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Cianán Brooks Russell
*Purdue University - Main Campus*, cianan@purdue.edu

Gabriela Weaver
*Purdue University*, gweaver@purdue.edu

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**Keywords**
SoTL of chemistry, Science laboratory, Student engagement in laboratories

# Student Perceptions of the Purpose and Function of the Laboratory in Science: A Grounded Theory Study

**Cianán B. Russell**
Purdue University
West Lafayette, Indiana, USA
cianan@purdue.edu

**Gabriela C. Weaver**
Professor of Chemistry and Science Education
Purdue University
West Lafayette, Indiana, USA
gweaver@purdue.edu

## Abstract

The laboratory has long been an important part of the undergraduate science experience. This paper reports on a qualitative, grounded theory study on students' perceptions of the purpose of the laboratory. Thirteen undergraduate chemistry students were interviewed about their experiences in the science laboratory to provide data on students' understanding of the purpose of the laboratory in science education. Results reveal that students had views that were polar opposites regarding the correlation between laboratory and lecture content material and the effectiveness of the laboratory at enhancing their learning in science. This paper also reveals the need for explicit instruction regarding the purpose of the laboratory to enhance student understanding. Interpretations of these and other findings are provided, along with a schema for approaching the undergraduate perception of the laboratory synthesizing current and past findings.

## Introduction: The Conceptual Background

It has long been a belief in science education that the laboratory has the potential to be a place where theory and practice can coalesce for students. This belief has contributed to the ongoing discussion of the purpose and function of the laboratory within science classes (Byers, 2002; Hofstein & Lunetta, 1982; Lagowski, 2000). The research literature on the laboratory describes the varied purposes that educators have for the laboratory, which echo, nearly verbatim, the purposes for the lecture and science learning in general (Hegarty-Hazel, 1990; Hofstein & Lunetta, 2004; Tamir, 1990). These articulated goals include an understanding of scientific concepts, interest and motivation, practical skills and problem solving abilities. Within the discussion of these goals, however, there exists very little evaluation of student perception of these goals or of student ideation of laboratory goals in general.

The dialogue on the purpose of the laboratory has created an ever-changing landscape of laboratory learning goals. Hodson (1993) and Trumper (2003) contend that the laboratory should focus on teaching students practical skills and abilities, and not the nature of science, scientific concepts, nor affecting student attitudes about science (Hodson, 1993; Trumper, 2003). There is little agreement on an underlying reason for the important status of the

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laboratory in science education, with only speculations available as to why the practice has reached its current stature (Hodson, 1996). Further, while the laboratory is wildly popular in some countries, it is excluded from the science curriculum in others (Abd-El-Khalick *et al.*, 2004). It is therefore difficult to determine which goals are intrinsically most appropriate for the laboratory.

The laboratory as a learning forum is under constant scrutiny by educational researchers with the goal of improving its educational merit and solidifying its place in science education (Hofstein & Lunetta, 1982, 2004). Hodson (1993) asserted that

> [The laboratory] is over-used in the sense that teachers engage in practical work as a matter of course, expecting it to assist the attainment of all learning goals. It is under-used in the sense that its real potential is only rarely fully exploited. Instead, much that we provide is ill-conceived, muddled and lacking in real educational value. (Hodson, 1993, p105)

The dialogue regarding the content and position of the laboratory in science education has fuelled a significant amount of work by educators or educational researchers leading to a relatively large body of research on the laboratory and improvements thereof. Similarly, though, these discussions have consistently failed to take into account the perspective of students in terms of their interpretations and internalizations of the laboratory goals. This omission has lead to curricular reform focused on conceptions of the purpose of the laboratory developed *ex situ*.

The literature has, however, identified a disconnect between student and professor perceptions of the purpose of the laboratory (Hofstein & Lunetta, 1982, 2004). This disconnect has thus far been studied only with respect to the purposes and goals of individual experiments (Hart *et al.*, 2000) rather than of the laboratory experiences as a whole. It was found that students' initial perceptions of experimental goals are significantly different from the goals expressed by the professor. However, prolonged student exposure to consistent experimental goals in the classroom can lead to better student-professor alignment (i.e. students adopting professorial goals for laboratory experiments). In the classroom studied by Hart *et al.*, student understanding of the professor's goals for the experimental unit were an eventuality that came late in the unit, and failed to develop at all for some students.

