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Student's objectives and achievement strategies for laborataory work

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STUDENT'S OBJECTIVES AND ACHIEVEMENT STRATEGIES FOR LABORATAORY WORK

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ABSTRACT

Owings, Taylor. M.S.. August 2014. Students' Objectives and Achievement Strategies for Chemistry Laboratory Work. Major Professor: Marcy Towns.

In this study, we look at students' objectives and strategies for completing their objectives for undergraduate labs. Students across two universities and three levels of chemistry were surveyed at the beginning of the semester in the fall of 2012 using an open ended survey to identify the goals students had for the course. The students responses were coded and used to create a survey that went out to the same courses at the end of the fall semester. Using data from the fall of 2012, the survey was modified and data was collected in the fall of 2013 at one university in two different general chemistry classes. Data and analysis indicate that students focus primarily on earning a good grade over other goals and use achievement strategies that align with this goal which aligned with the expectations of the research team as well as Edmondson and Novak (1993).

CHAPTER 1 – INTRODUCTION

A great deal of research has been conducted in the last few decades regarding laboratory research (e.g. Hofstein and Lunetta, 1982;2004, Reid and Shah, 2007, Kirschner and Meester 1988) . Hofstein and Lunetta, in their 1982 and 2004 reviews, highlighted the general themes of research leading up to each review and noted areas in which laboratory work was not meeting expectations (Hofstein and Lunetta, 1982; 2004). Their reviews suggested a numbers of areas in which the collective body of research need to look closer at ranging from the laboratory manual and involvement of argumentation in the laboratory to perceptions of the lab and different goals that faculty have for lab. Similar work has been performed in other reviews (e.g. Reid and Shah, 2007, Kirschner and Meester, 1988), and there is a continued theme across the majority of them: Lab, while there are many potential benefits, is providing limited returns. While some reviews provide guidance on the direction forward, many suggest that the issues lie with the teachers and faculty that design the labs and the nature of the labs not being open-ended enough.

A great deal of work within these reviews, and many other studies, has focused on faculty goals for lab. Bruck, Towns and Bretz (2010) most recently performed a qualitative study of faculty goals in which faculty from a number of areas and institution types were interviewed and used to evaluate the goals faculty had for students at different levels (general, organic and upper level chemistry). The findings from Bruck et al (2010) were used by Bruck and Towns (2013) to develop a survey to identify the faculty goals for the whole of the United States. This study had goals that mirrored the faculty goals across a number of other studies, which range from affective goals of enjoying lab to very technical learning goals associated with use equipment.

While these faculty goals are fairly well known and understood, Hofstein and Lunetta (2004) assert that the goals for faculty do not often align with those of the student. They state that students' perceived goals and the teachers' perceived goals are often mismatched. While the fact that student and faculty goals do not align is not of great surprise, the fact that the students perceived faculty goals and the faculty actual goals do not align may be an area that we need to look further into. In the few studies mentioned by Hofstein and Lunetta, goals based around completion and following instructions tended to be the most prolific. In this study, we proposed to look at students goals by surveying courses across two universities. We developed a survey from student responses and then analyzed the results with the objective of painting a picture of students' objectives for lab and how they go about achieving them.

This thesis will be separated into five chapters. This first chapter serves as an introduction to the study. The second is a review of the literature, which discusses the inspiration of this study presented above: the growing case of literature arguing against the need for laboratory work. The literature review will also delve into literature related to faculty goals, and finally, address literature related to student perceptions about chemistry and chemistry laboratory work.

The third chapter contains the methodology for the study. This chapter will highlight the steps taken to collect data and the adaptations made to the survey as it progressed through the two year study. This chapter will also describe the participating students, classes, and universities in which they were drawn from.

The fourth consists of survey results and analysis. This chapter will look individually at the each of the four data collection points and analyze the data. At each point, the courses, universities, and level of chemistry will be compared. The chapter will conclude with a discussion as to how goals and achievement strategies ranged across the second year of the study, both comparing individual courses at both points and all participants at both points.

The final chapter includes a conclusion and implications for moving forward. This begins by highlighting the findings of the study ranging from what goals and achievement strategies students found most important to how the goals and achievement strategies the students focused on changed across a semester of study.

CHAPTER 2 – REVIEW OF LITERATURE

Introduction

This review of literature is written with the intent of painting a picture of the common trend from the research toward practical work in the recent years. I will highlight the general consensus regarding the goals faculty for laboratory work, and show some students' perspectives for laboratory work that have been found in other studies. I also hope to highlight some of the arguments against having laboratory and practical work as a part of the curriculum as we hope to better understand students' goals for lab because recent literature has noted that there are some researchers in the field that believe that the cost and time requirements associated with laboratory work outweigh the potential learning gains. Understanding the arguments against laboratory work will also help us better frame what can be done to make laboratory more effective and useful moving forward.

The Case against Laboratory work

Reid and Shah (2007) and Millar (2004) stated that laboratory work has been a key component of the scientific curriculum for over a century. While current literature suggests that practical, laboratory, is widely used as a part of the curriculum (Reid and Shah, 2007, Hofstein and Lunetta. 1982, 2004, Johnstone and Al-Shuaili, 2001), a number of more recent studies and reviews have begun to question whether laboratory work is worth the high cost given mixed results in terms of learning gains (Hofstein Lunetta, 1982, 2004, Reid and Shah, 2007, Kirschner and Meester, 1988, Prades and Espinar, 2010).

In their review, Reid and Shah (2007) indicate that, on average, students cost the university 15 times as much as a lecture for 100 students. Now, while this figure may not paint the whole picture of laboratory and lecture costs and gains, it brings to mind the questions, are the learning gains associated with laboratory 15 times greater than lecture? Are they even equal to lecture? And if the gains are not 15 times greater than the gains for lecture time, are the gains being made essential enough to justify the higher cost? Kirshner and Meester (1988) seconded these concerns in their study saying "There appears to be an overall agreement that laboratory work at present provides a poor return of knowledge in proportion to the amount of time and effort invested by staff and students." While they did go on to say that this does not mean that laboratory work is not important, due to the fact that there are more than knowledge goals associated with the lab, but it implies that the time and resources put toward lab may not be being used to their greatest potential.

Hofstein and Lunetta, in their 1982 laboratory review, were seeing a similar trend as they stated that laboratory work, at the time, was not being efficiently used. Many labs were promoting a very narrow view of science. They suggested that this was due, at least in part, to too many of the labs being trivial at the secondary level. This was compounded by the fact that a there were a lack of teachers that were competent enough to use laboratory work effectively (Hofstein and Lunetta, 1982, Novak, 1988). Some studies have found that there was no significant difference between students who were actively engaging in laboratory work and their non-laboratory counter parts on exams (Flansburg, 1972, Kirschner and Meester, 1988, Novak, 1988). While exams are one way to assess student performance that is often used, there may be more to this than can be seen simply by comparing exam scores.

While some faculty use laboratory time as a time to connect lab and lecture, other faculty, and students, believe that the time is being used to confirm what they already know (Flansburg, 1972, Kirschner and Meester, 1988, Tsai, 1999). This brings back the notion that time spent in the laboratory can be trivial and meaningless (Hofstein and Lunetta, 1982, Kirschner and Meester, 1988, Tamir and Lunetta, 1981). Tamir and Lunetta suggest that secondary teachers and faculty prefer the more “smooth” flow of the “demonstration and verification” type laboratories. With Inquiry and Discovery labs possibly taking more time, and requiring the teacher to fall into a different, possibly more uncomfortable role, teachers and faculty may feel more at home in a more structured setting.

Due possibly in part to the demonstration and verification nature of many of the labs, it is not uncommon to see a student leave lab with little to no understanding of what they have done (e.g. Kirschner and Meester, 1988, Novak, 1988, Shepardson, 1997, Hart, et al, 2000, Edmondson and Novak, 1993, Bogden, 1977, Buchweitz, 1981, Waterman, 1982, Taylor-Robertson, 1984). This may be in part to the “cookbook” nature of many laboratories in use still to this day in classes. Cookbook labs are labs in which students are guided, step by step through a set of instructions to reach a predetermined result. This style of lab has been said to create a poor understanding of how science actually takes place (Hofstein and Lunetta 1982, 2004, von Aufschnaiter and von Aufschnaiter, 2007, Deacon and Hajek, 2011). Hofstein and Lunetta (2004) suggest that the use of cookbook style labs may be, at least in part, due to the lack of time and resources, often equipment, needed to properly do inquiry laboratory work, and while colleges have the resources and more flexibilities with schedules, they may be limited by large class sizes.

The use of cookbook style labs may be used to ease the workload on the teacher. As Tobin (1986, 1990) asserts, teachers have a lot on their mind when they implement a lab. Gallager and Tobin (1987, Tobin, 1990) suggest that teachers, in part, are preoccupied with managing the laboratory activity rather than using it as a learning opportunity where they can challenge and provide assistance as needed. Tobin (1990) suggests that we need to begin reconceptualizing the role of teacher and student in the laboratory space to being to make the most of it. While these issues may not be as prevalent as suggested by Tobin and Gallager nearly 30 years ago, we should keep them in mind as a criticism of laboratory work and give teachers the support and challenge their students. The role of the teacher and student has continued to grow as well with more emphasis being placed on student centered classrooms.

Another reason that laboratories may be lacking is that the teachers may either be unaware of the research or it may be unavailable to them. Similarly, they may not be aware that their laboratories are not to the level they should be and Tobin (1986) suggests additional feedback for teachers as a way for them to improve their practice.

Hodson (1996b) offers a similar critique in his summary of lab work. Hodson argues that lab is both overused and underused simultaneously. Hodson argues that laboratory is a place that students can learn a great deal about science given the proper environment. One key point that Hodson makes is that faculty need to be clear about what their goals and subgoals are for a given lab. von Aufschnaiter and von Aufschnaiter (2007) had similar findings in their study saying that students often miss the purpose of the laboratory activity and this is aided by laboratory manuals that can distract from the main point. Hodson argues that simply having students arrive for their laboratory and do practical work is "no longer enough". Meester and Maskill (1995) suggest that a small number of departments that give students any guidance to the learning objectives of a given lab. They also suggest this as an easy area for improvement of labs, beginning simply with a brief description in an experiment. If labs are well designed with clear learning goals, the students will take more of the material deemed most important by faculty.

While teachers spend a good deal of planning how time will be used, in terms of using objects, Abrahams and Reiss (2012) found little evidence that teachers spend time "explicitly planning how students will learn about ideas". Teachers felt that their ideas would emerge from the activity (Millar, 2004, Abrahams and Reiss, 2012, Abrahams and Millar, 2008). This may lead to one potential reason for the lack of explicit goals given by teachers and faculty about the learning objectives, because, as Abrahams and Millar (2008) suggest, practical work provides a place for observables and ideas to be connected, but these ideas do not just formulate out of thin air, they need to be introduced.

One final critique of laboratories, from Hofstein and Lunetta (2004), is that there is very little adequate practical assessment of students. Hofstein and Lunetta indicate a lack of assessment, particularly when it relates to standards, by all groups, even on high stakes testing. This lack of assessment includes not only skills and abilities, but also the purpose of laboratory activities (Hofstein and Lunetta, 2004, Prades and Espinar, 2010). Johnstone and Al-Shuaili (2001) similarly indicates assessment being an issue that needs addressed in laboratory practice. Johnstone and Al-Shuaili (2001) state that using the traditional laboratory report, we assess only a small section of the common faculty goals for a laboratory activity and that manipulative skills and ability to plan an experiment, laboratory goals listed in this paper, are particularly left not being assessed given the current model of laboratory reports.

Faculty Goals for Laboratory

Before delving into the literature surrounding student goals for laboratory, I wish to first spend time discussing the objectives that faculty believe are most important for students doing practical work based upon peer reviewed research. While certain faculty objectives varied slightly in terms of importance between levels of chemistry (Bruck and Towns, 2013, Bruck, Towns and Bretz, 2010, Bretz, Fay, 2013), institution type (Bruck and Towns, 2010, Bretz, et al, 2013), and success at grant writing (Bruck, et al, 2010, Bretz, et al, 2013), a number of goals are generally accepted as important parts of the laboratory experience.

The first goal discussed will focus around the affective part of the laboratory experience. This goal pertains to developing students' interest in not only chemistry, but in science in general (Shulman and Tamir, 1973, Anderson 1976, Bruck et. al, 2010, Bruck and Towns 2013, Hoffstein and Lunetta 1982, Hodson, 1996a, Hodson, 1993, Johnstone and Al-Shuaili, 2001). This goal centers around the idea that lab allows students to interact with the material and observe some of the more exciting parts of science. Anderson (1976, as cited by Hofstein and Lunetta, 1982) suggested that laboratory work should foster interest in science, where Shulman and Tamir (1973, as cited by Hofstein and Lunetta, 1982) added that creating and fostering curiosity in science was a goal of laboratory work. Bruck et al (2010) found that general chemistry faculty focused on this more so than other faculty, which Bretz et al (2013) noted as well saying this goal fades out in the third and fourth year of studies.

A second goal that tends to be associated with chemistry labs, again more so general chemistry than upper level, is development of general, sometimes considered transferable skills, such as teamwork (Reid and Shah, 2007, Kirshner and Meester,1988, Bruck et. al, 2010, Bruck and Towns 2013, Hodson, 1996a, Hodson 1993). Lab work, currently, is more than simply showing up and mixing chemicals. Students are asked to work in small groups to perform the laboratory. In addition to this, students are often required to complete labs within a set time period with a report or assignment often associated with a lab. As demonstrated by the studies above, faculty ackno(Shepardson, 1997)wledge that there are more skills that students can take away from laboratory work than the technical and conceptual portions. Reid and Shah (2007) and Towns and Bruck (2013), included ideas such as time management, making solid arguments in their reports, and generalizable skills that can be tied to other fields. Bruck et. al (2010) found that general chemistry professors, particularly non-successful grant writing faculty, focused in on this as a goal more so than faculty in other chemistry courses. Bruck and Towns (2013) saw similar result in terms of general chemistry faculty putting this at a higher level of importance than organic faculty, but found no difference between general and physical chemistry faculty, with physical chemistry viewing this as more of a goal than the organic faculty as well.

