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Abstract

The science laboratory learning environment has been a distinctive area in science education since the 19th century. Unfortunately, students are generally not aware of what science instructors expect from laboratory experiences, and far too often, the undergraduate science laboratory curriculum lacks explicit, well-defined goals. Science instructors assume that they have created their laboratory curriculum in such a way as to reflect an ideal science instructional laboratory, but students may not recognize this. What previous studies do not indicate is the extent to which students understand the laboratory goals for instruction as intended by the instructors. This study, therefore, using a quantitative design, examined undergraduate science major (biology, chemistry, and physics) and non-major students‘, and female and male perceptions of their science instructional laboratory with respect to instructors‘ goals for the laboratory. Data was collected via the Student Perceptions of the College Instructional Laboratory Survey (SPCILS) at a Midwestern University in the USA. The findings suggest that, on the whole, students perceive their instructional labs much as intended by their instructors. Female and male students were just as likely to view their instructional laboratories as intended by the instructors. Moreover, the study found no differences between science majors and non-majors. This study provides baseline data for future qualitative studies about how major and gender might be impacting students‘ laboratory experiences in ways beyond what was measured on this survey. Our research was done at a teaching-oriented, midsized university. It would thus be appropriate for similar investigations to be carried out at a research-oriented university.

Introduction

The science laboratory learning environment has been a distinctive area in science education since the 19th century (Hofstein and Lunetta, 1982; 2004). Students differ in their perceptions of the science instructional laboratory, and these perceptions affect how and what students learn (Luketic and Dolan, 2012; Berger, 2015; Ramsden, 1979). Several researchers have assessed *high school* students‘ perceptions of their science instructional laboratory (for example, Fraser and Lee, 2009; Lang, Wong, and Fraser, 2005; Luketic and Dolan, 2012). However, there are fewer studies that have examined *undergraduate* students‘ perceptions of their science instructional laboratory (De Juan, Pérez-Cañaveras, Segovia, Girela, Martínez-Ruiz, Romero-Rameta, Gómez-Torre, and Vizcaya-Moreno, 2016; Membiela and Vidal, 2017). Furthermore, none of these studies examined students‘ perceptions of their science instructional laboratory with respect to their science instructors‘ goals of the laboratory setting.

One reason why there are no studies that assess the degree to which students perceive the laboratory as it is generally intended by science instructors is that there are no appropriate instruments. But recently, an independent study was undertaken where the authors published an article about the development of the Student Perceptions of the College Instructional Laboratory Survey (SPCILS). The SPCILS was developed using a foundational model and a bottom-up approach (Cobern and Adams, 2020). In this case, the model had to be built inductively by a panel of faculty experts that created and taught undergraduate science laboratories. The faculty generated a list of statement items that best reflected what they intended for their labs to convey to students. Subsequently, the authors used statistical analysis for item reduction and determining category internal consistency. The item reduction was accomplished by item to item correlation and expert opinion. Cronbach‘s alpha and expert opinion were used to affirm category internal consistency and validity; reliability was established by Pearson correlations coefficients between test and retest data.

With this instrument, we can examine gender and major as possible factors in student perceptions of their science instructional laboratory, as it compares to what science instructors have determined to be a ―good” or ―ideal” lab experience for their students. This study used a quantitative design (Fetters, Curry, and Creswell, 2013; Creswell, 2014), via the Student Perceptions of the College Instructional Laboratory Survey (SPCILS), to answer the following questions:

1. What are undergraduate science students‘ perceptions of their science instructional laboratory as measured by the SPCILS categories?
2. What are the differences/similarities between science majors (biology, chemistry, and physics), and non-majors in their perceptions of the college instructional laboratory as measured by the SPCILS categories?
3. To what extent are student perceptions correlated/associated with gender as measured by the SPCILS categories?

Science educators argue that the science laboratory engages students across these three learning domains: cognitive, affective, and psychomotor. This study used Reigeluth‘s (1999) conceptual framework learning outcomes/purposes can occur in three domains, cognitive (C), affective (A), and psychomotor (P). In order for meaningful learning to take place, students must experience the integration of their thinking, doing, and feeling. That is, students should learn science through all three of the learning domains. (Bretz, Fay, Bruck, and Towns, 2013). Science educators argue that the science laboratory engages students across these three learning domains: cognitive, affective, and psychomotor. For a science laboratory course to be successful, it must have explicit goals and learning objectives (Boud, Dunn, and Hegarty-Hazel, 1989). The literature suggests that student learning benefits from understanding science instructors‘ goals of the science instructional laboratory (Hofstein and Lunetta, 1982; 2004; Coppens, Vanden Bossche, and DeCock, 2016; George-Williams, Ziebell, Kitson, Coppo, Thompson, and Overton, 2018).