There appears to be no general consensus about whether or not the purpose of the laboratory is to bridge theory and practice. Boud *et al.* (1980) conducted a quantitative study of current students, recent graduates, and practicing scientists about the observed and preferred aims of the laboratory. This study found that only the current students ranked "to illustrate material taught in lecture" and "to help bridge theory and practice" in the top five preferred aims while the recent graduates and practicing scientists ranked those issues much lower (e.g. illustrating material taught in lecture was ranked as 14 and 17 out of 22 items, respectively). Similarly, graduates and scientists ranked "to train students in observation" and "to foster critical awareness" in the top five preferred aims, while current students ranked those issues lower (e.g. students ranked these same items 7 and 14 out of 22, respectively). The authors went on to discuss the function of the professor in explicitly evaluating the goals that they have set for the laboratory and communicating those to students. The specific suggestion that the authors proposed was adjusting the balance between practical skills and opportunities for students to understand the connections between theory and practice.

In contrast, other works show that some professors purported that the aim of the laboratory is to make connections between practice and theory through direct implementation of concepts (Gunstone & White, 1981; Wilkinson & Ward, 1997). The Wilkinson and Ward study evaluated student and teacher perceptions of the purpose of the laboratory. The study asked participants to rank survey items (e.g. "to gain practice at making accurate observations and interpreting them", "to help students understand theoretical parts of science", and "to make science more interesting and enjoyable through actual experience"), each of which was a supposed aim of the science laboratory, on a 5-point Likert scale. The study found that teachers ranked "to make science more interesting and enjoyable through actual experience" as most important, with "to gain practice at making accurate observations and interpreting them" and "to help students understand theoretical parts of science" tied for the second most important aims of the laboratory. Interestingly, "to give training in solving problems and conducting investigations" was ranked seventh out of the ten items by the teachers. The absence of consensus on the issue of theory-and-practice may well indicate a deeper gap in the literature, namely knowledge about the constructed link between theory and practice in the minds of student learners. As the existence of this link is regularly assumed by students and often by educators and researchers, it follows necessarily that an evaluation of the assumption is absolutely necessary.

A study conducted by Pickering described the goal of many traditional labs as following the pattern of "procedure-before-theory", but they observed that students failed to grasp the theory from laboratory experience at all (1987). Hart *et al.* (2000) noted that students often participated in laboratory courses with the expressed purpose of linking theory with practice, but that they often failed to make the connections between lecture and laboratory settings. This failure to make a connection may stem from 1) insufficient integration between theory and procedures in traditional laboratory manuals, 2) too much material covered during the laboratory period (i.e. an over-emphasis on breadth of content or procedural experience at the detriment of depth of understanding), or 3) the prominence of hands-on practice in the laboratory to the almost complete exclusion of theory and its connections to practice. Students placed in a context wherein the explicit goal is to complete the experiment, especially when given a small time window, are likely to first follow the procedures, with little notion of the theory as it affects the methods involved (Pickering, 1987).

The discussion in the literature of student perceptions of the purpose of the laboratory has seemingly only begun to delve into the complexities of this arena by (1) approaching student perceptions from a quantitative perspective, (2) addressing the laboratory in terms of individual experiments, and (3) qualitatively examining student perceptions. The qualitative studies provide a rich picture of the many competing views of the purpose and function of the laboratory, but these studies are so far very limited in number and scope. The purpose of this study is to bring additional depth to the body of work that qualitatively studies student perceptions of the laboratory, specifically approaching student perceptions using grounded theory to develop a schema for elucidating student experience of the laboratory. One important contribution that this paper makes is that it provides evidence regarding students' perceptions of the purpose of the laboratory that are widely believed to be true but are not presented in the literature. Specifically, this study seeks to address the following research questions: (1) What do students perceive to be the purpose of traditional laboratory courses? (2) How do students' perceptions of the laboratory affect their attitudes about the lab? and (3) What are students' learning goals for the laboratory?