Another goal focused on by faculty was helping students make connections between the lecture and the laboratory (Reid and Shah, 2007, Kirshner and Meester,1988, Bruck et. al, 2010, Bruck and Towns 2013, Anderson, 1976, Hofstein and Lunetta, 1982, Hodson, 1996a, Johnstone and Al-Shuaili, 2001). As laboratory is a key part of the curriculum, some institutions try to time the labs such that the material in the lecture will line up with the material in the lab. The intention is connect the principles learned in the lectures to the lab. Bruck et al (2010) found this to be more of a focus of successful grant writing faculty teaching general chemistry courses than other groups, though Bruck and Towns (2013) did not find a significant difference between general chemistry and other levels of chemistry.

Some faculty will extend this goal from simply connecting laboratory and lecture to an opportunity to teach specific science concepts (Abrahams, 2012, Hodson 1996a). In their study, Abraham, e. al (1997) found that this was the most important goal to faculty, but Abraham (2012) found this to be the least important goal to faculty. So there is some discrepancy among studies as to how important this goal is to faculty.

A fourth common objective of faculty for the laboratory experience focused around helping students' understand and appreciate how science happens (Hofstein and Lunetta, 1982, Bruck et al, 2010, Bruck and Towns. 2013, Shulman and Tamir, 1973, Anderson 1976, Reid and Shah, 2007, Kirschner and Meester, 1988, Hodson, 1996a, Hodson,, 1993, Abraham, 2012, Johnstone and Al-Shuaili, 2001). One of the initial goals of laboratory work was to get students engaged in the scientific process. Reid and Shah

(2007), in their review, highlighted that faculty goals tended to tie back to the scientific method. While the scientific method may not be the most accurate representation of how science progresses, other reviews and research have offered similar objects in that practical work should allow students to engage in science and understand how it progress. Kirschner and Meester (1988) made a point to discuss the importance of understanding what laws and theories mean, and being able to craft a hypothesis. The study by Bruck et al (2010) found this, again, was more of a focus of the general chemistry faculty as opposed to upper level courses like Organic and other upper level chemistry faculty.

Many faculty also attribute laboratory time as a place for student to develop their skills of performing techniques and becoming comfortable with making measurements and using glassware (Hofstein and Lunetta, 1982, Bruck et al, 2010, Bruck and Towns. 2013, Shulman and Tamir, 1973, Anderson 1976, Reid and Shah, 2007, Kirschner and Meester, 1988, Hodson, 1996a, Hodson, 1993, Johnstone, 2001, Abraham, 2012, Johnstone and Al-Shuaili, 2001). Similar to the goal of understanding how science progresses, understanding how to perform the techniques associated with science is an objective agreed upon by most courses. Kirshner and Meester (1988) , in their review, stated that this could not be the sole purpose of the laboratory as it would create "Teaching laboratory skills through detailed instruction is an admirable way to train technicians, but is of little value for (the training of) scientists.". While this may be the objective of some faculty, possibly more so in the upper levels, the view by Kirshner and Meester may not reflect the opinion of faculty as a whole. Many students that come through general chemistry courses have no desire to go on and become scientists. While many faculty will hope to impart some skills to their students and help them to have a better grasp of the techniques used by trained chemists, faculty do not have the explicit objective turning every student that comes into lab into a scientist. Johnstone (2001) highlights teaching observational skills and teaching students how to design an experiment as key goals in this area.

A part of developing techniques and measurement abilities, typically more a focus of upper-level courses (Bruck et al, 2010, Bruck and Towns. 2013), centers around understanding the error associate with these measurements. In both Bruck (2010 and 2013) studies Error Analysis was not as important to Organic Chemistry faculty, but the 2010 study also did not list error analysis as a focus of general chemistry faculty. Studying error in instruments and measurements is traditionally most associated with the labs in analytical chemistry, but is covered in other courses as demonstrated in the Bruck and Towns study.

Faculty feel that lab also should allow students to develop problem solving skills as well as encourage critical thinking (Hofstein and Lunetta, 1982, Bruck et al, 2010, Bruck and Towns. 2013, Shulman and Tamir, 1973, Anderson 1976, Reid and Shah, 2007, Kirschner and Meester, 1988, Hodson, 1996a, Kirschner, Meester, Middelbeek, and Hermans, 1993, Johnstone and Al-Shuaili, 2001). As stated above, while this may be a goal for many faculty, those researchers who do not believe laboratory has a place in the science curriculum argue that we are not developing critical thinking in laboratory work. Studies have shown that students put little thought into laboratory work (Bogden, 1977; Buchweitz, 1981; Waterman, 1982, Edmondson and Novak, 1993) , particularly when the lab is laid out in a “cookbook” style as noted above. A push towards more inquiry based laboratory activities where students are asked to design the experiment or laboratory activities in which students are asked to apply their knowledge from lecture to a lab to solve a problem are movements that allow for more critical thinking and problem solving from the students towards the activity. While not every

A goal, similar to error analysis, which tends to be emphasized more in non-general chemistry classes, is the development of writing skills (Bruck et al, 2010, Bruck and Towns. 2013, Reid and Shah, 2007, Kirschner and Meester, 1988). Students in general chemistry are not typically required to write long laboratory reports, so that tended not to be a focus of the faculty in the study by Bruck and Towns (2013). Bruck and Towns found that general chemistry faculty's response was significantly lower than the faculty of the other courses surveyed. Bruck et al (2010) found similar results, but saw the focus on lab writing focused mainly in the courses taught by organic faculty, and less so in other upper level courses.

One last objective for lab, which some faculty found of importance, was to get students involved in research (Bruck and Towns 2013). This goal was focused around a few different ideas in the paper by Bruck and Towns (2013). One thought behind this objective, that faculty had, was related to preparing students to do research at the next level. Another possible link for this could revolve around helping see how science is done in the real world, with this referring to in non-school situations. The final way that this was tied in the paper by Bruck and Towns was related to having students conduct labs that mimicked research experiences. Looking at this goal as a whole, Bruck and Towns found that this goal tended to be favored significantly less by general chemistry faculty as compared to the faculty in the Organic and Upper level courses.

Student Perceptions of Laboratory Work

While faculty goals have been studied in great depth, the objectives of students for the laboratory period have not been studied as extensively. Hofstein and Lunetta (2004) suggest that researchers have not looked as in depth into the affective domain and how different affective factors can affect their laboratory experience despite the literature in science education stressing the importance of laboratory work on the curriculum.

Deacon and Hajek (2011) developed a study that investigated student perceptions on what students thought were the biggest factors in their success in a chemistry lab. Their findings indicated that the biggest factors that affect their success in lab were their preparedness coming to lab, the laboratory information sheet, the helpfulness of the Teaching Assistant, and finally and most importantly adequate time to complete both the experiment and the report.

How students perceive lab may be tied in part to the career path of the student (Hofstein, Gluzman, Ben-Zvi, and Samual, 1980). While the laboratory experience itself may not be different for science and non-science majors, how the students perceive the experience or what they take from it may be different. Hofstein et al (1980) found that the students not intending on studying science found the laboratory environment much less satisfying and less goal directed than their science oriented peers. On top of feeling more satisfied with the practical experience and feeling it was more goal oriented, the science students also found that the laboratory work was harder than their peers. This piece suggests that students are very cognizant of the learning environment that they are placed in and how it compares to their peers. Similarly, this suggests that students are not deterred by a more difficult course if the environment created is more satisfying and is well directed with clear goals.

While the perceptions of science and non-science students were found to be different by Hofstein et al (1980), this may be due, at least in part, to self efficacy. For the purpose of this literature review, I will use self efficacy as it was defined by the Generalized Self Efficacy Scale created by Schwarzer & Jerusalem (1995) based on the work of Schwarzer (1992) which looks at self-efficacy as " the belief that one can perform a novel or difficult tasks, or cope with adversity -- in various domains of human functioning." Reardon, Traverse, Freakes, Gibbs, and Rhode (2010) found in their study that the biggest factor contributing to course perceptions was the students' generalized self-efficacy. In this study, Reardon, et al distinguished between generalized self-efficacy and content specific self-efficacy. Generalized self-efficacy, in this study, accounted for 19 percent of the variability with no other variable contributing more than 4 percent. Similarly, a students' self-efficacy and perceived level of control over their academic performance in the class had significant differences in students' outcomes in an organic chemistry course (Lynch and Trujillo, 2011) with males generally having higher self-efficacy and perceived control in the class (Lynch and Turjillo, 2011).

There is often a disconnect between faculty goals and students goals or what student's perceive are the goals of the faculty (Hofstein and Lunetta, 2004). Tasker (1981, as cited by Hodson 1993) highlights that this disconnect happens on multiple levels. Tasker suggests that students' mindset is that lessons are isolated events and that there is very little connection between one lesson and another. This aligns well with the idea that students don't connect lab and lecture that was stated above.

Gifted students in a Taiwan secondary school showed a few preferences when surveyed using the Chemistry Laboratory Environment Inventory (Lang, Wang, and Frazer, 2005). The students reported a preference more open-ended laboratory sessions, and having a laboratory that was well stocked with equipment was also preferred by the students. Frazier, McRobbie, and Giddings (1993) found, using their SLEI instrument, that the students' perceptions of the learning environments accounted for greatly varied learning among the students (Hofstein and Lunetta, 2004).

Similarly, students' view of science has an impact on how they perceive laboratory activities. Tsai (1999) showed that students' view of science not only relates to how they interact with other students and perceive the laboratory experiment, but also found that it has an impact on student performance. Students with more of a constructivist view of laboratory work tended to discuss the meaning involved in their laboratory work more often than their peers with a more empirical view of science. The study found that the students with more constructivist views of science were more focused on, and discussed more, the concepts involved in the laboratory activity than their empirical view peers.

Tsai, in their study (1999), implied that the nature of the laboratory environment, inquiry or a "cook book" style, may cause epistemological struggles for students who view the nature of science from a more constructivist view as confirming a known result conflicts with their more open-ended view of science.

Faculty do not make the purpose of the lab clear (Tasker 1981, Hofstein and Lunetta, 2004) which may lead to students having a different purpose for the lab, often one more focused around completion or getting the correct answer, rather than the purpose associated to the laboratory activity by the faculty (Tasker, 1981). Likewise, the perceived importance of outcomes for the students are often not the same as the faculty (Tasker, 1981).

While students' perceived goals may not align fully with faculty (Wilkinson and Ward, 1997), Boud, Dunn, Kennedy, and Thorley (1980), found that student goals often align fairly closely with graduates and practicing scientists. In their study, the found that students felt the five most important goals for practical work should be "to be trained in making deductions from measurements", "familiarize themselves with techniques", "to learn basic practical skills" (all of which aligned with graduates and practicing faculty), "to illustrate material from lecture", and "to help bridge theory and practice". Similarly, students felt that the five least important goals for practical work should be "to simulate conditions of an R&D laboratory", "to train students in keeping a day to day diary", "to teach theoretical material not covered in lectures" (all of which aligned with graduates and practicing faculty), "to develop problem solving in a multi-solution situation" and "to show use of practicals as a process of discovery". Students in this study also found all laboratory goals to be more important than faculty felt they should be. The study by Wilkinson and Ward (1997) found student and faculty did agree on some objectives with the goals "To prepare students for examinations," "to give practice at following a set o f instructions," and "`to make science more interesting and enjoyable through actual experience".

Summary

As we look at the body of literature, a case has been made by a number of researchers that laboratory work is not being used to its full potential. Faculty report emphasizing a number of goals ranging from laboratory (techniques and writing) and course specific (teaching concepts) goals to more affective (developing interest) and transferable skills (team work), but there is little literature available that details what students find important in laboratory work. Given Hofstein and Lunetta (2004) noting in their review that one factor that may be detracting from laboratory work is the fact that there is a disconnect between faculty and student perceptions on lab. This study hopes to fill this gap by creating a survey to look at students' goals for lab and what achievement strategies they employ to accomplish said goals.

Research Questions

The following study was based upon these research questions.

- What are undergraduate students' goals pertaining to lab?
- How do undergraduate students go about accomplishing these goals?
- How do student's goals and achievement strategies change over the course of a semester?
- How do the undergraduate students goals compare to the faculty goals found in the literature?

CHAPTER THREE - METHODOLOGY

Introduction

This chapter will highlight the methods used to develop the final survey and the analysis that was performed on the data collected using the survey. All statistical analysis was performed using SPSS software ® (IBM, 2012) and qualitative analysis was performed using Atlas TI ® (Dowling, 2008). This survey was developed using student responses and was reevaluated after each round of administering.

Data for this study were collected over an 18-month-period at two universities both via electronic and pencil and paper survey methods. Data was collected across the two universities and three levels of chemistry in the first year of the study. In the second year, data was collected at one university in two different general chemistry courses. The survey did not ask for any identifying information from the students with the exception of which class they were enrolled in. This was done so that students wouldn't have to worry about any repercussions of their professors seeing the responses. Professors were not shown any of the results during the course of the semester.