The misalignment between instructor goals and students‘ perceptions is a possible reason why science instructional laboratories seem to have a limited impact on student learning outcomes (Hofstein and Lunetta, 1982; 2004). Unfortunately, students are generally not aware of what science instructors expect from laboratory experiences, and far too often, the undergraduate science laboratory curriculum lacks explicit, well-defined goals (Brucks, Towns, and Bretz, 2010). Science instructors assume that they have created their laboratory curriculum in such a way as to reflect an ideal science instructional laboratory, but this may not be recognized by students. In other words, students may not perceive the science instructional laboratory to be the same as what those labs are ideally intended to provide and therefore do not learn from them as much as is intended. There are four recent studies that assessed the goals chemistry instructors have for their instructional labs (Fay, 2008; Bretz et al., 2013; Bruck and Towns, 2013; Bruck et al., 2010). These four studies showed that chemistry faculty have two primary goals for their undergraduate chemistry instructional laboratory. They want students to acquire hands-on techniques and skills and to develop critical thinking skills.

On the other hand, there is research that assessed students‘ goals for their science instructional laboratory. Three studies characterized undergraduate students‘ learning goals for their undergraduate chemistry laboratory course (Dekrover and Towns, 2015; Dekrover and Towns, 2016; Santos-Díaz, Hensiek, Owings, and Towns, 2019). These three studies showed that students‘ goals included completing the lab experiment as quickly as possible and earning a good grade. Therefore, students‘ goals in undergraduate chemistry labs do not align with the goals of their chemistry instructors.

What these studies do not indicate, though, is the extent to which the students understand the goals for instruction with respect to faculty intent. The studies about instructor (Fay, 2008; Bretz et al., 2013; Bruck and Towns, 2013; Bruck et al., 2010) and student (Dekrover and Towns, 2015; Dekrover and Towns, 2016; Santos-Díaz, Hensiek, Owings, and Towns, 2019) goals were in chemistry instructional laboratories. Our study seeks to examine undergraduate science major (biology, chemistry, and physics) and non-major students‘, and female and male students‘ perceptions of their science instructional laboratory with respect to instructors‘ goals for the laboratory. However, one recent study George-Williams et al. (2018) assessed students and teaching staff at two Australian universities and one UK university aims of doing a chemistry practical lab. Qualitative analysis of the responses indicated that students and teaching staff views of teaching laboratories, particularly focused on development of practical skills or enhancing understanding of theory. Moreover, there were some differences between students and teaching staff aims of chemistry practical labs. This study examined only teaching staff and students in chemistry courses and did not indicate the mode of laboratory instruction style.

Introductory undergraduate science laboratories are historically taught using direct instruction/confirmatory labs (Travis and Lord 2004; King, Van derTouw, Spowart and Lawlor 2016; Brownell, Kloser, Fukami, and Shavelson 2012). These undergraduate courses are direct instruction labs; the instructor introduces the topic, presents the theoretical aspects of procedures, and identifies the lab objectives. The typical lab manual explicitly states the experimental goals of the experiment and provides instructions for data collection and analysis (Johnson and Case 1998). Within the lab manual, there are questions and suggestions that enable students to consider the concepts relevant to their investigations and to evaluate their experimental procedures. The students follow the procedures given by the instructor or from the lab manual to obtain the predetermined outcomes. Sometimes the students are unaware of the expected outcome, and the teacher directs or helps them to obtain the desired outcome (Domin 1999; Beck 2012). The actual practice of the direct instruction labs, however, likely varies with the instructor and the intended purpose of the lab (Beck 2012).

The undergraduate laboratory sessions in this institution comprises 1.5 contact hours of the four-hour course and consists of eleven laboratory activities in a 15-week semester. All the lab experiments were direct instruction activities, and students worked in groups of two to four, they were expected to complete the experiments in the allotted 1.5-h lab time. The laboratory experiments are from customized versions of the biology, chemistry, and physics lab manuals. All instructors follow a standard laboratory schedule throughout the semester. This scheduling allows the asynchronous presentation of lecture and laboratory activities. The laboratory experiments reinforce biological, chemical, and physical concepts that are directly connected to the lecture. One lab experiment is completed each week, with the exception of weeks in which there is a laboratory exam. For some labs, the same instructor teaches both lab and lecture sessions in other labs; a different instructor teaches the lab and lectures. Although students may have had different instructors, all were exposed to the same eleven laboratory activities within the semester. During the semester, students were assessed on their understanding of laboratory procedures and experiment content via laboratory exams. Each lab room held a maximum of 24 students with one instructor per lab room

