: (i) statements pertaining to the TA being knowledgeable, (ii) statements pertaining to the TA having good communication skills, and (iii) statements pertaining to the affective domain. The free-response data are summarized in Table 3 using a thematic conceptual matrix display; a type of qualitative data display that organizes data based on conceptual themes *(21)*.

Theme 1: Knowledge of the TAs

Both students and TAs differentiated knowledge into four major areas: (i) knowledge specific to the laboratory experiment (procedures, techniques, and safety concerns) (ii) knowledge of the chemical concepts behind the experiments, (iii) knowledge concerning students and how they learn, and (iv) knowledge about teaching and teaching methods. The most frequently mentioned knowledge area concerned laboratory procedures, techniques, and safety. A sample statement is, "very knowledgeable, especially about the experiments and good lab technique" (SQ19-10).[3] As seen in Table 3, several students and TAs also suggested behaviors or actions that indicate this knowledge, such as demonstrates and corrects laboratory technique, or identifies potential pitfalls in the experiment. Students viewed this as important, believing that it made the laboratory more worthwhile and reduced errors.

Students and TAs also suggested that an effective laboratory TA should be knowledgeable about the chemical concepts behind the laboratory experiment. They indicated that a TA, "…needs to be prepared to help students understand concepts" (TA-14), and should "…understand not only the lab but the underlying concepts" (SQ34-7). Students suggested this was important because TAs with this knowledge could help students make connections between lecture and laboratory and could make laboratory more interesting or relevant by suggesting practical applications.

Third, both students and TAs valued knowledge about students and how they learn. Students mentioned the importance of a TA "…understand[ing] students and ways they learn" (SQ16-4) and "…understand[ing] that most of this stuff is new to us and is difficult" (SQ26-10). TAs mentioned being able to "…read into their [students'] actions or body language because students aren't normally good at voicing their questions" (TA-36) and being aware of "typical student difficulties" (TA-20).

Finally, students and TAs agreed that knowledge about teaching and teaching methods was important. Again a number of students and TAs simply said a good TA knows how to teach. Others were more descriptive and made suggestions about things they thought a good laboratory TA who knows how to teach should do. The most common responses described a TA that interacted with and monitored students during the laboratory. Both students and TAs also described an effective TA as one who guides students and helps them solve their own problems rather than giving them the answers.

Theme 2: Communication Skills

These statements identified effective lab TAs as people who communicated their ideas well, explained things at an appropriate level, and spoke English clearly. Communication skills seemed an appropriate heading for this coding category because a considerable number of the student responses actually mentioned communication as being important, such as "The most important asset a TA can have is his/her ability to communicate well" (SQ25-15).

Many statements focused on a TA's ability to explain material on a student's level and on a TA's ability to present clear, thorough explanations. For example: "able to break down complex material into a way in which students can understand better" (SQ15-4) and "explains how to do a problem every step of the way" (SQ11-14). Some students specifically stated that clearly spoken English was important, in addition to being able to clarify the material so students could understand. In some cases this meant explaining concepts in "plain English" rather than "scientific vocabulary" (SQ11-14) or "technical terms" (SQ28-9), in others it stemmed from an experience with a TA who did not speak English fluently. Additionally, students valued communication because they

Table 3. Summary of Student and TA Free-Response Answers

Theme	Subarea	What demonstrates this quality?	How does this help students?
Knowledge	Procedure, techniques, safety	Demonstrates and corrects technique	Helps students avoid senseless mistakes
		Tell students if something looks wrong, identify pitfalls in lab	Makes lab worthwhile
		Ensure student understanding of purpose and procedure	
	Chemistry concepts	Tie in lecture material	Some students do not see connections
		Identify practical applications	Creates interest in the lab and chemistry
	How students learn	Understanding of student learning, aware of typical difficulties	
		Understand that stuff is new and difficult for students	
		Read into student's actions	Students not good at voicing questions
	Teaching	Monitor and get involved with students	
		Do not sit back and talk to other TAs	
		Guide rather than give answers	
		Fair grading, useful feedback for lab reports	
Communication skills		Breakdown and rephrase complex material	Written instructions may be hard for students to understand
		Use layman and scientific language	Helps complete lab on time
		Speak in plain English	
Affective domain	Student concern	Never discourage or belittle student	
		Tries to get to know student	
		Gives individual help and attention	
	Wanting and willing to help	Takes time to explain well	
		Enthusiastic about teaching, wants to teach	Students more willing to learn
	Available and approachable	Available outside the lab	Not many people for students to get help from
		Friendly	Students feel more welcome to ask questions