Year 1- Participants

Participants in the first year of the study came from two Midwestern universities. The first university was a large research-intensive institution. The students surveyed consisted of science and engineering majors. Two universities, rather than one, were used with the objective of gathering data from different populations. We did not come in with expectations of differences existing or not, but, rather, we wanted to find what the goals of students were for chemistry laboratory work

Students were selected from three courses during the fall semester of the school year at the large Midwestern research institution. The first class was designed for engineering and non-chemistry science majors and consisted of mostly engineering students. The class includes around 2,000 students each fall. Students have two required one hour lectures per week, one three hour laboratory period and a fifty recitation period per week. There was an attendance policy in place for laboratory that required students attend a minimum of 75% of labs during the semester. The second class surveyed was a course for students majoring in chemistry. This class generally has around 100 students per fall semester and like the engineering course consists of two one-hour lectures per week, one three hour laboratory period, and a fifty minute recitation per week. The final class at the large research institution was a senior level physical chemistry laboratory course. This course contains students from engineering fields and typically has around 50 students per fall semester.

Data was collected in two different courses at the smaller Midwestern highly research active liberal arts institution. The smaller Midwestern institution has one general chemistry course in which all science majors enroll in. Students enrolled in the course had to specify, during enrollment, if they were taking the class as a major or as an honors student. The class consisted of lecture, recitation and laboratory components. The other class surveyed at the small Midwestern institution was a course for organic chemistry students. The organic course consisted of a one hour and fifty minute laboratory with a fifty minute pre lab once per week as well as lectures. The lectures at the smaller Midwestern institution were a separate course from the laboratory component with students receiving separate grades for lecture and laboratory work.

Year 1 - Data Collection and Analysis

The first semester data was collected at a large Midwestern Research Institution and a small Midwestern research institution. Students were surveyed in all general chemistry courses for science and engineering students at both universities. Students enrolled in organic chemistry at the small Midwestern research institution and physical chemistry at the large Midwestern research institution. Students were surveyed twice over the course of the semester, the first week and the final week.

In the first week of the semester, students at both institutions were asked to complete electronic surveys consisting of 2 questions, "What are your goals for lab?" and "How do you plan on accomplishing these goals?". The survey was left open for one week for all classes. The physical chemistry class was sent the link to the survey a second time and the link was left open for an extra week due to low response rate.

Data Analysis

The data was open coded using a grounded theory approach (Strauss and Corbin, 1990). All student responses were coded in classes with under 100 responses, and 10% of data was randomly selected and coded for classes with more than 500 responses. The researcher would look at a statement from the survey and attach fitting codes to the statements. Statements could have multiple codes if the student mentioned multiple goals or achievement strategies in the statement. One example would be the following statement: "To learn chemistry in a way that is going to help me later in my job." This statement would have codes of *learn in reference to chemistry* and *also connect chemistry to a future job*. The codes were grouped thematically to determine if any themes were present in the data. Codes that were very similar in nature, for example *to earn an A*, *to earn a good grade*, and *pass the class* were the first grouped together. From there, codes were condensed into themes until there were no more codes that could be grouped. This process was an iterative process with the intent of insuring each theme represented the codes. For both the goals and achievement strategies, a group of miscellaneous codes were left without a group. Examples of themes that arose from the goals were themes such as "grade-oriented goals", "lab skills goals" and "safety goals".

Inter-rater Reliability

A subset of responses was coded by two other coders. Each person reviewed the subset of data, 19 survey responses, individually and was given a list of all of the codes used when coding the whole set. After each person had coded the subset, the initial codes were compared and discussed. The initial inter-rater reliability was found to be exactly 80%. For the sections of text that we did not initially agree, the coders and the researcher discussed the discrepancies until agreement was reached. The inter-rater reliability reached a final agreement of 99% as the coders and the researcher could not reach an agreement on one statement.

Creation of Survey for the End of the Semester

The codes and themes from the beginning of the semester data was then used to create the end of semester survey. To select the statements that were included in the survey, codes with high numbers of responses, for example "to earn an A or B" as a goal and "to work hard" as an achievement strategy, were first included in the survey. Other statements included were codes that were similar to responses to the faculty goals survey from Bruck et al. (2010), for example "to develop my lab writing". Lastly goals codes that required further exploration were also included in the survey to help better understand the students goals were for the survey, for example "to be efficient in lab". The researchers attempted to make sure all of the major themes were represented in this initial list of goals statements. The statements were reviewed by the research team and reduced down to the final number of 36. A similar strategy was used in the development of the achievement statements. Due to far fewer themes arising in the achievement section, each theme was more represented than in the goals portion. The final list of achievement statements consisted of 24 statements.

For each of the goals statements, students were asked 2 yes-no questions, "Was this a goal for you in August" and "Is this happening?". One of the 36 statements was a reading check statement to determine if the students were reading the survey. Data was coded into 1 of 4 possible combinations of yes-no responses, with yes-yes being a 1, and no-no being a 4. The overall responses of each student were calculated by summing all of the responses each student gave. Student responses for each statement were counted using SPSS software. The SPSS software was used then to create graphs of the counts and overall responses for the entire data set and for each university. McNemar's Chi-

Squared test (McNemar, 1947) was used to determine if the number of students moving from a yes response in the beginning of the semester to a no response at the end of the semester was the same as students moving in the opposite direction. McNemar's Chi-Squared statistic was calculated for each of the goals statements. Factor Analysis was also run on this data set to determine if any factors existed in the student responses.

The achievement statements were four point Likert response ranging from Strongly agree to strongly disagree. For the 24 statements, students were asked to respond to the level in which they agreed with the statements on whether or not they were doing the stated achievement strategy. One of the 24 statements included was a reading check statement to ensure that students were reading the survey, and 4 of the statements were worded in a negative fashion, again to ensure students were reading the survey as they completed it. Likert responses were coded on a 1 to 4, with 1 being strongly agree and 4 being strongly disagree. Responses to the negative responses were recoded by the researcher so that the responses aligned with the scales for the other responses. An overall score was calculated for each student by summing a student's response for each individual statement. Histograms were created for the overall score and individual statements using SSPS. Overall responses and responses for each individual statement were compared using both t and Mann-Whitney U test statistics. Likewise, a Wilcoxon signed rank test was used to determine if each individual question had a different median response than the overall median. Percentage of responses that showed agreement with each statement were calculated by the researchers as well as the number of responses in agreement with each statement that strongly agreed with the statement, rather than just agreed, and strongly disagreed with a statement, rather than just disagreed, were calculated.

The survey was again administered at both the large Midwestern research institution and the small Midwestern research institution. The survey was again administered to the large Midwestern research institution as an electronic survey in the general chemistry courses and the physical chemistry course. At the small Midwestern institution, the survey was administered by pencil and paper during the class period in both general chemistry and organic chemistry.

Year 1 – Analysis of Data

Data from the year one's survey was analyzed and used to create a new version for implementation. For the goals statements, statements that were deemed too similar, too vague, or that lacked variability were removed from the statement list. Twenty-two statements, including a reading check statement remained in the survey for the second year of the study. The question format was changed from asking if the statement was a goal for each student, the students were asked to respond to a five point importance likert scale for each statement.

The change in format was due to limited variability and the large number of the students did not respond correctly to the reading check question in the initial survey. Switching from the yes-no format to the importance format not only gave students more options to respond to, which in turn increased the variability of the responses, but also decreased the number of students simply clicking the same response for every statement and subsequently failing the reading check question.

For the achievement statements, statements that were deemed too similar and statements which had over 90% respondents answer the question the same way were removed as they did not provide any new information. Only 10 of the 24 achievement strategies remained for year 2 of the study and there was no reading check. One question, “not working hard”, remained in the negative form of the statement, with the other 9 positive wording.

Each of the following statements pertains to a learning goal for laboratory. Please indicate the importance of each goal to your learning as you complete experiments. The scale ranges from "Extremely Important" to "Not at all Important"

		Extremely Important (A)	Somewhat Important (B)	Neutral (C)	Not Very Important (D)	Not at all Importa nt (E)
1	To earn an A or B.					
2	To prepare for the career I want to pursue.					
3	To develop my lab writing skills.					
4	To learn how to carry out experiments.					
5	To develop lab skills.					
6	To make connections between lab and the real world.					
7	To learn how research is done.					
8	To become more comfortable with lab techniques.					
9	To be efficient in lab.					

Figure 3.1: Final version of the Goals and Analysis Survey

10	To connect chemistry to my major.
11	To enjoy chemistry more.
12	To connect lecture material with thelabs.
13	Please select "Somewhat Important" (B). if you are still reading
14	To apply concepts learned to problemsin the lab.
15	To better understand what a chemist does.
16	To gain lab experience.
17	To be more comfortable with glassware.
18	To learn about chemical reactions.
19	To work as a team.
20	To learn error analysis procedures/calculations.
21	To learn how to design experiments.

Figure 3.1: continued

Please indicate the level to which you agree with the following statements in terms of how you will go about accomplishing your goals in lab

		Strong Agree (A)	Agree (B)	Neither Agree or Disagree (C)	Disa gree (D)	Strongly Disagree (E)
22	I will not procrastinate.					
23	I will work hard.					
24	I will seek out help.					
25	I will analyze data.					
26	I will take detailed observations.					
27	I will not manage my time.					
28	I will come to lab prepared.					
29	I will discuss lab after class.					
30	I will finish lab as quickly as I can.					
31	I will analyze what I am doing.					
32	I will read the lab before my laboratory period.					

Figure 3.1: continued

Year 2- Participants

The data collection took place solely at the large Midwestern research institution in the second year of the study. Given the low response rate from the upper division courses and the small sample sizes at the small Midwestern institution, we focused the study more on two large general chemistry courses at the large Midwestern research institution which allowed us to see how the survey worked in larger populations and gain a focused understanding of the goals and achievement strategies that non-chemistry majors have for laboratory work. The two courses surveyed were slightly different based on the background of the student and type of student that generally enrolls in the class, the first was designed for engineering and non-chemistry science majors from year one of the study, and the second consisting primarily of agriculture and health and human science majors. The class for engineers and science majors consists of around 2,000 students each fall. Students have two required one hour lectures per week, one three hour laboratory period and one required one hour recitation period per week. The class for agriculture and health and human science students consists of around 850 students each fall. Students have two required one hour lectures per week, one three hour laboratory period and one one hour recitation period per week. Both classes have a minimum attendance policy in which students are required to attend a minimum of 75% of the labs over the course over the semester or they fail the course.

Year 2 - Data Collection and Analysis

The survey was administered during the second week and the final week of the semester in two general chemistry courses, one primarily for engineering and non-chemistry science majors and one designed for agriculture and health and human science (HHS) students. The survey was administered electronically in the class for the engineers and collected via pencil and paper during lab time in the class for the agriculture and HHS students. For the electronic survey, the survey was left open for one week. Students who did not respond to 90% of the questions in a section had their data removed from that section and students who did not answer the reading check correctly were removed from the study entirely.

Analysis was performed first on the beginning and end of semester data separately, they were then compared. When looking either at the beginning or end of the semester, means and standard deviations were calculated for each statement. A Chronbach's alpha coefficient (Chronbach, 1951) was calculated for both the goals and analysis portions of the survey to determine if the survey had internal consistency. An overall score was calculated for each student similarly to what was done in year one of the study. Using the overall scores of all the students in the data set, Levene's test for inequality (Levene, 1960) was used to determine whether the data was normal for use in further statistics. If the data is normal, parametric statistics (i.e. t-test, ANOVA) can be used in analysis, if the data is found to be non- normal, the corresponding nonparametric statistics must be use (i.e. Wilcoxon Sign Rank test (Pratt,1959, Wilcoxon, 1945), etc…). Median and mean scores for each statement were compared for both the goals and achievement statements separately using Wilcoxon signed rank test and a Z test depending on whether the data was normal or non-normal. Similarly to the data from year one, the two courses were compared to determine if an difference existed between the two different courses. Likewise, each individual statement was compared between the two courses using a t-test or Mann-Whitney U, depending on whether or not the data was determined to be normal by Levene's test for equalities.

When comparing the beginning and end of the semester, the overall score means for both the goals and achievement statements were compared using a t-test or Mann-Whitney U test to determine if students' perceptions changed over the course of the semester. These comparisons took place for both the chemistry for engineers and the chemistry from the agriculture and health and human science students. Differences were calculated over the course of the semester for each individual statement using Mann-Whitney U tests to determine if students perceived importance or agreement with a statement changed over the course of semester. The direction of the shift was found for each statement as well, regardless of whether the shift was significant or not.

CHAPTER 4 - RESULTS AND ANALYSIS

Year 1 – Beginning of Semester

Students were surveyed at the 2 institutions at the beginning of the fall semester. The survey administered electronically at both institutions and was left open for one week for all classes, with the exception of the physical chemistry class at the large Midwestern research institution which was left open for an extra week due to the low initial response rate. Student responses from each class are displayed in table 4.1 and 4.2 below. The survey consisted of two questions, what are your goals for your laboratory course and how do you plan on achieving those goals.

Table 4.1: Year 1, beginning of semester student responses from Large Midwestern research institution

Course	Number of responses
Gen Chem for engineers and science majors	734
Gen Chem for majors	43
Physical chem. for engineers	10

Table 4.2: Year 1, beginning of semester student responses from small Midwestern research institution

Course	Number of responses
Gen Chem	84
Gen Chem for majors	16
Honors Gen Chem	4
Organic Chem	34

Student Goals

For the question about student goals several themes emerged from the data. The most frequently appearing goals students listed for the lab course were grade-oriented . Students frequently reported goals of “getting an A or B”, “passing the course”, or “surviving the course”. Another common theme that came from the data was that students wanted to learn. A handful of students mentioned learning in general, but most students tied the learning back to either lab or lecture material. Several different course concepts were mentioned ranging from Organic Chemistry (mentioned in response from both General and Organic students) to thermochemistry or reactions. Students also talked about learning in the lab. These responses ranged from making connections between lab and lecture, learning hands on, developing lab writing skills, and most frequently learning lab skills such as how to use glassware and laboratory techniques.