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## Methodology

### Participants and Setting

This study took place over the course of two semesters (Fall 2005 and Spring 2006) at a large research university in the USA. Of the total participants (n=13), there were five males and eight females, ranging in age from 18 to 21. Eight of the 13 participants were first-year students at the time of participation, with the others being in later years. Participants were recruited at the beginning of each semester from science courses at a large Midwestern university. This study will describe students' experiences in science courses that they took *prior* to the semester in which they were recruited; therefore the exact composition of the course from which they were recruited is irrelevant. Instead, it is important to note that these students had taken typical 1st and / or 2nd year science core courses for the science degree. The specific courses that they are referring to will be described in more detail below.

The participants in this study were representative of the institution in terms of their demographics. Table 1 shows demographic data for the participants.

| | African American | Asian | Hispanic | Native American | White, non-Hispanic |
|---|---|---|---|---|---|
| Freshman | 0 | 0 | 1 | 0 | 8 |
| Sophomore | 0 | 1 | 0 | 0 | 3 |
| Male | 0 | 1 | 1 | 0 | 3 |
| Female | 0 | 0 | 0 | 0 | 8 |

Table 1. Participant demographics

All names presented herein are pseudonyms; each participant chose her or his own pseudonym.

### Data Collection

Participants were recruited from a laboratory course by email and asked to volunteer for interviews. The interviews were 45 minutes in length, semi-structured and took place during the first four weeks of the semester. Students were informed that the interviews would have no impact on their course grade. The semi-structured interviews focused on the students' ideas about the laboratory, based on laboratory courses they have taken from any science discipline. Some examples of the interview questions are:

> Have you liked attending your laboratory courses in the past? Why or why not?
>
> What are some modifications that could be made to make the lab a more enjoyable experience for you?
>
> Do you feel that you understood the purpose of the lab in your courses in the past? What do you think was the purpose of the lab in your course?
>
> If you were to design a lab class that suited your needs as a student, what would that course look like?

Each participant was allowed latitude in how the interview went and the direction it took – if a participant's answer pertained to a topic later on the list, the interview would just continue to that topic, instead of going linearly to the next topic on the list, but eventually covering all predetermined topics. Further, the issues that the participants were interested in discussing were deemed of the utmost importance, thus framing the relationship of interviewer and interviewee. This allowed for continuity from the perspective of the participant and gave the participant more opportunities for elaboration and topic connections (Patton, 2002). The topics covered in the interviews were (1) overall perceptions of lab, (2) utility of lab when taking exams and doing homework, (3) connections between lab and lecture, (4) group work in lab, (5) memory of specific experiments from previous courses, and (6) changes to the laboratory structure that students would suggest.

### Data Analysis

All interviews were transcribed verbatim. The analysis process for the interview data was three-fold. The initial analysis consisted of listening to the tapes of the interviews and reading the transcripts to find major concepts emerging from the data. This level of analysis allowed for a broad picture to develop for each interview participant, and created a foundation of the concepts on which later analyses would be based. The secondary analysis process involved combing through the individual interviews to solidify concepts and create and assign categories for concept demarcation using the software package QSR N-Vivo®. This level of analysis required more attention to detail with respect to the specific words that the participants chose and the interpretive meanings of the participants' statements, such that categories would be as well developed and defined as possible. The tertiary analysis involved exploring the concepts among the participants, and recategorizing as necessary, so as to develop synergies of ideas. This final stage allowed for a broadened approach to the data as a set, which enriched the overall understanding of the categories. After the categories were well refined, themes were developed using the categories as a framework. This analysis is based on the approach described by Rubin & Rubin (2005).