Most universities require both science majors and non-majors to take at least one introductory science laboratory course (Barthelemy, Hedberg, Greenberg, and McKay 2015; Gasiewski, Eagan, Garcia, Hurtado, and Chang, 2012; Robinson, 2012). Interestingly, four of these studies found evidence that science majors and females have more favorable perceptions of their science instructional laboratory than non-majors and males. Moreover, four studies conducted with high school students found that students who were science majors perceived their science instructional laboratory more favorably than non-majors (Lang et al., 2005; Fraser and Lee, 2009; Luketic and Dolan, 2012; De Juan et al., 2016). On the other hand, one study that examined high school students (Wong and Fraser, 1994) and another that assessed college students (Robinson, 2012), showed that there were no differences in perceptions between science majors and non-majors. The findings are mixed; moreover, such findings do not mean that students perceive the lab as it is intended to be by science instructors. Indeed, there are no reported studies of how major status influences students‘ perceptions of their science instructional laboratory, with respect to science instructors‘ goals for the laboratory. Three research studies on high school students assessed whether there were significant differences between females‘ and males‘ perceptions of their science instructional laboratory. These studies showed that there were significant differences between males and females. The results from these studies claim that females perceive their science instructional laboratory more favorably than males (Wong and Fraser, 1994; Hofstein et al., 1996; Lang et al., 2005). However, two studies, one that assessed high school students (Gupta and Sharma, 2018) and another that assessed college students (Robinson, 2012), showed that there were no gender differences in students‘ perceptions of their science instructional laboratory. However, there are no reported studies of how gender influences students‘ perceptions of their science instructional laboratory, with respect to science instructors‘ goals for the laboratory.

High attrition rates of students in science, technology, engineering, and mathematics (STEM) programs have been reported in undergraduate education (Seymour & Hewitt, 1997). Seymour‘s & Hewitt‘s (1997, 2002) study showed that students in STEM courses withdrew and enrolled in non-STEM programs and that 83% of the students indicated a lack of content relevance, poor teaching laboratory methods (90%), and lack of interest in science (60%) as the major reasons for switching majors. Yet in most universities‘ students are required to take general biology, chemistry, or physics introductory science courses. The benefits of students participating in science instructional laboratory activities include: increased understanding of scientific concepts (Hofstein and Lunetta 1982; 2004; Singer, Hilton, and Schweingruber 2006), increasing student interest and motivation towards science (Hofstein and Lunetta, 1982; 2004; Singer, Hilton, and Schweingruber 2006), providing ―hands-on" experiences when studying facts/concepts (Pyatt and Sims 2007) and developing practical skills (Hofstein and Lunetta 1982; 2004; Russell and Weaver 2008). Therefore, it is reasonable to assume that science instructional labs contribute to whether or not students persist in STEM, especially as related to gender and race/ethnicity. Even for non-STEM students, the lab may have a profound effect on their perceptions of their science instructional laboratory. Understanding students‘ perceptions can help science instructors modify undergraduate science laboratory activities to create a positive experience for students. This, in turn, may lead to the retention of students in science majors and/or progression of these students into science-related careers.

Methodology

Participants

A total of 790 participants were recruited from undergraduate introductory biology, chemistry, and physics laboratory courses at a Midwestern, liberal arts university as per Human Subjects Institutional Review Board requirements. The participants were college students enrolled in 19 sections of introductory biology taught by ten different instructors, 14 sections of introductory chemistry taught by nine different instructors, and 10 sections of introductory physics taught by five different instructors, with 20-24 students per section. All instructors were either adjunct or full-time faculty. The students were between the ages of 18-22 and included mostly freshmen, a few sophomores, juniors and seniors. Most of the instructors had taught these lab courses for more than 3 years.

Instrument

As noted earlier, the SPCILS is a newly developed instrument for assessing student perceptions of laboratory instruction with respect to instructor goals and was used in this study. The SPCILS represents an ideal model (as validated by the panel of experts) for what the goals are for a typical instructional science lab. The model is comprised of five categories described below (see Table 1). The SPCILS consists of 20-items across these five categories, with four items per category. Responses are recorded on a five point-Likert scale from Strongly agree to Strongly disagree.