Students also tended to make references to connecting this current course to other areas, including areas in the future, such as career or future course goals. Students had goals of connecting lab to lecture, the “real world”, other courses they are enrolled in or ones they hope to enroll in the future, and their future career. The number of students who mentioned making connections was far fewer than learning or grade-oriented goals, but still saw a fair number of students mention them.

Two other major themes emerged from the data, an affective goals theme and a safety theme, but both had a limited number of responses. The affective responses referred to building self-confidence, enjoyment of chemistry, and increasing interest in the subject among other responses. The safety responses tended to be towards learning proper safety procedures and students hoping to do no harm to themselves throughout the course of the semester. Finally, a miscellaneous category was created for the remaining data. This was filled with codes that didn't fit into other categories.

As stated above, several themes appeared throughout the goals data. The largest number of responses were for grade-oriented goals. This indicates that student's primary objective is likely to perform well in terms of the letter grade that they receive. Students also tended to focus on learning in their goals, which is positive for the both the teachers and university as students do have learning goals for their time spent in lab, but these goals tended to focus more on what the author would consider the lecture portion of the course. Students said they hoped to learn things like "Course Material" or a more general "Chemistry" or would mention specific concepts like "Thermodynamics", "Organic Chemistry", or "Chemical Reactions". While it is promising that students have learning as an objective for chemistry lab, these students statements focus more on the lecture material than specific laboratory techniques.

Many students did also list lab related learning goals on top of the course learning goals. The majority of these focused on students wanting to learn laboratory skills, which was very promising in regards of the usefulness of laboratory work, but there were only

40 occurrences of this code across the data set, so only a small subset of the students deemed this important enough to list as an objective prior to beginning the course. Other students listed that they hoped to use the laboratory to do some “hands-on” learning. Similar to the goal of “learning lab skills”, there well only a limited number of students who listed this as a goals seeing only 12 students listed “learning lab skills” as a goal in. Only 7 students made note of learning how to properly take notes or write in the laboratory setting. One promising observation was that only one student made mention of focusing on efficiency in the lab.

Two other major themes to come out of the data was students focused on connecting laboratory to courses and their major, and goals related to using laboratory time towards preparing for the future. These two themes are similar in that the goal is evidence that students are thinking outside of this individual course. Eighteen and sixteen students responded that they wanted to prepare themselves for future courses and a future career, respectively. Thirty-six students cited wanting to connect lab to the material that they were learning in lecture which was also very promising as it aligned with a common faculty goal (Reid and Shah, 2007, Kirshner and Meester,1988, Bruck et. al, 2010, Bruck and Towns 2013, Anderson, 1976, Hofstein and Lunetta, 1982, Hodson, 1996a, Johnstone and Al-Shuaili, 2001). Other responses in both themes saw 10 or less responses, though some connections mentioned were to connecting chemistry to other fields like Biology, or their major. In addition to those 5 students did mention that one of their goals was to connect chemistry to “real life” or the “real world”. Again all of these codes show some students are thinking outside of this particular course, which is something as educators we hope students are trying to accomplish in our courses.

The last theme to come out of the open ended beginning of the semester courses was a grouping of affective responses. These tended to be ideas like “building confidence”, “have fun”, and “enjoy chemistry (more)”. All of the codes in this theme had very low response rates, but the theme shows that some students had non-academic goals for their chemistry courses. Similarly, a handful of miscellaneous codes were found that did not fit into any theme, they were codes that did not fit into a specific theme, and most did not have a very high number of instances.

Student Achievement Strategies

Two major themes arose from the question regarding how students planned to accomplish their goals for chemistry lab. The first, and more frequent, of these was students listing what the author would consider good student practices. These responses included achievement strategies like “reading the textbook,” “Attending lecture,” “Going to office hours,” “Seeking out extra help if needed”, “read assigned readings,” “Ask questions,” and finally “Studying”. The second major theme to come out of the achievement portion of the survey was the idea that students would use good laboratory practices. These included things like attending lab (on time), following instructions, reading the lab manual, and coming to lab prepared. A few other miscellaneous codes came out of the data, but none had very high frequencies.

Only two primary themes arose from the data in terms of strategies students planned to use for students to accomplish their goals. Considering the largest theme to arise from the student goals were grade-oriented goals, it was not a surprise that many of the students focused on achievement strategies that would generally boost their performance, measured as grades, in the course. The first, and larger, theme to come out of the data was one of good student practices. These included achievement strategies that professors, in general, hope that there students will do. Many of these were things like, "attending lecture", "studying", "working hard", and "doing homework". While these are all things that professors generally hope that their students are doing, they do not apply directly to laboratory work. This, along with the focus on grades in the goals portion of the survey may imply that students focus on lecture more so than laboratory, and that they may see lab as only a part of lecture and not as a separate entity for which they should have specific learning goals.

The second major theme to arise from the data was students having good laboratory practices. Some of these are similar to things in the good student practices, i.e. "turning in pre lab work" and "attending lab", but there was a focus on other areas of having what the author would deem good laboratory practices. Some of those included safety related goals, "coming prepared to lab", "keeping good data", "discussing lab after class", and "engaging in the lab". These are all promising things we hope to see from students in lab, but the most frequency of these achievement strategies was far less than the frequency of students responding with codes from the other primary them.

As with the goals statements there were a few miscellaneous codes that did not fit into anyone one theme, these included things like working efficiently, focusing, and being prepared in general. These codes all had 6 or less responses so very few students put a large emphasis on them.

Year 1 – End of Semester

The students at both universities were surveyed again at the end of the fall semester after the completion of their final laboratory. Students at the large Midwestern research institution were surveyed again electronically, and the students at the small Midwestern research institution were surveyed via pencil and paper during their final laboratory period. Students were given a list of goals and asked to respond yes or no to two questions regarding each statement, "was this a goal?" and "are you accomplishing it".

Student Goals

The majority of students at the large Midwestern research institution did not answer the reading check question correctly, so that data was removed from the study due to the inability to determine if the students were actually reading the survey and filling it out meaningfully. The resulting data set had 226 students respond all from the small Midwestern research institution. The survey had a Chronbach's alpha value of .92 which is well above the accepted value of 0.70 needed for a reliable instrument. On average 133 participants responded yes to both questions "Was this a goal?" and "Are you accomplishing it?". McNemar's test was run on all of the statements to determine which showed a statistically significant shift from a yes-no response to a no-yes response and the reverse. Results are shown in the appendix. Due to limited variability in the data, Factor analysis was not performed as most students responded yes-yes to questions.

Due to the limited variability, there was limited analysis that could be performed on this data. McNemar's test, a test similar to Chi Squared analysis that required data fall into a 2x2 table., was used to determine if the students who changed their opinion of a statement as a goal, from yes at the beginning of the semester to no at the end of the semester or the reverse, did so in one direction or the other. 22 of the 37 goals statements showed a significant difference in counts from the students report beliefs at the beginning and of the semester. As stated above, the majority of responses from students showed no change in an item being a goal at the beginning of the semester versus the end of the semester. The McNemar test is looking solely at the students who did report a change in something being a goal or not a goal.

The goals statements that showed a shift from it being a goal prior to the semester to not being a goal at the end of the semester showed results. Students who aimed to get an A or B in the course showed the largest shift in this direction ($\chi^2 = 96$) which wasn't as a surprise as very few students aimed to not perform well in the course, but many found by the end of the semester that an A or B may not be attainable. Other goals that showed a significant shift in this direction were "pass the course", "to prepare for the career I hope to pursue", and "to enjoy chemistry more". The shift in this direction for "pass the course" is not a surprise when using the same logic that was applied to "earning an A or B". It does lend validity to the idea that students goals toward grade-oriented issues shift from being a goal at the beginning of the semester to being a lesser priority at the end of the semester, which is a promising finding for those who hope that their students are taking more away from their chemistry laboratory experience than a letter grade.

For the goals "to prepare for the career I hope to pursue" and "to enjoy chemistry more, the shift may be slightly harder to explain. For some students, they may arrive in lab hoping that it will be the "fun" part of the class. If this is the case, the laboratory experiments are not as exciting as they hoped coming in. That may not be a large surprise as professors surveyed in Bruck et al. (2010) did not cite entertaining students as a primary objective professors have for any chemistry course. Likewise, students may have been dissatisfied by the lab because they expected the laboratory experience to relate more closely to their future career than it did in actuality. Some of this may be attributed to individuals who had a change of heart about the direction they hope to go with their major, but this could also be that the labs do not relate closely enough with the "consumers" fields of study. That is to say, the labs may not be targeted at things the students in the course are studying.

Lastly for significant shifts from being a goal to not accomplishing it, the statement "to become a better chemistry student" showed a significant shift ($\chi^2 = 8.00$, p = .005) in this direction. This is a troubling shift because students do not feel that they are becoming a better chemistry student as a result of attending lab. Now, this may be a result of the wording of the statement, but, this shift is not one that should lend to professors feeling that chemistry lab is being utilized to its full potential. Students who showed a shift in their feelings toward the statement felt they were not better at chemistry for being in lab which is something that should be addressed if the chemistry community still values lab as an integral part of the chemistry curriculum (Kirschner and Meester, 1988).

For the statements that showed a significant shift from not being a goal prior to the semester to being a goal at the end of the semester, some very promising trends came out of the data. Three of the four most significant shifts were lab related statements that students now felt that they were taking away from the lab. The goals "to become comfortable with glassware" ($\chi^2 = 74.71$), "to develop lab skills" ($\chi^2 = 16.333$), "to develop lab writing skills" ($\chi^2 = 63.22$), "to learn error analysis" ($\chi^2 = 49.47$) and "to learn safe lab practices" ($\chi^2 = 71.73$) all had p values less than 0.001. In addition to this, the statement "to gain lab experience" ($\chi^2 = 8.04$, $p = .004$) also showed a significant shift from not being a goal to being something the students felt they accomplished. This may show that students, while not initially coming in with this goal, are realizing that these are important skills and ideas to take away from the lab. This paired with the shift away from grade-oriented goals may show that students may be valuing the skills and information more so than just the letter grade by the completion of the course. This may also be an indication that students are not aware coming into lab of what they are supposed to be taking away from the lab, if this is the case, professors may need to be more explicit from the beginning of the semester that the purpose of lab is to develop skills like using glassware, performing error analysis, and learning lab writing skills, particularly in classes predominantly filled with students who are planning to continue forward in the Science and related fields.

Another goal that showed a significant shift from a non-goal to a goal students felt they accomplished was "working as a team". This was one of the things that the general chemistry professors cited as a goal for general chemistry in the study by Bruck et al. (2010). It is interesting that 68 students did not feel that this was a goal prior to the semester, but this again may be something that professors need to focus on being more explicit about it being an key part of laboratory work.

Similarly to the shift in "working as a team", a significant shift was seen in this direction for students meeting people in lab. This was one of our affective statements, but 88 students had not intended on meeting people in their laboratory course and found that they did in fact meet people. This would lend itself to the idea that students do not expect to be working in teams with other students as a part of their laboratory work.

Student Achievement Strategies

Most students from both institutions answered the reading check question correctly for this portion of the survey, so the data was viable for analysis. The Chronbach's alpha for the achievement portion is 0.87 which is above the accepted value in of 0.7. The two universities were found to be significantly different on their overall score of achievement responses ($t = -13.061$, $p<0.001$) with the Large Midwestern research institution students having a lower overall score which means that they showed an overall higher agreement with the statements than the students at the small Midwestern research institution. Over 90% of the students responded either strongly agree or agree with 17 of the 29 statements in this section of the survey. The fewest number of students showed agreement with the statements "I did not procrastinate", "I finished lab as quickly as possible", and "I discussed lab after class," though significantly more students at the small Midwestern research institution discussed lab after class than at the large Midwestern research institution. "I did extra problems" was the least used achievement strategy at both institutions. Significant differences were found for each statement individually and median values for each statement were compared and can be seen reported in the appendices.

The achievement goals were counted based on the number of students strongly agreed and agreed to statements. 90% of students responded that they either strongly agreed or agreed to 17 of the 29 statements. This again shows very limited variability within the data set so factor analysis was not possible. The students at the two institutions were found to have responded to the statements as a whole significantly differently ($t = -13.061$, $p < .001$).

A number of individual statements showed significant differences between the universities. Students did not show significant changes on “Did not work hard”, “Did not study”, “Took detailed observations”, “Did extra problems”, “Attended lab”, “Came prepared to lab”, “Worked in groups”, “Took my time”, and “Followed directions in the lab manual”. This trend shows that the achievement practices that are required, or not required, by the course tended to show no difference between the institutions. The affective achievement practices tended to show more differences. The largest differences between institutions were seen on “Paying attention to detail” and “Finishing lab quickly”. For both of these achievement statements, the research university showed less agreement with the statement than large research institution.

While a significant difference was not found in “Did not work hard”, a significant difference was found in the pair question “Did work hard” ($U = 1.962$, $p = .054$). Likewise, the paired questions had significantly different responses ($t = 10.19$, $p < .001$). Despite these to questions being consecutive on the survey, the difference could suggest that this portion of the instrument lacked some reliability due to the different responses from the achievement strategies.

Students showed the least agreement with the statement “Did extra problems” with the most students disagreeing with that statement. This goes along with a lower agreement by students with “Discussing lab after class”, though the students at the large research institution showed statistically less agreement than those students at the small midwestern institution. Required parts of lab such as attendance and turning in pre laboratory work showed high percentages of students agreeing with the statements, which should be expected seeing as these are a required part of the course and not doing them would impact their goal of performing well in the course. All of the student achievement statements except “Sought out help” and “Read assigned readings” had different median positions than the overall median for the data set.