### Theoretical Underpinnings and Their Implications for this Study

Historically, constructivism has been linked most directly to students' learning and integration of course content. The principles of constructivism are not, however, limited to learning course content; all information is situated in scenarios (e.g. personal experience and classroom setting) that affect the method by which it can be learned (Brown *et al.*, 1989; Jarvela, 1998). Information, such as how to learn in a certain setting, must also be learned in order to participate effectively in that setting. Social constructionism accounts for the interactions of individuals in the process of learning and developing meaningful knowledge (Vygotsky, 1962). That knowledge is further associated with the arena in which it is learned, and can best be learned in an atmosphere of situated cognition. Situated learning experiences are those in which the material is presented within or in conjunction with a context relevant to the material (Brown *et al*., 1989; Hendricks, 2001; Stewart *et al.*, 2003). In science education, the laboratory would seem to be an appropriate place for situated cognition to occur.

Each student creates her or his own unique perspective of the purpose of the laboratory through experiencing the laboratory and the course as a whole. The intended purposes of the laboratory, as constructed by the professor, cannot be directly transferred to the student. The student has the will and ability, by nature, to build her or his own perspective, independent of professorial intentions. The conceptions that students construct lead them to develop unique approaches to or mechanisms for functioning within the structure of the laboratory. These mechanisms of interaction are based on the students' larger goal of

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learning the information that they perceive to be most critical, independent of the professor's intentions with respect to relevance.

The students' perspectives of the laboratory are an as yet extremely under-explored area in science education. As such, there is little previous work on which to base the findings of this study. However, grounded theory is the theoretical framework that informs the data collection and analysis of this study. In grounded theory, the researcher endeavors to extract a theory grounded in the views of the participants in the study (Strauss & Corbin, 1990). Primary characteristics of this framework are constant comparison of data with categories as they emerge and sampling of different groups of participants to maximize the depth of information.

## Results and Discussion

Three major themes emerged during analysis: the authority of the laboratory manual, students as visual and kinesthetic learners, and degrees of connection between laboratory and lecture. Each theme will be described along with supporting data and analysis. As will become clear, the themes in students' perceptions of the laboratory sometimes agree with, and sometimes disagree with, the views of science instructors and science education researchers.

### Authority of the Laboratory Manual

Traditional laboratory courses are based on written instructions that students follow to complete laboratory activities. Students in this study perceived that the written documents and structured experiments held authority over the science that they were allowed to perform. For the purposes of this study, authority is defined as the power to influence thought or behavior. Authority, in this context, comes from the written documentation of the experiment, as well as from the instructors, and teaching assistants. Students and instructors can express acknowledgment of authority through strict adherence to the experiment as written in the manual. One student, when discussing the difficulties with traditional laboratory design, said that it was often implied that, "Here are the experiments. Follow it as close as you can, and this is what you should get in the end" (William, September 2005). He went on to express that this was a limiting approach for him, saying that participating in an experiment in which he made no choices was stifling to his education. Another student expressed similar sentiments when discussing the structure of a specific undergraduate course, saying, "In... regular chem labs, you have certain things that have to be done in the three hours that you're given" (Mark, September 2005).

Mark seemed resigned to the authority of the text. While discussing the relative weighting of different aspects of the course for grades he said, " 'Cause in labs it's kind of, like, just if you can follow directions, normally". This statement shows Mark's perception that the expectation for his participation in lab is simply to follow directions. Another participant showed similar conceptions of the practices in the laboratory:

> You basically just show up and, you know, do exactly what they tell you and then you get five points for basically just being there... You just did whatever they said and you never really had to think about why you were doing it or what you were supposed to get from it (Kathryn, January 2006).

From Kathryn's perspective, the nature of the laboratory manual on which the class was based allowed students to participate in laboratory courses without needing to think about the process, but instead by just following directions almost as robots. This is because of the particular procedural boundaries it specifies, and the enforcement of these boundaries by course instructors.

These students' perception of the goals of the course have led them to conclude that their participation is limited to following the instructions provided in the laboratory manual. Kathryn's use of the phrase "do exactly what they tell you" implies that deviation from the manual and the instructor's directions is discouraged. Each of these evidentiary pieces shows students' perception that the laboratory manual or course structure does not allow for creativity on the part of students.