Table 1. SPCILS Categories and Descriptions of Each Category

Categories	Category Descriptions
Social Relationships	Social interaction is an important aspect of the classroom environment and lab activities foster interactive learning.
Future Oriented Outcomes	The laboratory curriculum includes knowledge and skills students might need for future laboratory experiences.
Habits of Mind	Students are regularly engaged with a range of practices that reflect the broader methods of science.
Relationship to Content	Content depth and practical experiences in the laboratory go beyond, but are directly related to, what is covered in lecture settings.
Skills	A priority is placed on developing the fundamental skills and techniques students need to appropriately engage in the general laboratory setting.

For the current research, we added additional items for collecting student demographic information (see Appendix A). We defined science majors and non-majors using the university‘s academic catalog. Any student enrolled in Biology, Chemistry, Computer Science & Information Systems, Electrical & Computer Engineering, Mathematical Sciences, Mechanical Engineering, and Physics was considered a science major. Any student enrolled in Kinesiology, Nursing, Occupational Therapy, Social Work, Teacher Education, Accounting, Law & Finance, Economics, Management/Marketing, Art, Communication, Criminal Justice, English, Geography, History, Humanities, Modern Foreign Languages, Music, Philosophy, Political Science, Psychology, Rhetoric & Professional Writing, Sociology, and Theatre was considered a non-major.

Data Collection

The SPCILS was administered to 790 students and 779 completed the survey during the fifth week of undergraduate, laboratory courses, Spring 2020. By the fifth week of lab sessions, participants have been in the lab long enough to have formed opinions about the science instructional laboratory. This sample is accessible and a convenient population because the researcher is a faculty member at the college. Therefore, I was able to collect data from students in my colleagues ‗labs in biology, chemistry, and physics. The lead author administered the Student Perceptions of the College Instructional Laboratory Survey (SPCILS) during beginning of the lab sessions and it took about 10 minutes to complete the survey. The lead author informed the participants on the instructions on how to fill out the survey that there are no ―right” or ―wrong” answers to the survey questions and students need to indicate on their agreement or disagreement with the statements. The SPCILS items were randomly assorted, and students responded using Scantron sheets. The scantrons from each of the sections were scanned, and the data was entered into an Excel spreadsheet. All of the data from each section was then compiled into one large data set. Data was downloaded to the computer, and then exported from excel and imported into Statistical Package for the Social Sciences (SPSS) Version 26. We used Statistical Package for the Social Sciences (SPSS) Version 26 to tabulate the data. We revalidated the SPCILS category internal consistency by calculating Cronbach‘s alpha for each of the five categories (see Table 2). We got the same internal consistency, as reported by Nyutu et al. (2020).

Table 2. Cronbach Alpha Coefficients for the 20-item SPCILS survey

Categories	Cronbach's Alpha
Social Relationships	0.724
Future Oriented Outcomes	0.750
Habits of Mind	0.807
Relationship to Content	0.814
Skills	0.744

Data Analysis

We determined the effect of gender, science majors and non-majors, and disciplines using a one-way analysis of variance (ANOVA). For all tests, a p-value of <0.05 was considered significant. Results from the Levene's test for equality of variances for each independent variable indicated that homogeneity of variance was not violated.

The resulting p-values from the Levene's test were greater than 0.05; hence the assumption of equal variance was met. The resulting p-values from the Levene's test, based on individual items, were greater than 0.05, hence the assumption of equal variance was met. Participants respond to the SPCILS items using a five-point Likert scale: 1) Strongly Disagree, 2) Disagree, 3) Neutral, 4) Agree, and 5) Strongly Agree (see Table 3).

Table 3. Qualitative Interpretation of 5-Point Likert Scale Measurements

Likert-Scale Description	Likert-Scale	Likert Scale interval
Strongly disagree	1	1.00 - 1.80
Disagree	2	1.81 - 2.60
Neutral/Uncertain	3	2.61 - 3.40
Agree	4	3.41 - 4.20
Strongly agree	5	4.21 - 5.00

For the primary analysis, we calculated descriptive statistics (means, standard deviation, and frequencies) for the SPCILS aggregate database. The means were interpreted as follows: Strongly disagree in the point range of 1.00 - 1.80, Disagree 1.81 - 2.60, Neutral 2.61 – 3.40, Agree 3.41 - 4.20, and Strongly agree 4.21 - 5.00 (see Table 3) (Pimentel, 2010).

Results

We calculated the category internal consistency using Cronbach alpha for gender, non-major/science major, and the course students were enrolled in (Biology, Chemistry, or Physics) during this study in case consistency varied across demographics or the course the students were enrolled in. As shown in Table 4, the Cronbach alpha values were found to be acceptable across these factors (=> 0.70).