Year 2- Beginning of Semester- Student Goals

At the beginning of year two, the updated version of the survey was used for data collection. Nine hundred and four students completed the survey at the beginning the semester. Eight hundred of the students were from the Chemistry for HHS and Agriculture students with the other 104 coming from the chemistry for engineers. The mean score was 41.60 for the sum of the goal responses ($\sigma = 12.051$). The survey was determined to have internal consistency by a Chronbach’s α of .931. Using Levene’s Test for inequality, the distribution (Figure 1 below) of the data was determined to be non-normal ($F = 20.044$, $p < .001$) so non-parametric statistics were used for the remained of the analysis.

It was determined that the two courses were not significantly different ($U = .393$, $p = .964$). Mann Whitney U tests were then run on each individual question to determine if difference existed between the 2 courses. Specific individual question means and differences are presented in Table 4.3 below, the complete table can be found in the appendix. The median responses were then compared to the median response of the average response score, those results can be seen in the appendix as well.

Table 4.3: Year 2 Goal Statement Results. Mann Whitney U results * = $p < 0.10$, ** = $p < .05$, *** = $p < .01$.

Statement	Ag/HHS	Engineer
To get an A or B	1.10	1.11
To prepare for the career I want to pursue.	1.69	1.67
To connect lecture material with the labs. ***	1.73	2.00
To be efficient in lab. ***	1.72	2.12
To work as a team. **	1.77	1.97
To learn how to design experiments	2.13	1.93
To develop my lab writing skills.	2.26	2.23
To enjoy chemistry more. ***	2.36	1.91
To better understand what a chemist does. ***	2.56	1.88
To be more comfortable with glassware. ***	2.74	1.99

Table 4.4: Year 2 Goal Statement Results with significant differences. Mann Whitney U results * = $p < 0.10$, ** = $p < .05$, *** = $p < .01$.

Statement	Ag/HHS	Engineer
To connect lecture material with the labs. ***	1.73	2.00
To be efficient in lab. ***	1.72	2.12
To connect chemistry to my major. ***	1.97	2.27
To work as a team. **	1.77	1.97
To become more comfortable with lab techniques. **	1.95	1.70
To apply concepts learned to problems in the lab. ***	1.99	2.51
To gain lab experience. ***	1.93	2.93
To enjoy chemistry more. ***	1.93	2.93
To better understand what a chemist does. ***	2.56	1.88
To be more comfortable with glassware. ***	2.74	1.99

Student goals in the two courses were not significantly different meaning that the students entering the course answered the survey as a whole similarly regardless of the course in which they were enrolled, though 10 of the 21 individual statements showed significant differences between the courses (Table available in the appendix). Of the 10 statements that showed significant differences, 6 of the statements showed the students who found in more important were students in the chemistry for agriculture and HHS students, with the other 4 being more important for the students in the chemistry for engineers' course.

Students in the chemistry for engineers course showed higher importance for "becoming comfortable with laboratory techniques", "enjoying chemistry more", "to better understand what a chemist does", and "to become more comfortable with glassware". As this class consists of all students from STEM related fields, it makes sense that becoming comfortable with lab techniques and glassware would be higher than students who are predominantly in agriculture and health fields where lab work is not a normal part of the routine. Likewise, students in STEM fields would also, likely, want to understand exactly what a Chemist does than students in health and agriculture fields as they would be more prone to interact with them. Also considering a portion of the engineering students have a focus of chemical engineering, the importance for students in that course would likely be higher. The affective goal "to enjoy chemistry more" is more difficult to fully understand possible reasoning for a preference towards students in the STEM fields, one explanation may be that students in the agriculture and HHS course are merely taking the chemistry course because it is assigned to them and have either been turned off to chemistry by prior experience or by word of mouth, and are more driven by simply completing the course rather than developing an interest in the subject matter. While the chemistry for engineers did show preference to both “enjoying chemistry more” and “to better understand what a chemist does”, these goals were the 2 of the 3 goals that were found to be least important to the students.

The students in the chemistry for HHS and agriculture students found several of the goals more important than their chemistry for engineering peers. These students placed a higher emphasis on making connections (chemistry and their major, lecture material and lab, and concepts with problems in lab) than the students in the chemistry for engineers’ course. Students in the chemistry for agriculture and HHS students also assigned higher importance to workings as part of a team and being efficient in the lab. Both of these are surprising in that these are skills that engineers tend to be associated with. That said my personal experience with both courses makes this result slightly less surprising. The students in the chemistry for Agriculture and HHS degrees tend to be more responsive to discussing problems in lecture and working in teams for in class exercises than their engineering counterparts.

The final statement that showed preference to the agriculture and HHS students was “to gain laboratory experience”. This was surprising as these students are less likely to be doing lab work as they move into their careers than students in the STEM fields from the other course. This may be due to the fact that was revealed in a course survey that many of the students in the chemistry for agriculture and HHS students have not previously had chemistry lab courses, where the students in the course for Engineers have almost all had some laboratory experience prior to coming to college.

The grade-oriented goal “to get an A or B” was rated, at the beginning of the semester, by students in both courses as the most important goal ($\bar{x}$ = 1.10). This reflects the results from the beginning of the semester in year 1 of the study with the vast majority of students listing a grade-oriented goal in their open ended responses. Also similarly to the beginning of the semester in year 1, learning how to use glassware ($\bar{x}$ = 2.65) and lab writing skills ($\bar{x}$ = 2.25) were both of low importance to the students with glassware being cited as the least important goal based on the mean position. Students did find “becoming comfortable with laboratory techniques” ($\bar{x}$ = 1.92) more important than using glassware and lab writing skills, but it still was barely above the average mean response ($\bar{x}$ = 1.95).

Students in both courses found “preparing for the career I want to pursue” as one of the most important goals ($\bar{x}$ = 1.69). This is not surprising that students would want to prepare themselves for their future career. This may apply to the course in general more so than just the laboratory portion as so many student ranked common laboratory activities like being comfortable with glassware and being comfortable with laboratory techniques as some of the lowest objectives.

Year 2- Beginning of Semester - Achievement Strategies

For the achievement portion of the survey, 839 students filled out the survey completely with 735 of them coming from the chemistry course for agriculture and HHS students. The mean was found to be 21.01 (σ = 4.124) for the sum of the student responses to each statement. Levene’s test for inequalities was used to determine if the distribution (Figure 4.1 below) of the data was not significantly deviated from normality

(F = 3.002, p = .084) so parametric statistics could be used for the analysis of the overall data set. The two courses were determined to be both significantly and practically different (t = 5.689, p < .001, d = .55). The survey was determined to have sufficient internal consistency using with a Chronbach's α of .732. Mann Whitney U statistics were calculated for each of the individual questions to determine if the two courses responded differently to the questions. The means for each of the individual statements can be seen in 4.8 below. The median values for each statement were then compared to the median for the overall average response of students using the Wilcoxon signed rank test. Results for this can be seen in Table 4.5.

Table 4.5: Year 2 Achievement Statement Results. Mann Whitney U results * = p < 0.10, ** = p < .05, *** = p < .01.

Statement	Ag/HHS	Engineer
I will work hard **	1.25	1.37
I will come to lab prepared ***	1.29	1.42
I will read the lab before my laboratory period ***	1.44	1.68
I will seek out help ***	1.50	1.88
I will analyze data ***	1.52	1.67
I will take detailed observations ***	1.51	1.80
I will analyze what I am doing ***	1.53	1.82
I will not manage my time	1.69	1.42
I will not procrastinate ***	1.70	1.92
I will discuss lab after class	2.27	2.34
I will finish lab as quickly as I can **	2.47	2.72

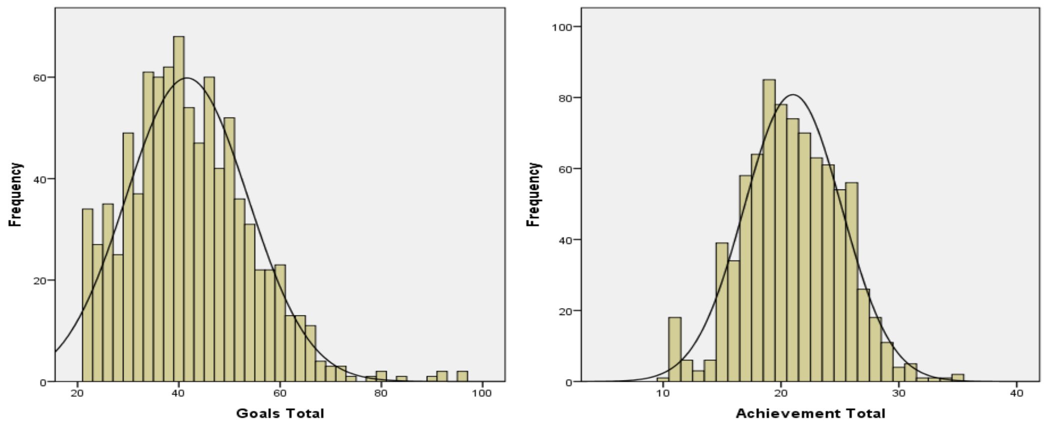

Figure 4.1: Distribution of student responses – beginning of year 2. Distribution of Goals (Left) and Achievement (Right) of overall student responses with normal curve.

The two courses were found to be significantly different in how the students responded to the statements based on the overall score. The chemistry for Agriculture and HHS students had a lower overall score, meaning they agreed with the achievement statements more than the Chemistry for engineers' students. As for the individual statements, eight of the ten showed a significant difference. This is not surprising as a difference existed between the two courses, with time management and discussing lab after class being the two statements that did not show a significant difference. All of the goals with a significant difference were lower, more agreement, for the Chemistry for Agriculture and HHS students.

The achievement strategy that students agreed with most in both courses was " to work hard". This is promising because, as instructors, we want to see our students working hard, but from this response it is hard to tell what the students meant by it. For some students working hard may be studying 1-2 hours a week for the course, for others it may be that amount of time each night. Regardless it is promising that the students do plan to work hard and put forth a good effort to accomplish the goals they have for the course. The next five highest achievement strategies, in terms of agreement, in both courses applied directly to lab work. Students were aware coming in that they would be analyzing data and that would be important for them to accomplish their goal. Likewise, they noted that they would need to arrive in lab prepared for the laboratory work, they would have to read the lab manual, and that they would need to complete their pre laboratory exercises. they were also aware that they would have to analyze what they were doing to accomplish their goals. Again it is promising to see students putting things tied directly to lab work higher on their strategies to achieve their goals, particularly when the most important goals for the students focused around their grades and less on the laboratory skills they develop.

On the opposite end of the spectrum, the achievement students agreed with least were “finishing lab quickly”, “discussing lab after class”, and “not procrastinating”. While we saw a handful of students in the initial study mentioning “discussing lab after class” as an achievement strategy, it is not shocking that students rate it as one of the statements that they agree with least. At the large Midwestern University at which this study took place, students are required to complete and turn in the laboratory report worksheet for each lab before leaving, so the curriculum does not necessitate that the students spend ample time outside of lab focused on laboratory. The result is that this is not of importance to the students to complete their goals. The students also showed some self awareness in that they know that not procrastinating may not happen. The most surprising of the lowest 3 was the fact that the students did not make “getting out of lab quickly” a priority. We expected that students would want to spend as little time as possible in lab prior to the study, but the students showed a lower agreement with this statement than most other achievement strategies. Students may have felt that they may not perform as well or pick up on the concepts as well if they were rushing out of the lab, that said, the mean response for the question showed more of a neutral response rather than a negative feeling towards the goal($\bar{x}$ = 2.50).

<u>Year 2 – End of Semester – Student Goals</u>

729 students completed the goals portion of the survey at the end of the semester in year 2 with only 33 coming from the general chemistry for engineers' course. The low number of responses from the chemistry for engineers' course will mean the average responses will reflect mainly those of the chemistry for agriculture and HHS. The statements were identical to those in the beginning of the semester and had a similar internal consistency (α = .940). The average overall sum of the responses was 46.26 (σ = 13.499). The data set was determined to be non-normal (distribution below in Figure 4.2) using Levine's test of Normality (F = 5.864, p = .016). The Mann Whitney U test was then used to determine that the two courses were not significantly different (U = -1.014, p = .311). Mann Whitney U statistics were calculated for each of the individual questions to determine if the two courses responded differently to the questions. The means for specific statements can be seen in Table 4.6 below with the entire list of questions being available in the appendices. The median values for each statement were then compared to the median for the overall average response of students using the Wilcoxon signed rank test. Results for this can be seen in the appendices.

Table 4.6: Year 2 Goal Statement Results. Mann Whitney U results * = p < 0.10, ** = p < .05, *** = p < .01.

Statement	Ag/HHS	Engineer
To get an A or B	1.22	1.09
To be efficient in lab.**	1.93	2.33
To work as a team.	2.01	2.18
To prepare for the career I want to pursue.	2.08	1.85
To gain lab experience.**	2.08	2.45
To learn how to design experiments	2.44	2.09
To develop my lab writing skills.	2.57	2.45
To enjoy chemistry more.**	2.59	2.13
To be more comfortable with glassware.**	2.67	2.18
To better understand what a chemist does.***	2.70	2.00

The students in the two courses responded more similarly near the end of the semester compared to the beginning of the semester. Only sever of the 21 goals had significantly different responses by course compared to eleven of the 21 questions that had significantly different responses at the beginning of the semester. Likewise, the statements at the end of the semester with significant differences had higher p values compared to only one of the statements not having a $p < .001$ at the beginning of the semester.