An expressed purpose of the laboratory from the perspective of science education researchers is to increase student interest and motivation (Hegarty-Hazel, 1990; Hofstein & Lunetta, 1982, 2004; Lagowski, 2000). In these students' experiences, an increase in interest is not occurring; Kathryn's description as "never really [having] to think" shows her despondence about her laboratory. Further, this type of laboratory experience may fail to teach students how to think about the laboratory course content on their own, and may result in a distorted image of the practice of science. The types of laboratory experiences that these students described perpetuate the image of science as perfunctory and dull without the opportunity for imagination, while many science practitioners would argue quite the opposite.

**Students as Visual and Kinesthetic Learners**

More than half of the participants referred to themselves as visual and / or kinesthetic learners (n=9, 69%), though rarely in those words, and indicated that the laboratory provided them with a necessary space for learning visually and / or kinesthetically. For example, John stated:

> Basically, we read the textbooks all the time, but sometimes [I] wonder what am I actually solving for? What am I doing? What is this? What does sodium hydroxide look like? What does this kind of acid look like? What happens when they're mixed together? No book can really illustrate that, unless it has very good pictures [laughs], but just to see it unfold right before your eyes, I mean, it instantly imprints a memory in your head, so I can say, next time you read the book, what happens when sodium hydroxide reacts with acid? I've seen that before. I know what happens (John, September 2005).

John's explanation of his interaction with the material is very visual; he needs to have a picture in his mind, whether still or moving, of the chemical scenario to solidify the memory. This type of visual learning was cited by another participant who, when referring to a reaction that produces a gas, said,

> You can't really remember that, but if you see, you know, you put something in and then all of a sudden there's an explosion, you know that gas was released. You know that there's that pressure and everything, and it's a very different thing to see that actually work versus just memorizing the formula (Joanne, September 2005).

Joanne mentions both visual and kinesthetic aspects of the laboratory experience, citing both "[putting] something in" as well as seeing. It is possible that there is more kinesthetic connection for this participant than she is aware of, and the action of participating in the reaction promotes active learning over memorization.

A third student also made a connection between kinesthetic and visual learning styles, saying, " 'Cause it helps you, at least for me, 'cause I am definitely a kinetic [sic] learner. I learn better by actually seeing and, like, doing things than I do by just sitting there and being a sponge" (Amber, September 2005). Amber has obviously thought about her learning style, making specific note of the type of learner she believes herself to be. In her analysis, she believes that participation in the lab activities helps her to "learn better". Finally, one student made a comment about the impact of the specific techniques carried out in the laboratory and their educational functions, saying,

> When you try to measure out the molarity, and then just doing the M1V1 M2V2, but that's, writing it out is good, but if you have to apply that, you have to measure out the volume, and then you have to get the weight, learn how to use the scale, and then with significant figures, you also have to apply that (William, September 2005).

William's statement shows the impact that laboratory procedures have on his learning. His discussion of the individual actions of the laboratory implies a level of importance for kinesthetic learning for William as he works in the laboratory. Educational researchers and practitioners agree on the importance of learning practical skills as a goal for the laboratory (Hodson, 1993, 1996; Hofstein & Lunetta, 2004; Trumper, 2003). These students' perceptions coincide directly with those expressed goals.

### Differing Degrees of Connection between Lab and Lecture

While some students depend heavily on the laboratory for reinforcement of lecture concepts, others find the laboratory more tedious than helpful. Students' views of the laboratory as integrated-and-useful or disconnected-and-not-useful affect not only their construction of their perceptions of the laboratory, but also how they choose to interact with the laboratory activities as tasks within the course. Students in this study seemed to fall into one of two categories – those who felt that the laboratory was connected to the lecture, and those who felt that there was no connection. Students have the ability to see the laboratory activities as integral to course success, tangential, or somewhere in between, and where the student falls on this continuum has an impact on how the student constructs her or his perception of the laboratory.