Table 4. Cronbach Alpha SPCILS Coefficients for Gender, Non-major/Science Major and Course

Categories	**Cronbach's Alpha**						
	Male	Female	Non-major	Science major	Biology	Chemistry	Physics
Social Relationships	0.764	0.752	0.728	0.713	0.727	0.736	0.768
Future Oriented Outcomes	0.751	0.747	0.730	0.781	0.779	0.794	0.751
Habits of Mind	0.842	0.781	0.796	0.833	0.788	0.800	0.887
Relationship to Content	0.809	0.816	0.795	0.846	0.800	0.815	0.844
Skills	0.750	0.737	0.740	0.747	0.729	0.767	0.755

We then ran a one-way ANOVA to check if there were any differences between the three courses students were enrolled in with respect to the SPCILS categories and found statistically significant differences involving four of the five categories (see Table 5). Post hoc t-tests identified only three significant differences in the categories of Future Oriented Outcomes (between Chemistry and Physics) ($p = 0.027$), Relationship to Content (between Chemistry and Biology, and between Chemistry and Physics) ($p = 0.034$), and in the Skills category (between Chemistry and Biology) ($p = 0.023$). The Cohen‘s d values used to determine effect size were, respectively, as follows: $d = 0.17$, $d = 0.18$, and $d = 0.15$. According to Cohen (1988) we judged that these effect sizes were too small to have practical significance. Thus, on the basis of these small effect sizes following our one-way ANOVA procedure, and the consistent findings from our internal consistency analyses, we concluded that the data could be aggregated across discipline areas.

Table 5. ANOVA Results on Courses and SPCILS Categories

Categories		Sum of Squares	df	Mean Square	F	Sig.
Social Relationships	Between Groups	3.020	2	1.510	3.268	.039*
	Within Groups	358.489	776	.462		
	Total	361.509	778			
Future Oriented Outcomes	Between Groups	6.162	2	3.081	5.321	.005*
	Within Groups	449.306	776	.579		
	Total	455.467	778			
Habits of Mind	Between Groups	.938	2	.469	.858	.424
	Within Groups	424.075	776	.546		
	Total	425.013	778			
Relationship to Content	Between Groups	6.509	2	3.255	5.914	.003*
	Within Groups	427.038	776	.550		
	Total	433.547	778			
Skills	Between Groups	5.358	2	2.679	5.285	.005*
	Within Groups	393.360	776	.507		
	Total	398.718	778			

(*) Indicates the mean difference statistically significant at 95% confidence level

Analysis of students‘ demographic information showed that out of 779 students who completed the SPCILS survey, 500 (64%) were female, 278 (36%) were male, and only one student identified as non-binary. There were 512 (66%) non-majors and 267 (34%) science majors. There were 121 (16%) female science majors, 380 (49%) female non-majors, 146 (19%) male science majors, 132 (17%) male non-majors and one (0.1%) non-binary non-major (see Table 6).

Table 6. Summary of the Frequency Demographics

Demographics	**Frequency**
Gender	
Binary	0.1%
Female	64%
Male	36%
Student Majors	
Science majors	34%
Non-majors	66%
Student majors combined with gender	
Binary non major	1%
Female science major	16%
Female non-major	49%
Male science major	19%
Male non-major	15%

R1: What are undergraduate science students' perceptions of their science instructional laboratory as measured by the SPCILS categories?

Overall, students‘ perceptions of their science instructional laboratories generally aligned with instructor goals; with SPCILS category means ranging from 3.84 to 4.23, between ―agree" and ―strongly agree" (see Table 7). The strongest mean score was for Social Relationships (M=4.23), followed by Skills (M=4.02), Relationship to Content (M=3.94), Habits of Mind (M=3.92), and Future Oriented Outcomes (M=3.84).

Table 7. Category Means of the SPCILS for All Students

Categories	**Mean Score**	**Std Deviation**	**Level**
Social Relationships	4.23	0.69	Strongly Agree
Future Oriented Outcomes	3.84	0.74	Agree
Habits of Mind	3.92	0.73	Agree
Relationship to Content	3.94	0.74	Agree
Skills	4.02	0.70	Agree

R2: What are the differences/similarities between science majors (biology, chemistry, and physics), and non-majors in their perceptions of the college instructional laboratory as measured by the SPCILS categories?

We ran a one-way ANOVA to check if there were any differences between science majors and non-majors‘ perceptions of their science instructional labs with respect to the SPCILS categories. There were no statistically significant differences between science majors and non-majors (see Table 8).