The goal that was most important to students was still "to earn an A or B" ($\bar{x}$ = 1.22), showing that students feel that their grade is most important objective in a course. "Working as a team" and "be efficient in lab" were the next two most important goals to the students, which both fell more towards the middle of the responses at the beginning of the semester. Students may not have initially realized the amount of group work they would be expected to do prior to doing laboratory work. Likewise, students may have not been aware of the importance of working efficiently in lab. Often times, early in the semester, students at the large Midwestern University struggle to complete the labs in the allotted time due to not using their time effectively. Students begin to pick up on time management skills and division of labor that allows for them to work better with their time as the semester progresses. Both of these goals, despite being some of the more important goals for the end of the semester, had lower means than at the beginning of the semester.

The students in the chemistry for engineers' course placed a higher emphasis on the importance of learning how research is done than the HHS and agriculture students. As the students in the chemistry for engineers' course tend to be in STEM fields, they are more likely to go into fields where they will be asked to do laboratory research, so learning how to do research in a laboratory work and understanding how laboratory research is done likely appeals more to them more so than their counterparts in the HHS and agriculture disciplines. Likewise, the students in the general chemistry for engineering course put more importance on enjoying chemistry and better understand what a chemist does. The students in the chemistry for engineers' course also found "learning chemical reactions" and "becoming more comfortable with glassware" more important than their agriculture and HHS peers. These may be due, again, to the fact that more of the students in the chemistry for engineers course will be going forward with more courses in STEM fields than the HHS and agriculture students.

Students in the chemistry for agriculture and HHS students found "to be efficient in lab" more important than their chemistry for engineering counterparts. As stated above, a larger portion of the students in the chemistry for agriculture and HHS students do not have laboratory experience prior to coming into the course than the chemistry for engineering students. The need to be efficient may have become a higher priority than at the beginning of the semester due to experiencing the time restrictions that come with working in the lab. The students in the chemistry for agriculture and HHS students also had "to gain laboratory experience" as higher importance. Seeing as many of these students did not have chemistry laboratory experience prior to the beginning of this course, it makes sense that many of them would list gaining laboratory experience as more important than the engineering students who likely had more experience prior to taking the course.

Year 2 - End of Semester - Achievement Strategies

Seven hundred and six participants completed the achievement portion of the survey at the end of the semester. As with the goals, only 33 of those students came from the general chemistry for engineers' course. The statements for this part of the survey were updated so that the responses were in the past tense to reference that the students were to reflect on what they had done over the course of the semester, otherwise no changes were made to the statements. Like the goals portion of the survey the internal consistency remained fairly similar ($\alpha = .741$). The mean of the overall sum of responses was 21.73 ($\sigma = 5.151$). The data was found to be non-normal (figure below in Figure 4.2) using Levine's Test for Normality ($F = 4.913$, $p = .027$). The two courses were determined to not be significantly different ($U = .275$, $p = .783$) in their overall responses. Significant differences were found for each statement individually (specific statements listed in Table 4.7 below) and can be found in appendix and median values for each statement were compared (appendix).

Table 4.7: Year 2 Achievement Statement Results. Mann Whitney U results * = p < 0.10, ** = p < .05, *** = p < .01.

Statement	Ag/HHS	Engineer
I came to lab prepared	1.57	1.52
I worked hard	1.64	1.70
I read the lab before my laboratory period	1.67	1.52
I analyzed data	1.77	1.85
I analyzed what I did**	1.83	2.03
I took detailed observations	1.92	2.15
I did not manage my time	1.95	1.92
I sought out help	1.99	2.09
I did not procrastinate	2.16	1.97
I finished lab as quickly as I could	2.22	2.24
I discussed lab after class	3.13	2.88

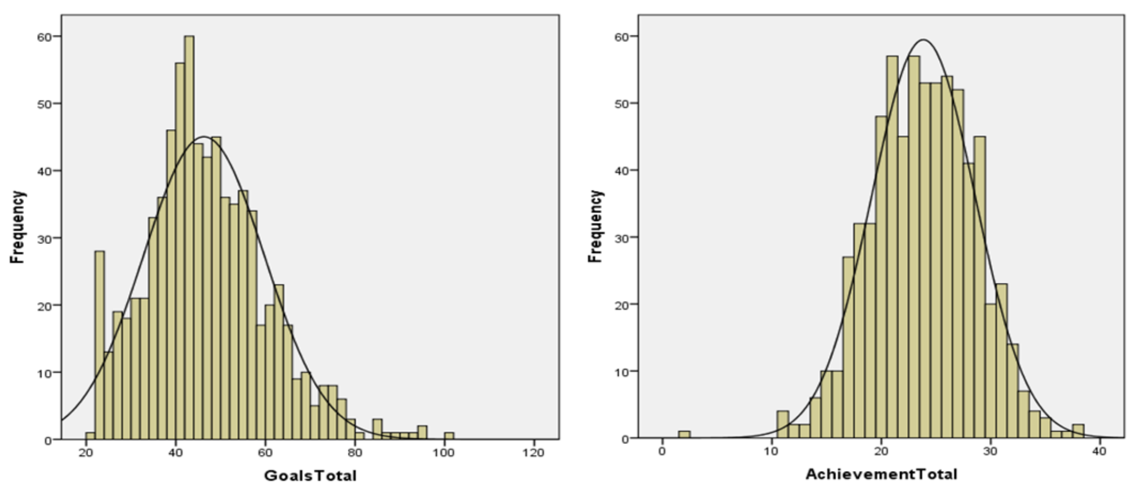

Figure 4.2: Distribution of student responses – end of semester year 2. Distribution of Goals (Left) and Achievement (Right) of overall student responses with normal curve.

At the beginning of the semester, there was a significant difference between these two courses, but by the end of the semester that difference no longer existed. The students from the chemistry for agriculture and HHS course had, prior to the semester, had shown higher levels of agreement than their counterparts in the course for engineers, but that difference had disappeared with time. Similarly, only one of the 10 achievement strategies was found to have a significant difference between the courses.

The one achievement strategy that showed a significant difference was “I analyzed what I did”, which the students in the chemistry for agriculture and HHS students reported stronger agreement. This is slightly surprising as you would expect the engineers to be more analytical about what they were doing, but the students in the engineering course may not report as high of agreement with this strategy because they usually analyze what they are doing.

The most used strategies were used “coming to lab prepared” and “reading the lab before coming to lab”. These are both promising as students taking the time to be prepared for lab will help them potentially take away more from the lab and be able to be more productive with their laboratory time.

Comparing Results Across Year 2 - Chemistry for Ag and HHS Students – Student Goals

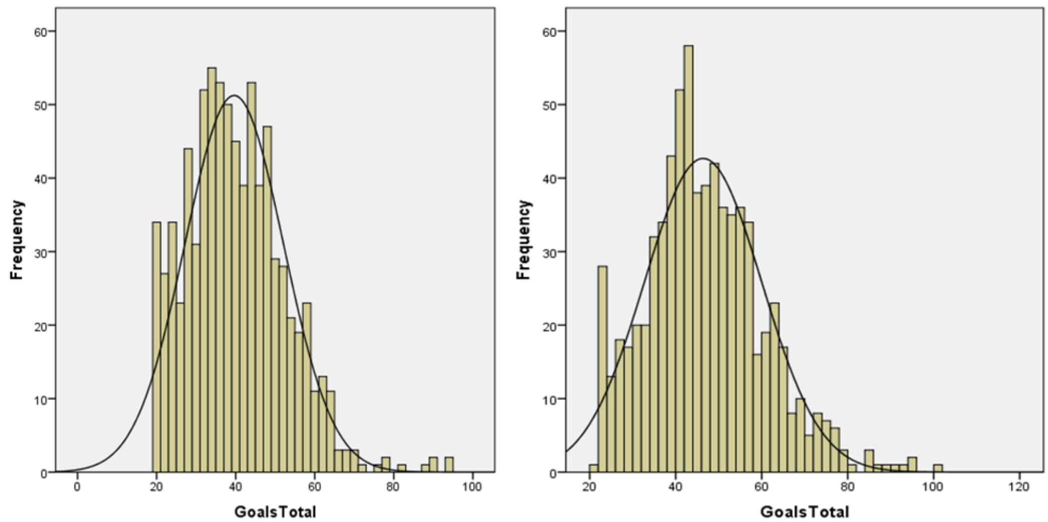

Figure 4.3: Distribution of Ag and HHS student responses. Distribution of Goals for the beginning (left) and End of the semester

Student’s summed total of the responses were graphed and presented in the figure above. Reliability for the survey was found using Chronbach’s alpha, and the survey was determined to have very good internal consistency ($\alpha = .937$). Levene’s test for inequalities was first run to determine if the data set had a normal distribution. It was determined that the data set was not significantly non-normal at the $p = .05$ significance level, but was found to be non-normal at the $p=.10$ significance level. Because of this a Mann-Whitney U statistic was calculated for the two means and it was determined that the end of semester goals was significantly higher, less important, than the beginning of the semester ($U = 9.884$, $p < .001$). Individual questions were then compared to determine if there was a significant difference between the beginning and end of the semester. Specific statements can be seen in the table below with the full table in appendix. Mann Whitney U was used to determine significance.

Table 4.8: Goals Results Comparison Across Year 2 . Mann Whitney U * = $p < 0.10$, ** = $p < .05$, *** = $p < .01$.

Statement	Beginning	End
To get an A or B ***	1.10	1.22
To prepare for the career I want to pursue. ***	1.69	2.08
To develop my lab writing skills. ***	2.26	2.57
To learn how to carry out experiments. ***	1.99	2.20
To develop lab skills. ***	1.99	2.17
To make connections between lab and the real world. ***	1.91	2.21
To learn how research is done. ***	1.89	2.26
To become more comfortable with lab techniques. ***	1.95	2.15
To be efficient in lab. ***	1.72	1.93
To connect chemistry to my major. ***	1.97	2.30
To enjoy chemistry more. ***	2.36	2.59
To connect lecture material with the labs. ***	1.73	2.13
To apply concepts learned to problems in the lab. ***	1.99	2.25
To better understand what a chemist does. **	2.56	2.70
To gain lab experience. ***	1.93	2.08
To be more comfortable with glassware.	2.74	2.67
To learn about chemical reactions. ***	2.03	2.23
To work as a team. ***	1.77	2.01
To learn error analysis procedures/calculations. ***	1.96	2.19
To learn how to design experiments. ***	2.13	2.44

At the end of the semester, the students found all the goals significantly less important than the beginning of the semester with the exception “to become more comfortable with glassware”. This is very promising as the students’ emphasized using glassware more at the end of the semester which is one objective professors want students to take away from a general chemistry course (Hofstein and Lunetta, 1982, Bruck et al, 2010, Bruck and Towns. 2013, Shulman and Tamir, 1973, Anderson 1976, Reid and Shah, 2007, Kirschner and Meester, 1988, Hodson, 1996a, Hodson, 1993, Johnstone, 2001, Abraham, 2012, Johnstone and Al-Shuaili, 2001). Even though students’ views on the importance of glassware did not significantly change over the course of the semester, it was still one of the least important goals to the students. Despite the significant shift to less importance for all of the other goals for lab, the importance of glassware was low enough at the beginning of the semester that it remained one of the bottom two goals.

The most important goal across both semesters was “to earn an A or B”. While it did shift from a mean position of 1.10 to a mean position of 1.22, it was still more important than any other goal in either semester. Likewise, being efficient in lab was of high importance both at the beginning and the end of the semester, moving to the 2nd most important goal at the end of the semester. The goals “To work as a team”, “To gain lab experience” and “To prepare for the career I want to pursue” were clustered together as the 3rd through 5th most important goals at the end of the semester. While there was some rearrangement in position for those goals, they all ranked in the top half in terms of importance at the beginning of the semester so, it appears that these goals are important to students throughout the course of the semester. On the other end of the spectrum, goals like “to develop my lab writing skills”, “to better understand what a chemist does”, "to enjoy chemistry more" and "to become more comfortable with using glassware" still ranked near the bottom in terms of importance to the students. While we saw an overall trend of less importance for goals at the end of the semester compared to the beginning, the order of the goals remained relatively the same. That indicates that students did not change much in terms of which goals were important to them over the course of the semester.

Comparing Results Across Year 2 - Chemistry for Engineers – Student Goals

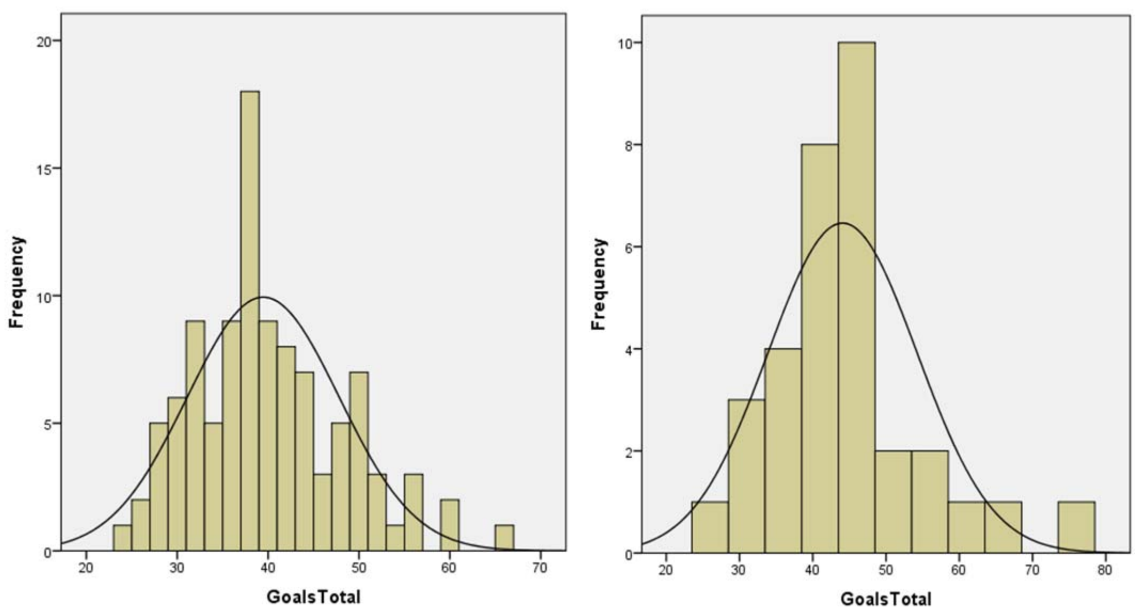

Figure 4.4: Distribution of Engineering student responses. Distribution of Goals for the beginning (left) and End of the semester.