#### *No Connection*

One student described herself, saying, "I am one of those people where the lab never reinforced what I learn in lecture. I don't know, it's always been totally separate for me, and I understand what I'm doing. I can get through that but it doesn't connect for me to the lecture to help me learn anything" (Kristi, January 2006). Kristi's feelings about the function of the laboratory come through in this statement, making it clear that she finds the laboratory does little to promote her understanding of the lecture materials. Another student agreed when responding to a question about laboratory application to the course, saying "how I always viewed the lab: as just kind of an activity to do with the course" (Hannah, January 2006). Later, Hannah went on to say, "It never really seemed to tie in for me, it never really helped me learn too much. It was just kind of an extra thing to do, usually". With this particular student, her opinions of lab focus on the activities being a burden on her time, and she has failed to see any connections between the activities in the traditional laboratory and the concepts being discussed in lecture.

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Students who have constructed perspectives that the laboratory is disconnected from the lecture also seem to feel that the laboratory doesn't help them to learn either lecture or laboratory content: Kristi says that the lab, "doesn't connect… to help me learn anything" and similarly Hannah says, "it never really helped me learn". The seeming relationship between the perspectives of the laboratory as disconnected from the lecture and that of the laboratory as a forum that does not promote learning is worth noting in the development of goal sets for the laboratory and for science courses in general.

*Connection*
Student participants often mentioned their beliefs that the traditional laboratory reinforces lecture concepts, either through repetition or through further exploration of a topic previously presented in lecture. One student discussed the necessity of repeating concepts from lecture to lab, saying, "When you learn, it's through repetition, and so you hear in the lecture, and you do it again in the lab" (William, September 2005). While William recognized a benefit of the laboratory-lecture connection based on seeing the material a second time, another student described the benefit in a more intricate way:

> I feel that we do [labs] to prove to ourselves the things that we are taught [in lecture]… we start with one basic principle and then build upon it each time. We're taught it as though it's fact, but then we prove it to ourselves, as if we were actually the researchers (Jake, January 2006).

Jake described the supplemental nature of the laboratory learning environment, explaining that the laboratory provides an opportunity for students to further engage with lecture material, as well as experience a repeat exposure.

One student talked about her personal perspective of a particular lab course, saying, "I think the purpose of the bio lab was just to restate what we were learning… it was kind of like review almost, is what it seemed like" (Kathryn, January 2006).

All of these students' statements rely on the idea that laboratory activities give students the opportunity to take concepts directly from lecture and reexamine them. William's statement focuses on superficial repetitive integration, while Jake notes the constructive nature of laboratory instruction. Each of these perspectives represents a unique approach to a common situation, and students have constructed those approaches based on their interpretations of the laboratory environment and learning materials. These students' statements demonstrate that the laboratory as a learning setting can be perceived differently, even by students who agree about its purpose - they see the laboratory as taking concepts from lecture and demonstrating them concretely. The student will interpret the information provided based on her or his perspective of the laboratory that has been constructed as a consequence of participating in the laboratory. Jake, who saw the laboratory as building upon previous course material from a variety of settings, may learn very different information than Kathryn, who described the laboratory as intimately connected with the lecture material.

Another student discussed her opinion about a theoretical alternative to laboratory coursework, saying, "I felt like if we had just been given the data and done the calculations with it, it would have been the same as just, you know, doing the lab and getting the data ourselves and doing the calculations. Like, the only important part was doing the calculations, not using the lab materials themselves" (Ginny, January 2006). This is a relatively bold statement in the current curricular context of the traditional laboratory,

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namely because of the important role that the laboratory takes in many chemistry instructor's perspectives on teaching. This participant may not, however, realize the implications of her ideas of replacing the laboratory with numerical exercises. Ginny is positing an idea worth consideration: if students perceive that they are simply going through the motions to achieve a predetermined answer, the goals of the laboratory could be more efficiently met for some students when replaced with word problems and calculations. Ginny's idea is essentially an extreme representation of a student understanding the laboratory as an extension of concrete demonstration of the lecture. Her goal in the alternative activity that she describes is to cut out the performance of the activities in the laboratory in favor of having the time devoted to practicing applications of the lecture mathematics and calculations.