Table 8. ANOVA Results on Non-major/Science Major and SPCILS Categories

Categories		Sum of Squares	df	Mean Square	F	Sig.
Social Relationships	Between Groups	.788	1	.788	1.696	.193
	Within Groups	360.722	777	.464		
	Total	361.509	778			
Future Oriented Outcomes	Between Groups	.844	1	.844	1.442	.230
	Within Groups	454.624	777	.585		
	Total	455.467	778			
Habits of Mind	Between Groups	.020	1	.020	.036	.850
	Within Groups	424.994	777	.547		
	Total	425.013	778			
Relationship to Content	Between Groups	.051	1	.051	.092	.762
	Within Groups	433.496	777	.558		
	Total	433.547	778			
Skills	Between Groups	1.511	1	1.511	2.957	.086
	Within Groups	397.206	777	.511		
	Total	398.718	778			

R3 To what extent are student perceptions correlated/associated with gender as measured by the SPCILS categories?

We ran a one-way ANOVA to check if there were any differences between females and males‘ perceptions of their science instructional labs with respect to the SPCILS categories. We found that there were statistically significant differences involving two of the five categories (see Table 9). Post hoc t-tests identified significant differences in the categories of Habits of Mind (between females and males) ($p = 0.043$), and Relationship to Content (between females and males) ($p = 0.030$). The Cohen‘s d values used to determine effect size were, respectively, as follows: $d = 0.17$ and $d = 0.12$. According to Cohen (1988) we judged that these effect sizes were too small to have practical significance.

Similarly, we ran a one-way ANOVA to check if there were any interactions between gender and science major/non-major perceptions of their science instructional labs with respect to the SPCILS categories. We found that there was a statistically significant difference involving one category, Habits of Mind (see Table

10). Post hoc t-tests identified significant differences in the category of Habits of Mind (between female and male non-majors) (p = 0.041). The Cohen's d value used to determine effect size was *d* = 0.00. According to Cohen (1988) we judged that this effect size was too small to have practical significance.

Table 9. ANOVA Results on Gender and SPCILS Categories

Categories		Sum of Squares	df	Mean Square	F	Sig.
Social Relationships	Between Groups	.415	1	.415	.892	.345
	Within Groups	361.095	777	.465		
	Total	361.509	778			
Future Oriented Outcomes	Between Groups	.300	1	.300	.513	.474
	Within Groups	455.167	777	.586		
	Total	455.467	778			
Habits of Mind	Between Groups	4.909	1	4.909	9.080	.003*
	Within Groups	420.104	777	.541		
	Total	425.013	778			
Relationship to Content	Between Groups	2.894	1	2.894	5.221	.023*
	Within Groups	430.654	777	.554		
	Total	433.547	778			
Skills	Between Groups	1.102	1	1.102	2.153	.143
	Within Groups	397.616	777	.512		
	Total	398.718	778			

(*) Indicates the mean difference statistically significant at 95% confidence level

Table 9. ANOVA Results Interaction between Gender, Major and SPCILS

Categories		Sum of Squares	df	Mean Square	F	Sig.
Social Relationships	Between Groups	1.548	3	.516	1.111	.344
	Within Groups	359.961	775	.464		
	Total	361.509	778			
Future Oriented Outcomes	Between Groups	1.524	3	.508	.867	.458
	Within Groups	453.943	775	.586		
	Total	455.467	778			
Habits of Mind	Between Groups	5.339	3	1.780	3.287	.020*
	Within Groups	419.674	775	.542		
	Total	425.013	778			
Relationship to Content	Between Groups	2.932	3	.977	1.759	.154
	Within Groups	430.616	775	.556		
	Total	433.547	778			
Skills	Between Groups	3.638	3	1.213	2.379	.068
	Within Groups	395.079	775	.510		
	Total	398.718	778			

(*) Indicates the mean difference statistically significant at 95% confidence level

Discussion

R1: What are undergraduate science students' perceptions of their science instructional laboratory as measured by the SPCILS categories?

The items composing each category reflect an idealization of instructor goals for an aspect of laboratory instruction. According to the model, when students respond to the items of a category, they are indicating the extent that their experiences align with instructor goals as described by the category. Our findings were that overall, students perceived their laboratory experiences as matching the idealized model. The mean score for the Social Relationships category was in the “strongly agree” range, and the mean scores for the other four SPCILS categories were in the “agree” range.