NOTE: A comparison of the student free-response answers based on the demographic variables did not yield any distinct differences. In addition, due to the small number of TA responses, all student and TA responses were considered as a whole in constructing this table.

sometimes had a difficult time understanding the written directions; therefore, a good verbal presentation was important to ensure understanding and to help students complete the experiment in the allotted time.

Although cultural differences are beyond the scope of this study, it should be noted that all international TAs at the institution involved in this study are required to pass a spoken English proficiency exam before they are allowed to become a TA. However, some student responses suggested English proficiency was a problem. On the other hand, several students and TAs talked about the importance of communication and did not mention English proficiency. In particular, both students and TAs mentioned it was important for an effective laboratory TA to be able to explain things in different ways or on a student's level. One might speculate that this is something that is especially difficult for international TAs who may not have a firm grasp of the English language. Though this is clearly an area that should be looked at more closely, the data from this study do not allow for any definite conclusions to be made.

Theme 3: Affective Domain

These statements fell into three general areas: (i) showing concern for students in general and as individuals, (ii) being a TA that is willing to help students, and (iii) being available and approachable. Many students and TAs placed importance on being concerned about student progress, being interested in how students are doing, and demonstrating that concern or interest. One TA said a good TA "will never discourage a student!… I like to tell them that I believe that they can all pass this class and I try to encourage them along the way that they are smart enough" (TA-3). Many students also expressed the importance of TAs demonstrating concern on an individual basis. For example: "they make sure you do understand concepts as each individual, not as a class" (SQ9-2).

Students also valued a TA who wanted to help them. Students suggested that a good TA "…takes their time to explain processes instead of rushing students and is willing to check with each individual to make sure things are going OK" (SQ28-11). Students also mentioned that a TA should not show annoyance at being asked a question and should not be condescending. Additionally, both students and TAs mentioned the importance of being enthusiastic about teaching and wanting to be there.

> A good lab TA is someone who is excited to teach. There is nothing worse than a TA that is here only because he/she is required to be to fulfill some purpose and has no interest in teaching or the student's education. A TA that enjoys his/her work is wonderful and in my opinion a better teacher. (SQ12-8)

> Always look like you enjoy what you are teaching. If you hate it then they won't like it either and will be less ready to learn it. (TA-3)

Finally, students valued TAs who are available and approachable, both in and outside of the laboratory. One student expressed that this was important because "…if I need help about something there aren't that many people to turn to" (SQ14-14). Many students also suggested that a TA should be friendly so that "…students feel welcome to talk and to ask questions" (SQ14-9). Students did not, however, clearly express characteristics, actions, or behaviors of TAs that help them perceive a TA as friendly or approachable.

Importance of Each Theme

It was difficult to identify patterns from the small number of TA responses. Therefore, only student responses were used to assess the relative importance of each of the three themes. Some responses consisted of more than one type of statement and thus could be coded for more than one theme. For example,

> A good lab TA should be someone who can communicate well with the students in a lab. They know what they are talking about and are enthusiastic about teaching it to others. They should be willing to help students both in and out of the lab setting. (SQ3-10)

The first part of this response was coded as Theme 2 (Communication), the second part as Theme 1 (Knowledge), and the third part as Theme 3 (Affective domain).

Reliability of the coding themes was established by interrater reliability. The second rater was a graduate student in chemical education with some previous experience in chemical education research. Using the coding scheme for the three themes established by the student researcher, the second rater coded a random sample of 20% of the student responses to the free-response question. Based on this sample, the coding of statements by the second rater and the primary researcher were in 80% agreement, which is considered acceptable.

Theme 1, statements pertaining to TAs being knowledgeable, was the most frequent category coded. Seventy-five percent of the student responses contained at least one statement coded as *knowledge*, 68% of the responses contained at least one statement that was coded as *affective domain*, and 40% of the student responses contained at least one statement coded as *communication*.