*Summary*

One notable commonality between the perspectives expressed by William, Jake, Kathryn, and Ginny is the assertion that the laboratory is not a forum in which they are required to learn new concepts or ideas. Their experiences are of revisiting concepts that they have previously learned in the lecture portion of their course, and they have come to understand the laboratory as a forum in which they are expected to relearn those concepts. Their explanations of their experiences are in direct contrast with those of Hannah and Kristi, who say that the laboratory does not interact with the material that they learn in the lecture, though the students have all taken the same courses. The ways that these students have constructed their perceptions of the laboratory have led not only to different understandings of the purpose of the lab, but in the cases of Kathryn and Hannah, for example, their expressions of their uses of the laboratory as "review" and "an extra thing to do", respectively, are disparate.

It is not surprising that students have constructed views of the importance of a connection between lecture and laboratory content that vary radically, as the views expressed by educators and educational researchers are also diverse. While some in the education community argue that the laboratory exists to teach in tandem with the lecture, others argue that the lecture and laboratory should teach separate content. The students in this study, finding themselves in the practical application of an educational theory controversy, have essentially chosen sides.

## Students' Laboratory Perceptions Schema

This study has allowed for the documentation of key pieces of knowledge regarding students' perceptions of the laboratory. Studies rooted in grounded theory culminate in products that represent the theories developed during the course of discovery; these products take many forms (Charmaz, 2006). As such, we have developed a schema representing the theory developed to incorporate the results of this work and previous research. We believe that this scheme helps to present a more complete picture of students' perceptions of the laboratory in science courses.

### Student Laboratory Perceptions Schema

*Professorial goals and intentions:* Students involved in undergraduate laboratories are not initially aware of their professors' goals for the lab, and may or may not come to understand or accept those goals during the course of the experiment.

*Laboratory manual authority:* Students perceive the laboratory manual as an absolute authority on activities to be performed in the laboratory, such that students may not develop an understanding of the role of creativity in the context of science practice.

*Laboratory/lecture connection:* Students disagree about the effectiveness of the laboratory in reinforcing and integrating with lecture content. Students do not grasp the theories beneath the practice in the laboratory setting, regardless of their perspective on the desirability of a connection between the laboratory and lecture content. For some students, the primary connection between laboratory and lecture comes in providing a kinesthetic or visual example of abstract lecture content.

The first of these items, professorial goals and intentions, is a synthesis of the research presented by Hart *et al.* (2000) and ideas discussed here. In the work by Hart *et al.*, the student participants rarely converge with their professor with respect to the goals of the laboratory. When students do come to understand the professor's goals, it is after significant time has elapsed. Together, this set of information shows students' underdeveloped sense of the purpose of the labs that they are completing. Further, students are not challenged to approach the laboratory metacognitively, meaning that students have little opportunity to analyze what they are learning in terms of stated or implied laboratory goals.

Secondly, students hold the laboratory manual in extremely high esteem. Students in this study explained their interactions with laboratory content almost entirely within the framework of the laboratory manual and devoid of perceptions of opportunities for creativity or independent thinking. The students in this study coming to this conclusion is reminiscent of some of the findings from the study by Boud *et al.* (1980), namely that students ranked "to foster critical awareness" and "to show the use of 'practicals' as a process of discovery" as 14 and 18 out of 22, respectively. The student participants in this study showed a belief that the laboratory did not exist to allow students to elicit their own understandings or meanings from the material. The integration of these findings shows the high regard that students have developed for the laboratory manual as an absolute authority on laboratory practices and procedures.

Finally, student perceptions of the connection between lecture and laboratory portions of integrated courses vary. However, students consistently are unable to integrate the theory from the laboratory into their understanding of experiments, both in practice (Pickering, 1987) and in their own perceptions of their experiences (Kristi). Further, Hart *et al*. (2000) discuss how students often participate in the laboratory with the express purpose of linking theory with practice (e.g. William), but that often they fail to make the connections between lecture and laboratory settings, an experience well exemplified by Ginny's discussion of replacing the laboratory with practice problems. Thus, regardless of the weight that particular students put on the correlation between lecture and laboratory content, students are ineffective at making theoretical knowledge gains during the lab.