The items composing the Social Relationships category represent the instructors‘ intention that the lab should promote social interaction and interactive learning. The “strongly agree” response indicates that students‘ experiences align with this instructor goal. It is reasonable that the students would affirm this category because of what they do in these courses, for example, working in groups. These labs are structured to allow for interaction among students and the instructor, other researchers have also found this to be important because it promotes collaborative and meaningful learning (e.g., Hofstein and Lunetta, 1982; 2004; Olave, 2013).

The Future Oriented Outcomes category represents instructor intention that lab activities help develop skills applicable to future science courses, to which the students “agree.” It‘s reasonable to conclude that because these were introductory science instructional labs, the students may realize that these courses prepare them for upper-level science courses. Even non-majors may have realized that failing gatekeeper courses could hinder their degree aspirations (Gaisiweki et al., 2012; Barthelemy et al., 2015; Santos-Diaz et al., 2019). On the other hand, it may be that the students did not “strongly agree,” given that there were many more non-majors (66%) than (34%) science majors. According to the literature science, majors understand that introductory lab courses give them a strong foundation so as to succeed in upper-level science courses and be prepared for science careers (Gaisiweki et al., 2012; Barthelemy et al., 2015; Santos-Diaz et al., 2019).

The Habits of Mind category represents instructor goals that laboratory students should regularly engage with a range of practices that reflect the broader methods of science. On average, students “agree” in response to items about their labs supporting scientific reasoning skills, the presentation of data, understanding the scientific method, and the development of good laboratory practices. This is consistent with other studies which have reported that the science instructional laboratory offers opportunities for students to investigate scientific phenomena. The students make use of scientific processes and materials to understand scientific phenomena. They make use of science process skills such as observation, collection, and interpretation of data during the scientific process (Luketic and Dolan, 2013; Hofstein and Lunetta, 2004).

The Relationship to Content category represents instructor goals that laboratory students should be able, through their laboratory activities, to connect content depth with practical laboratory experiences, and that laboratory activities are related to what is covered during lecture. On average, the students –agree.” The findings for this study are stronger than what has been found in previous studies that reported students often do not see the connection between their science laboratory instruction and lecture (Brownell et al. 2012; Lord and Orkwiszewski 2006; Domin, 1999). In these labs, the science instructors always make sure that they teach the lecture concepts before the students perform the lab experiments. Moreover, some of the lab courses allow students to attend the laboratory class immediately following a lecture or no more than two hours after the lecture has ended on the designated laboratory day.

The Skills category represents instructor goals that laboratory students develop fundamental skills and techniques for participating in laboratory exercises. The students –agree.” Their agreement was expected given that the syllabi for these introductory laboratories include instruction on various laboratory instruments and processes. Furthermore, several studies in the literature indicate that students recognize the importance of an instructional laboratory for the development of laboratory skills (e.g., George-Williams et al., 2018; Dekrover and Towns, 2015; Reid and Shah, 2007).

R2: What are the differences/similarities between science majors (biology, chemistry, and physics), and non-majors in their perceptions of the college instructional laboratory as measured by the SPCILS categories?

There were no statistically significant differences between science major and non-major students‘ responses to the SPCILS categories. This indicates that students‘ experiences, irrespective of their major status, align with instructor goals as per the idealized model. These results are consistent with two studies that used the Science Laboratory Environment Inventory (SLEI) and reported no significant differences between science majors and non-majors‘ perceptions of their science instructional labs (Wong and Fraser, 1994; Robinson, 2012). However, several studies that used the SLEI have also shown that science major students perceive their science instructional laboratories more favorably than non-majors (Lang et al., 2005; Fraser and Lee, 2009; Luketic and Dolan, 2012; De Juan et al., 2016; Wong and Fraser, 1994; Hofstein et al., 1996).

R3: To what extent are student perceptions correlated/associated with gender as measured by the SPCILS categories?

The differences between females and males were statistically significant, but the effect sizes were too small to have practical significance. This indicates that students‘ experiences, irrespective of their gender, align with instructor goals as per the idealized model. Previous research studies which used the SLEI showed that females had favorable perceptions of their science instructional laboratory than males (Henderson, Fisher, and Fraser, 2000; Wong and Fraser, 1994; Fraser, Giddings, and McRobbie, 1995; Lawrenz, 1987; Giddings and Fraser, 1990; Gupta, Koul, and Sharma, 2015). However, results are from two studies that used the SLEI and showed that there were no gender differences as measured by the SLEI subscales (Ozkan, Cakiroglu, and Tekkaya, 2008; Robinson, 2012). There were statistically significant differences between the interaction of gender and science major/non-major for only one of the five SPCILS categories; however, the effect size was also too small to have practical significance.