Looking at the distributions above in Figure 4.4, the distributions both appear to be fairly normal. This was confirmed using Levene's test for inequalities (F= .279, p =

.598). A t-test was then used to determine if the responses changed over the course of the semester. It was determined that, like the Ag and HHS students, the end of the semester had a higher mean set of responses than at the beginning of the semester ($t = 2.355$, $p = .023$). Individual t-tests were calculated for each question. The specific results are presented in the table below (full table can be found in appendix).

Table 4.9: Goals Results Comparison Across Year 2 . T-test * = $p < 0.10$, ** = $p < .05$, *** = $p < .01$.

Statement	Beginning	End
To get an A or B	1.11	1.09
To prepare for the career I want to pursue.	1.67	1.85
To become more comfortable with lab techniques.	1.70	1.85
To learn about chemical reactions.	2.01	1.88
To learn how to carry out experiments.	1.90	1.97
To learn how research is done.	1.94	1.97
To be efficient in lab.	2.12	2.33
To develop my lab writing skills.	2.23	2.45
To gain lab experience. **	2.93	2.45
To connect chemistry to my major.	2.27	2.56
To apply concepts learned to problems in the lab.	2.51	2.58

Unlike the General Chemistry for Agriculture and HHS students, the Chemistry for Engineering did not see an overall change from the beginning to the end of the semester. Likewise, the majority of the questions did not significantly change in terms of importance. Of the 5 goals statements that showed a significant change, 4 shifted to being less important and 1 shifted towards more importance. The goal “to gain lab experience” shifted towards more important. As with the non shift in “to be more comfortable with glassware” in the other course, this is promising to see these goals not falling in importance. At the end of the semester, “to gain lab experience had moved up two spots from the least important to the 3rd least important goal to the students. Unfortunately though, the goal is still the least important of the goals overall in terms of student responses with a mean across the two semesters of 2.82.

The goals that saw shifts towards less important were “to learn error analysis procedure/calculations”, “to enjoy chemistry more”, “to develop lab skills”, and “to make connections between lab and the real world”. Seeing significant shifts to lesser importance for both learning error analysis and developing lab skills is a problem.

“To develop lab skills” had a shift from 1.87 before the semester to 2.27 at the end of the semester, more importantly though, the goal went from being the 6th highest goal in terms of importance at the beginning of the semester to the 6th lowest, falling 9 spots. Though we may not know the exact reasons for the demotion of this goal by these students, the dramatic shift in importance is no less troubling. One possible explanation is that students may have felt that learning and developing lab skills was not emphasized as part of the curriculum. Another possible explanation may be that the students are typically asked to learn a number of different laboratory techniques and may have felt that they did not have time to develop the ones that they gained through the semester.

Similarly to “develop lab skills”, “to learn error analysis procedures/calculations” saw a shift of .39 from 1.82 to 2.21. Like the lab skills goal, the goal was one of the most important goals at the beginning of the semester, 5th, and ended the semester towards the bottom, 14th out of 21. As with “to develop lab skills”, the exact reason for the shift could not be pulled directly from the survey, but there are some possible explanations behind the shift. One possibility is that error analysis is not emphasized in the course. While students are asked to calculate percent error, there is not a large emphasis on why that is important or what the students are to be taking away from it. That may lead students to think that other goals are more important because they feel the course is emphasizing them more than the error analysis. Another explanation is that they students don’t feel that they learned many types of error analysis over the course of the semester, as the students are not asked to calculate standard deviation and other types of error calculations outside of percent error and percent recovery.

For students reporting the goal “to enjoy chemistry more” was less important at the end of the semester, there are many possible explanations due to the more affective nature of this goal. While this could be attributed to a lack of interest in the labs, the curriculum does have several labs that many of the students generally comment that they enjoy. Another perspective may be that the students realize that the intent of the lab is not solely to increase their interest in chemistry. Another connection could be tied to the goal that also saw a shift to lesser importance “to make connections between lab and the real world”. If the students don’t feel that the labs are relevant to their lives, they may lose interest or find the labs less enjoyable as a result. One more disheartening explanation could be that the course is simply turning students off to chemistry for one reason or another. The material in the chemistry course can be difficult and if students are struggling adapting to the higher workload, students may not enjoy the course as much as they thought that they would.

The goals that were most important to the students were led by the grade-oriented goal of "to earn an A or B". This was the most important goal both at the beginning and the end of the semester. Likewise, the goal "to prepare me for the career I plan to pursue" was the second highest at both points at which the students were surveyed and "to become comfortable with lab techniques remained" remained 3rd throughout the semester. This echoes the trend in the chemistry course for agriculture and HHS students in that the goals most important to students did not change dramatically across the semester. While in this course the 5th and 6th most important goals did shift significantly downward, the top 3 showed no change at all in terms of both order and overall response.

This trend was replicated at the other end of the spectrum with the same 3 goals being the lowest at both the beginning and end of the semester, though with a slight change in order. "to gain laboratory experience", "to connect chemistry to my major", and "to apply concepts learned to problems in the lab" all scored high in terms of least importance both at the beginning at end of the semester. While "gain laboratory experience" moved up from least important to 3rd least important, the other 2 goals shifted down to fill the lower spots.

Comparing Results Across Year 2 – Comparing Classes – Student Goals

The overall score from the student goals section for the beginning and end of the semester were compared. The Levene's test for inequalities found that the data was non-normal ($F = 7.199$, $p = .007$) thus requiring nonparametric statistical analysis. The Mann Whitney U test found a significant difference from the beginning to the end of the semester ($U = 10.348$, $p < .001$). Individual Mann Whitney U tests were run to determine if differences existed between the beginning and end of the semester and those can be seen in the table below. Of the 23 goals statements, 21 showed significant shifts, all of which shifted to being less important than at the beginning of the semester which was the same shift that was seen in the overall score across the semester.

Table 4.10: Goals Results Comparison Across Year 2 . T-test results * = $p < 0.10$, ** = $p < .05$, *** = $p < .01$. +/- indicates direction of the shift.

Statement	Beginning	End
To get an A or B. ***	1.10	1.22
To be efficient in lab. ***	1.76	1.95
To work as a team. ***	1.79	2.02
To prepare for the career I want to pursue. ***	1.69	2.07
To gain lab experience.	2.04	2.10
To learn how to design experiments. ***	2.11	2.43
To develop my lab writing skills. ***	2.25	2.57
To enjoy chemistry more. ***	2.31	2.57
To be more comfortable with glassware.	2.65	2.65
To better understand what a chemist does. ***	2.48	2.67

The trend of the end of the semester overall goals total being higher than the beginning of the semester mirrored that of the individual courses. The goals "to gain lab experience" and "to become more comfortable with glassware" were the only goals not to show a significant difference. The rest of the goals showed a significant shift towards less importance. Due to all the goals showing a shift in importance, the overall order of the goals did not change drastically.

The goal “to earn an A or B” was still the most important goal to the students followed by “to be efficient in lab”. The goals are not tied directly to lab learning, so this can be somewhat disappointing. One promising outcome was the goal “to gain laboratory experience” which shifted from the 11th most important goal prior to the semester to the 4th by the end of the semester. The reason for this shift could be tied to a couple of conditions. Students may feel they are getting more out of lab that initially expected which could be why the importance of this goal did not follow the overall trend of shifting towards less importance. The other possible reason for this goal climbing in terms of order of importance could be tied to being dissatisfied with the other goals. As this goal did not show a significant shift, the fact that so many other goals shifted may mean that they felt these others goals were not being satisfied, and that this goal was merely staying just about as important as it was prior to the semester. While the actual reason cannot be determine without qualitative follow up, the fact that it the goal was higher in terms of mean position at the end of the semester compared to the beginning is a promising takeaway.

The goals “to become more comfortable with glassware”, “to develop lab writing skills”, and “to better understand what a chemist does” were the 3 least important goals at both points in which the students were surveyed. The goal “to become more comfortable with glassware” did not show a significant shift in terms of importance, but the students had scored it so low at the beginning of the semester the fact that it did not shift significantly is not surprising.

In the general chemistry courses surveyed, students are not asked to write formal lab reports as part of their laboratory work, instead being asked just to complete laboratory report worksheets that are to be completed by the end of the laboratory period. As the students are not asked to perform large amounts of writing for the course, the goal developing of laboratory writing skills is not of very high importance to the students.

The goal of faculty for students to "enjoy chemistry more" also being low brings into questions the idea that some literature has proposed (Shulman and Tamir, 1973, Anderson 1976, Bruck et. al, 2010, Bruck and Towns 2013, Hoffstein and Lunetta 1982, Hodson, 1996a, Hodson, 1993, Johnstone and Al-Shuaili, 2001) about lab being a place to develop interest in chemistry is brought into question. Based on these results, it does not appear that this is not the case as students showed no real change in terms of order of importance, and a significant change towards less importance in mean score over the course of the semester.

Comparing Results Across Year 2 - Chemistry for Ag and HHS Students – Achievement Strategies

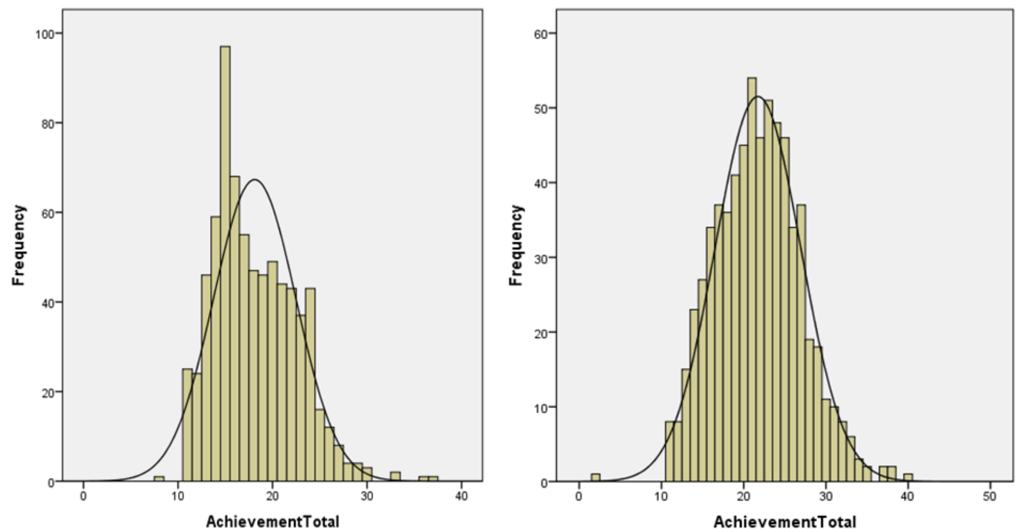

Figure 4.5: Distribution of Ag and HHS student responses. Distribution of Achievement scores for the Beginning (left) and End of the semester

The figure above shows the distribution of the overall summed achievement scores from the beginning and end of the semester. Reliability for the survey was found using Chronbach's alpha, and the survey was determined to have acceptable internal consistency ($\alpha = .751$). Levene's test for inequalities was first run to determine if the data set had a normal distribution, and it was determined that the distribution was not evenly distributed ($F = 15.113$, $P < .001$). A Mann-Whitney U statistic was calculated for the 2 means and it was determined that the end of semester goals was significantly higher than the beginning of the semester ($U = 13.326$, $p < .001$). Mann-Whitney U test was then used on each individual question to determine if the responses changed over the course of the semester. The results can be seen in Table 4.11 below.

Table 4.11: Achievement Results Comparison Across Year 2 . Mann Whitney U * = p < 0.10, ** = p < .05, *** = p < .01. +/- indicates direction of the shift.

Statement	Beginning	End
I came to lab prepared ***	1.29	1.57
I worked hard ***	1.25	1.64
I read the lab before my laboratory period ***	1.44	1.67
I analyzed data ***	1.52	1.77
I analyzed what I am did ***	1.53	1.83
I took detailed observations ***	1.51	1.92
I did not manage my time ***	1.69	1.95
I sought out help ***	1.50	1.99
I did not procrastinate ***	1.70	2.16
I finished lab as quickly as I could ***	2.47	2.22
I discussed lab after class ***	2.27	3.13

Similar to the goals shift in importance, the achievement strategies showed a shift away from strongly agree and towards strongly disagree. 10 of the 11 goals showed significant shifts towards strongly disagree, with the achievement strategy "I finished lab as quickly as I could" showing a significant shift back in the other direction. While every achievement strategy showed a significant shift, the order of the mean positions for each did not change drastically.

The achievement strategy that most students planned on using prior to the semester was "working hard". At the end of the semester work hard slid down to the 2^{nd} most used achievement strategy. The achievement strategy it traded places with was the strategy of "coming to lab prepared" which moved up from 2^{nd} most used prior to the. Considering that the 3^{rd} most used strategy at both times of sampling was reading the lab before their laboratory period we can see where the students are spending their time in regards to achieving their goals. On the other end of the spectrum, the least used achievement strategies through the course of the semester were “I discussed lab after class”, “I finished lab as quickly as I could”, and “I did not procrastinate” respectively.