## Conclusions

Student engagement in laboratories is governed in part by the perceived importance of different aspects of the laboratory itself and how those aspects fit into the larger course structure. Students in this study provided insight into their perceptions when indicating that the only goal they perceive for the laboratory is to complete the activities, but not mentioning any integration of theoretical understanding as a perceived goal. One student specifically suggested dismissing the theoretical and content connections of the laboratory materials in favor of completing the procedures (Kathryn). In concluding that the purpose of the laboratory is to perform the procedures, not to learn the theory, students are describing their perspectives of the learning demands that are placed upon them for the course. These perspectives govern their interactions with the course content such that student-learning goals focus on pure mechanistic performance of the laboratory activities, not interpretation of the information contained therein. A prime example of this conception of lab is evident in William's comments. William has determined that in order for him to succeed he must closely follow instructions and get the predetermined answer. When students participate in laboratory activities by following laboratory manual instructions to the letter, their belief that success in the science laboratory is based on keeping to predetermined procedures is reinforced, not on learning the theory and observing the processes taking place. It is clear that this may be a major component of the disconnect between faculty and student goals for the laboratory, as described in the introduction.

Students need to be made explicitly aware of the goals of the laboratory, both in terms of the laboratory *in toto* and each experiment individually. This would be best accomplished prior to the commencement of any laboratory activities. Without a clear understanding of their professor's goals, students cannot be expected to either achieve specific goals or to completely understand the purpose of the laboratory, as Ginny's perspective demonstrates.

An interesting finding of this study is the existence of contradictions in student perceptions. Several students said that they felt the purpose of the laboratory was to repeat and reinforce the lecture materials. However, students also said that their own laboratory experiences did not make connections with the lecture materials. The idea that the laboratory should repeat and reinforce the lecture seems to be so ingrained that students will point to this as a primary purpose of the laboratory even after repeated experiences to the contrary. Once students construct the idea that the laboratory is a place for repetition and reinforcement of lecture materials, it seems that even contradictory experiences have little sway on that construct. More importantly, having such a deep-seated expectation for the functioning of the laboratory may interfere with students' abilities to perceive or accept a laboratory experience where the purpose is to teach scientific process or, as described in the introduction, "to foster critical awareness" (Boud et al., 1980).

Our data also indicate that some students' laboratory expectations are met. Specifically, the laboratory serves as a vehicle for incorporating visual and kinesthetic learning into many courses for which lectures have traditionally been auditory and text-based. For students expressing a need for more hands-on experiences for meaningful learning, the traditional laboratory provides an appropriate avenue. However, even in cases when students mentioned feeling that the lab was an occasion for seeing or experiencing lecture materials in real life, those same students often returned to discussing the mechanistic nature of learning in their own laboratory experiences by following instructions. While students describe the laboratory as a setting in which they can gain hands-on experience, they simultaneously view it as devoid of opportunities for exploration.

Students in this study have constructed perceptions of the purpose of the laboratory that result from their personal laboratory experiences, as discussed by Kathryn and John, and from interactions with the laboratory texts, as exemplified by William and Mark. In both cases, students integrated information presented to them in a laboratory context into their understanding of how they should interact with the laboratory materials to succeed. At no time did the participants in this study discuss the laboratory as a tool for learning problem solving abilities or scientific practical skills, though this is one of the direct goals for laboratory instruction according to educational researchers (Hodson, 1993; Hofstein & Lunetta, 2004; Trumper, 2003). Students in this study constructed their understanding of the purposes for the laboratory around their needs for success, and the achievement of success is defined by the grading schemes and course structure. Our data indicate that students equate success with following instructions to achieve a desired product and getting out of the laboratory on time. An outcome of students constructing their perceptions of the purpose of laboratory in this way is that they may fail to attain the instructors' implicit goals since the students do not focus their actions toward these, nor, apparently are they made aware of them.

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