Conclusions

This study undertook the examination of student perceptions of the undergraduate, instructional science laboratory vis-à-vis instructor goals for the laboratory as described by an idealized model, the SPCILS, by addressing three research questions. The data was collected from a population of college students, most of whom were female and non-science majors. The SPCILS is not able to assess the intended outcomes of an individual experiment. The study, first of all, found that, on the whole, students perceive their instructional labs much as intended by their instructors. The study also found that there were no differences between male and female students. Female and male students were just as likely to view their instructional laboratories as intended by the instructors.

Moreover, the study found no differences between science majors and non-majors. In light of instructor goals, these laboratories appear to be effective at least in respect to student perceptions of the laboratories. The study did not address the possibility that academic achievement could be a factor. The success of these laboratories is perhaps attributable to what the lab instructors do, like motivating students and helping them feel comfortable so as to participate and enjoy the lab. Moreover, at the beginning of each lab, instructors present the theoretical aspects of procedures, identify the lab objectives, and do a wrap up at the end of the lab. The instructors use customized lab manuals that they created and tailored to meet the specific needs of each lab course.

Lastly, these lab courses are not taught by Teaching Assistants so most of the fundamental aspects of teaching are consistent, which might not be the case in courses taught by Teaching Assistants. There are, however, limitations to our findings. As noted above, we did not consider academic achievement, which is something that should be done in later studies. Our research, moreover, was done at a teaching-oriented, midsized university. It would thus be appropriate, for example, for similar investigations to be carried out at a research-oriented university. The potential for generalizability is tied to the number of different environments in which the research questions are investigated.

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Appendix A - Student Perceptions of the College Instructional Laboratory Survey (SPCILS)

Instructions:

There are no ―right” or ―wrong” answers to the following questions. We are simply interested in your opinion on whether the lab course you are attending is meeting these goals and your interest in science. Indicate the extent to which you agree or disagree with each the following statements.

Only fill one bubble per item.

1) Gender: Male **FILL OUT A in the scantron sheet**
Female **FILL OUT B in the scantron sheet**
Non-binary **FILL OUT C in the scantron sheet**

2) Academic Major (or intended major):

FILL OUT A in the scantron sheet If you are a (Biology, Chemistry, Computer Science & Information Systems, Electrical & Computer Engineering, Mathematical Sciences, Mechanical Engineering and Physics major)

FILL OUT B in the scantron sheet If you are a (Health Sciences, Kinesiology, Nursing, Occupational Therapy, Social Work, Teacher Education, Accounting, Law & Finance, Economics, Management/Marketing, Art, Communication, Criminal Justice, English, Geography, History, Humanities, Modern Foreign Languages, Music, Philosophy, Political Science, Psychology, Rhetoric & Professional Writing, Sociology and Theatre major)

Please respond to the rest of the questions using the scale provided:

Social Relationships					
3. In this lab course, I feel comfortable asking the instructor questions.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
4. I work with my lab partners cooperatively and collaboratively in this lab course.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
5. In this lab course, the process of thinking through an experiment is as important as obtaining the correct answer.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
6. I understand the purpose and outcomes for this lab course.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)

Future Oriented Outcomes					
7. The course lab activities help me develop skills that I can apply to future science courses.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
8. This lab course gives me an idea of how science is performed in the real world.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
9. The goal of this lab course is to prepare me for research experiences.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
10. The laboratory experiments of this lab course are applicable to various disciplines.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
Habits of Mind					
11. This lab course is designed to foster the development of my scientific reasoning skills.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
12. In this lab course, I learn how to present data in a form that is understandable.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
13. In this lab course, I am developing an understanding of the scientific method.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
14. In this lab course, I am learning good lab practices like how to use and organize my lab notebook.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
Relationship to Content					
15. In this lab course, I gain hands-on experience that reinforces and solidifies content knowledge.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
16. In this lab course, I learn to connect laboratory concepts to quantitative data collection procedures.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
17. In this lab course, laboratory activities help strengthen my understanding of concepts taught in lecture.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
18. In this lab course, laboratory activities help me develop a deeper understanding of science concepts.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)

Skills					
19. In this lab course, I am developing an understanding of the accuracy of measurements, calculations and data analysis methods.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
20. In this lab course, I am gaining skills in presenting the findings of my experiments in tables and graphs.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
21. In this lab course, I am developing skills in using scientific instruments.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)
22. This lab course is helping me develop practical laboratory skills.	Strongly disagree (A)	Disagree (B)	Not sure (C)	Agree (D)	Strongly agree (E)