Based on students' responses, initial analysis suggests that students consider knowledge-based qualities slightly more important than affective domain qualities, with communication qualities the least important. Further analysis supports the importance of knowledge-based qualities. In reviewing the statements coded as communication skills we noted that the key element in a number of these statements was "clear or understandable explanations". The ability to explain things clearly could also be considered a type of knowledge. In addition, statements concerning the ability to explain clearly often mentioned knowledge about chemistry concepts or laboratory procedure in conjunction. An example of this is, "Someone who can explain the lab in more than one way and knows fully well how to perform it" (SQ4-5).

In light of this, if themes 1 and 2 are grouped together, 32% of the student responses just contained *knowledge* or *communication* statements. On the other hand, 16% of the responses just contained statements that pertained to *affective domain* (theme 3). However, 52% of the student responses contained a combination of *knowledge* (or *communication*) and *affective domain*. This suggests a number of students consider affective domain qualities important. In summary, most students appear to consider some mixture of knowledge-based and affective domain qualities as important for an effective laboratory TA.

Discussion

Ranking of the Likert statements indicated fairly good agreement between students and TAs concerning the relative importance of certain qualities. The frequency distributions for the top-ranked statements also indicated a good agreement within the group of students or TAs. This agreement is consistent with the results of a meta-analysis of 31 studies reported by Feldman *(14)*. Comparing student and faculty ratings of attitudes, behaviors, and pedagogical practices important for effective instruction, Feldman reported that students and faculty valued knowledge of subject, preparation and organization, clarity and understandableness, teacher's enthusiasm (for subject or teaching), availability and helpfulness, and concern and respect for students. Similar statements were among the top-ranked statements in this study.

Although these similarities support this study, a direct comparison cannot be made owing to two factors. First, this study deals with laboratory instruction as opposed to classroom instruction and a number of the statements used in this questionnaire were more specific to the laboratory instructional context. Second, this study deals with TAs, not faculty. Therefore, some of the instructional dimensions examined by Feldman may not be applicable to TAs.

When the Likert data and free-response data are considered together, we note that students and TAs appear to rank knowledge-based qualities higher than affective domain qualities. Table 4 divides the Likert statements into knowledge-based statements and affective domain statements using the coding criteria for the free-response data.

However, the data also indicate that many students and TAs considered affective domain qualities to be at least somewhat important. This idea was expressed nicely by one TA who stated that,

> The primary qualities (most important) revolve around how they can help the students better understand the concepts. Of lesser importance (but sill important) would be exhibiting care about students performing and presenting an environment which will help students to learn. (TA-14)

Based on this pattern established in both the Likert and free-response data, we speculate that when many students and TAs think of the important qualities for an effective laboratory TA they consider knowledge-based qualities first, but they also consider affective domain qualities as important. For example, more than half of the students who responded to the questionnaire mentioned both knowledge and affective domain qualities in their descriptions of an effective lab TA.

Implications for TA Training

A TA Should Be Knowledgeable

Both student and TA questionnaire responses suggest that knowledge in four main areas is of particular importance: (i) procedures, techniques, and safety, (ii) chemistry concepts, (iii) how students learn, and (iv) teaching. This suggests that perhaps the first step in preparing TAs is equipping them with the appropriate knowledge in each of these areas. What little information is available concerning TA training programs in chemistry suggests that most programs focus primarily on safety issues, grading practices, and content specific to the experiments *(22–25)*. Although these areas are important, results from this study imply that TA training programs should also provide TAs with ways to help students make connections between lecture material and the laboratory experiments. This might include providing TAs with some practical or "real-world" applications of the laboratory techniques being used.

This study also indicated that TAs should possess knowledge about students and how they learn, and knowledge about teaching and teaching practices. One of the things that several students and TAs mentioned with respect to knowledge in these areas is that TAs should not do all the work for students but rather ask them questions to guide them to the answers. Students and TAs also mentioned that effective laboratory TAs should work through the experiment with students and ask them questions throughout the laboratory period rather than sitting back and waiting to be asked a question.

These suggestions are consistent with those made as a result of a study examining the most frequent behaviors and strategies of introductory chemistry laboratory instructors *(26)*. This prior study found that the most frequent behaviors and strategies used were not designed to develop higher-order thinking processes. Therefore, the authors concluded that laboratory instructors should be trained to act more as facilitators by assisting students in solving their problems rather than simply giving answers.

Table 4. Knowledge-Based and Affective Domain Likert Statements

Knowledge-Based Statements	Affective Domain Statements
Grades lab reports fairly	Shows respect for students
Is well prepared for lab	Is available for help outside the lab
Thoroughly understands the lab exercise	Is warm and friendly
Is able to help students understand what is going on in the lab	Is genuinely concerned with students' progress in the lab
Listens carefully to students and tries to understand their problems	Encourages students to ask questions or express opinions
Gives feedback on lab reports that is useful	Is enthusiastic about teaching the lab
Makes students aware of safety issues	Has a good sense of humor
Asks students questions to help them solve their own problems rather than doing it all for them	Motivates students to do their best in the lab
Explains and demonstrates necessary lab techniques	

A TA Should Know How To Communicate

Several students and TAs mentioned both clear and thorough explanations and being able to explain information on a student's level as being important. Specifically, they mentioned that TAs should explain each step of a problem and that they should explain things in plain English rather than using technical terms or scientific vocabulary. In terms of TA training this might mean stressing to TAs the importance of not skipping steps when explaining concepts and procedures even if they seem obvious. Additionally, the vocabulary used in science is believed to contribute to cognitive overload in the laboratory *(27, 28)*. A large portion of a student's working memory space can be occupied as they try to make sense of an unfamiliar word or phrase from its context. This suggests that one thing TAs might do to help students in the laboratory is explain any terms that might be unfamiliar to them.

A TA Should Demonstrate Concern for Students and Be Available and Approachable

Student and TA questionnaire responses indicated three main areas of affective domain qualities that were perceived important for effective laboratory instruction: (i) student concern, (ii) wanting and willing to help, and (iii) available and approachable. For the most part students mentioned the importance of a TA who cared about them as individuals, wanted to help them, and was available and approachable. One thing that both students and TAs mentioned that might address all of these issues is monitoring and interacting with individual students. By checking with individuals throughout the laboratory period to assess how they are progressing, a TA could possibly demonstrate concern for students, a willingness to help them, and availability to students. Although few students elaborated on the affective domain qualities, a number of students mentioned that TAs should not be condescending or make students feel inferior for not understanding. One implication for training TAs is that they should always try to be as positive as possible in their interactions with students.

In summary, though many of these suggestions may seem obvious to seasoned educators, new TAs may not possess this insight. They may not realize that just because students are not asking them any questions, does not mean that they understand what they are doing or why they are doing it. Furthermore, a more interactive approach might help TAs demonstrate both the knowledge and the individual concern that appear to be key elements of an effective laboratory TA.

Conclusions and Future Work

Research concerning teaching effectiveness in the laboratory is a relatively new area and as such there are many different aspects that still need to be examined. Although the results of this study were useful in suggesting some implications for training laboratory TAs, it also generated other questions. First, in describing an effective chemistry laboratory TA, many students and TAs mentioned qualities such as knowledgeable or approachable. However, we need more detail in terms of the behaviors of an effective laboratory TA and what kind of positive influence these behaviors exert.

Additionally, though some demographic variables were examined, there were others such as cultural background or learning style that were beyond the scope of this study. Both of these factors could play an important role in more culturally diverse settings. However, results of this study can provide a starting point for identifying student and TA perceptions of effective introductory laboratory instructors.

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Notes

1. In some cases "available for help outside the lab" was ranked as number 8 or as number 11, which slightly changed the top eight or bottom seven statements. Other differences involved statements in the top eight or bottom statements being ranked one position higher or lower when compared to the class ranking as a whole. However, since exact ranking of each statement was not compared, these were considered to be minor differences.

2. The one exception is the statement: "gives feedback on lab reports that is helpful". Twelve percent of students rated this statement below 4.

3. The indicated notation refers to the questionnaire from which the passage was taken. SQ refers to Student Questionnaire, the first number refers to which of the 36 laboratory sections the questionnaire came from and the second number indicates a particular questionnaire within that laboratory section. TA refers to TA questionnaire and the number refers to the TA questionnaire number.

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