There are some promising trends that come out of the data in this course. Students reported working hard and doing things to prepare themselves for the laboratory work they would be doing in the lab. These achievement strategies remained high from the beginning to the end of the semester. Students also were aware that they were analyzing data, and analyzed what they were doing which are all things that students can actively do to help them engage with the lab. While these are potentially strategies that could help students better understand the lab and the processes and techniques that the they use in the lab, we must keep in mind that the top goal for this same group of students ranked “to get a good grade” so the students may be using these strategies so that they can earn a high score on their laboratory report. This may be especially true due to the lower importance of goals related to laboratory techniques, glassware and lab writing.

The achievement strategies that students employed least were somewhat promising as well. Prior to beginning this study the research team feared that students’ primary object for lab would be to finish as quickly as possible. The students ranked this in the bottom 2 in both rounds of data collections for this course. Whether they feel if they push to complete the lab quickly their grade will suffer or some other reason, the students did not report employing this achievement strategy, though the average response did imply more use at the end of the semester compared to the beginning. While discussion of the lab with their peers after lab may help students retain material learned in the lab, given that this course does not allow students to work on laboratory reports outside of class, it is not a surprise that students do not employ this strategy as frequently. Likewise with only roughly 10% of test questions coming from the laboratory portion of the course, the effect on doing this is limited given their primary goal of earning an A or B in the class. While avoiding procrastination is also low in terms of how frequently it was employed by the students, this may be more of a case that the students are self aware of their procrastination, and are conceding that it will happen despite their best efforts.

Comparing Results Across Year 2 - Chemistry for Engineering Students – Achievement Strategies

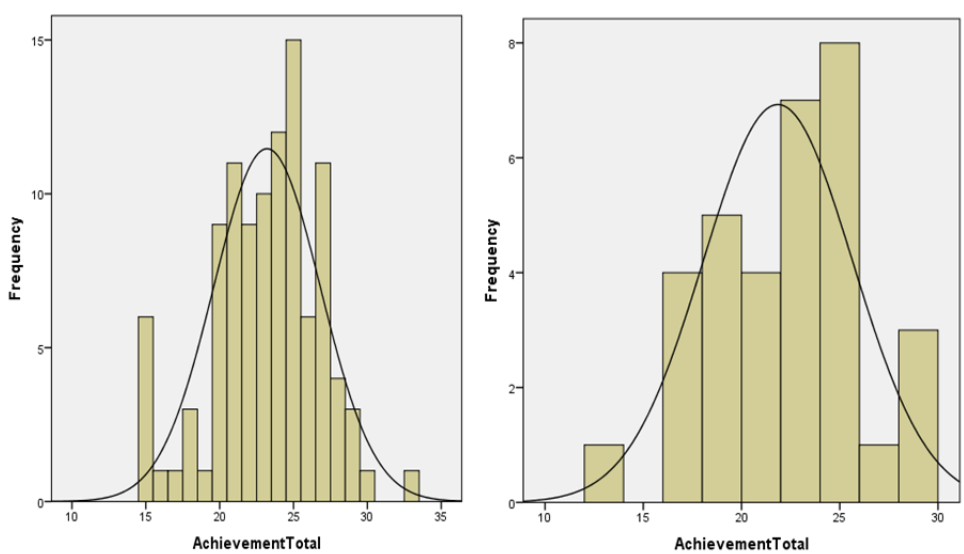

Figure 4.6: Distribution of Engineering student responses. Distribution of Achievement scores for the Beginning (left) and End of the semester

Figure 4.6 above shows the distribution for the achievement scores for the chemistry for engineers students. A Levene's test for inequality was used to determine that the distribution was normal (F = .061, p = .805). A t-test was then used to determine if the two populations, beginning and end of the semester responded different to the survey. The second semester, like the chemistry for agriculture and HHS students, showed a significantly higher score at the p = .10 significance level (t = 1.803, p = .077). The individual questions were then compared using the t- test to determine if the individual questions responses changed over the course of the semester. Those results can be seen below in Table 4.12.

Table 4.12: Achievement Results Comparison Across Year 2 . t- test * = p < 0.10, ** = p < .05, *** = p < .01. +/- indicates direction of the shift.

Statement	Beginning	End
I came to lab prepared	1.42	1.52
I read the lab before my laboratory period	1.68	1.52
I worked hard ***	1.37	1.70
I analyzed data *	1.67	1.85
I did not manage my time	1.92	1.91
I did not procrastinate	1.92	1.97
I analyzed what I am did **	1.82	2.03
I sought out help	1.88	2.09
I took detailed observation**	1.80	2.15
I finished lab as quickly as I could**	2.72	2.24
I discussed lab after class ***	2.34	2.88

More than half of the achievement strategies in this section showed a significant shift. The strategy "I finished lab as quickly as I could" showed the same shift as in the other course with it being employed more by the students at the end of the semester than the beginning. Similarly to with the other course, this is not the most promising result, but still was one of the least used strategies in the course. The other strategies to show significant shifts “I worked hard”, “I analyzed data”, “I took detailed observations”, “I discussed lab after class” and “I analyzed what I was doing” which all shifted towards less use.

As is with the case in the chemistry class for agriculture and HHS students, the students in this course are not allowed to work on the laboratory reports after completion of the laboratory period. This may limit discussion of the lab after the laboratory period which may explain the shift towards less use of that particular strategy. Despite its shift towards less use, the strategy did not change much in terms of order of importance of the mean positions of all the achievement strategies by moving from the 10th most used to the 11th in a list of 11 strategies.

The results of the “I worked hard” strategy was similar to that of “I will discuss lab after class” as it saw a significant shift towards less implemented, but the overall position changed by only two spots from the most used to the 3rd most. The strategies that ended ahead of working hard were “coming prepared to lab” and “reading the lab before coming to lab” which are both tied to being prepared to do the in lab work.

The strategies of “analyzing data”, “I analyzed what I was doing” and “I took detailed observations all saw significant shifts towards less use as well. These may be tied into the “working hard” strategy falling because these are all practices we, as educators and researchers, would like to see students engaging in. The reason for these shifts may be tied to how the students are being assessed in lab. If students do not feel they need to analyze data, or take detailed observations to complete their primary objective of earning an A or B, there may be less incentive for the students to employ these strategies compared to others on the list. Given that information, these strategies all fell toward the middle when comparing the means for each strategy individually, so students were still employing them more so than other strategies.

Comparing Results Across Year 2 – Comparing Classes – Achievement Strategies

The mean responses, by time in the semester, were compared for both courses to determine if a difference existed. A Levene's test found a significant result ($F = 11.806$, $p < .001$) meaning that the data was not normal and nonparametric analysis would have to be performed. A Mann-Whitney U test was run to determine if the two points in the semester had significantly different overall scores. The Mann Whitney U test revealed that the two points in the semester were significantly different ($U = 13.089$, $p <.001$) and that the mean responses to the end of the semester were higher than those of the beginning of the semester. The table below shows the beginning and end of semester means as well as the results of individual Mann Whitney U tests for each question.

Table 4.13: Achievement Results Comparison Across Year 2 . Mann Whitney U test. * = $p < 0.10$, ** = $p < .05$, *** = $p < .01$. +/- indicates direction of the shift.

Statement	Beginning	End
I came to lab prepared***	1.30	1.56
I worked hard***	1.26	1.65
I read the lab before my laboratory period***	1.47	1.66
I analyzed data***	1.54	1.77
I analyzed what I am did***	1.57	1.84
I took detailed observations***	1.55	1.93
I did not manage my time***	1.65	1.94
I sought out help***	1.54	1.99
I did not procrastinate***	1.73	2.15
I finished lab as quickly as I could***	2.50	2.22
I discussed lab after class***	2.28	3.12

With every goal showing a significant shift towards using the strategy less with the exception of "I finished lab as quickly as I could", the order of the achievement strategies did not change drastically from the beginning to the end of the semester. The achievement strategy "I finished lab as quickly as I could" showed a change in both course towards being more important. While this shift can be seen in both courses as being more used more often, in terms of most frequently used, this strategy is still one of the least implemented with the second highest mean score at the end of the semester after being the least used at the beginning.

The most frequently used strategies focused around hard work and preparedness. The three most frequented strategies at both points surveyed were "hard Work", "coming prepared to lab" and "reading the lab before my laboratory period". These are all generally effective strategies for making lab run smoother for the students and potentially will help them to better understand what they are doing in the lab. While the goals of the students need to be taken into consideration, if the students are genuinely reading the lab they should be able to discern the individual goals for the lab. These goals also do tie nicely into the goals of the students in that "hard work" and "being prepared for lab" will help students earn an A or B in their laboratory work.

As seen in the individual courses, students' strategies for achieving their goals did not change much over the course of the semesters. The strategies the students said they would employ prior to the semesters were generally the ones they reported using at the end of the semester. The goals that showed the largest shifts towards less use were the goals that students reported planning to use less at the beginning of the semester, so the order of the strategies was not greatly influenced.

CHAPTER 5 – CONCLUSIONS AND IMPLICATIONS

Across the two years of the study, one main theme arose from the survey data: students' primary motivating force is the grade that they receive in the class. Both in the open-ended survey responses from year one and in the Likert importance scale responses from year two, the students showed a strong affinity towards earning high marks in their respective courses. This result was not limited to one university or class as it showed high responses in the initial survey across universities and different courses of general chemistry. While professors tend to hope that their students have the primary driving force of understanding the material or learning transferable skills (Bruck et al, 2010, Bruck and Towns, 2013), the analysis demonstrates that students view those as secondary to their performance, in this case judged by their courses grade. Likewise, across two years, students showed very little interest in laboratory-oriented goals. They consistently rated goals like "becoming more comfortable with glassware" near the bottom in terms of frequency of responses and importance on Likert scale questions.

While the top and bottom goals did not align with the goals of students from the Boud, et al (2007), it is worth noting that in their study they surveyed students from science fields using a list of generic laboratory goals for any science field as opposed to the more focused goals of chemistry in this study. Similarly their survey was created to compare with recent graduates and practicing scientists where our study focused on comparing the goals of the students, ultimately, with those of the faculty. Similarly, the students were asked not explicitly what their goals were for laboratory work in this study, but what they felt should be the aims of laboratory work. This distinction in the question asked by Boud, et al (2007) changes the perspective slightly from what students hope to accomplish in the lab to what the students feel should be emphasized in the lab which might lead to a goal about procedural techniques being rated higher in their study than ours.

Hofstein and Lunetta (2004) suggested that the goals of faculty and what students may not be aligned. Based on our data, we can say that this is the case for some goals. While goals relating to laboratory work, particularly using glassware, and designing experiments were ranked lower by students despite them being goals of faculty, some faculty goals, like transferable skills (e.g. teamwork) were important to students. One possible reason that some student and professor's goals are so out of line from one another may lie in the professors' ability to confer to the students what they expect the students to take away from a given laboratory activity. Faculty at the large Midwestern research institution may focus more on what the students will be doing, more from an psycomotor perspective, rather than what the students should take, cognitively, from the laboratory activity. Likewise, if the laboratories are framed in a manner where completion of the laboratory is the most important objective, students may put less effort towards understanding the material covered in order to achieve completion in a timely manner.

This disconnect could also be attributed, in part, to the design of the laboratory reports and the structure of the labs. Given that at the large Midwestern research institution the laboratory reports are due at the end of the three hour laboratory period, students know that completion of both the activity and the report is of upmost importance. The unintended emphasis on laboratory activity completion may hinder students' leaving the laboratory with an understanding of the skills or concepts that the instructor intended to be emphasized in the laboratory. Another unfortunate effect from the focus on students' completing the activity, especially given students' primary aim to attain good grades, may lead to students not enjoying the laboratory as much as they may have otherwise. Similarly, students are rarely asked to design their own experiments in the general chemistry classes surveyed in this study. The structure of the lab as a whole may have an effect on students' emphasis on goals as a result. The labs and the way those labs are presented may have influenced what goals students have for labs. As a result, structuring the lab and the laboratory reports in such a way to emphasize the desired goals of the faculty may help shift the students goals to be more in line with those of the faculty.

A final theme related to goals that arose from the data showed that students tended to not drastically change their responses, as judged by the order of goals in terms of importance from the likert scale data, towards individual goals across a semester. In the second year of the study, we saw little change, in terms of order, in how students ranked the goals in terms of importance, though we did see significant shifts towards less importance in 19 of the 21 goals. The goals the students found least important at the beginning of the semester maintained their low ranking at the end. This theme suggests one of two possible explanations. The first explanation is that the students' goals are very set in by the time that they reach the college classroom and as a result are difficult to change. A second interpretation may be that we are reinforcing the goals that the students have in place are being reinforced by the design of our laboratory sessions. As the students' goals tend not to change over the course of the semester, the faculty and the curriculum may in fact be reinforcing the students' goals, particularly the grade-oriented goals.

Given that we have compared student and faculty goals, it is worth pointing out that student and faculty goals may never fully align. Faculty really made no mention of grade related goals for laboratory work, yet students find that the most important. As many of us in the field know or could likely guess, students need certain grades to advance or remain in the program, and, particularly with non-majors, progressing in their field will likely be more important than learning a specific technique that they may never use again. That said, as we saw in the first year of the study, students are more aware of accomplishing goals that they know exist. If faculty can make explicit what goals they have for lab and why they are important, we may see students reporting them as being more important. This goes beyond simply telling the students, but designing labs that help reinforce these ideas. Students report teamwork as an important goal for laboratory work, and they are required to work in groups across a semester. This alignment of a faculty goal and laboratory design helps emphasize the goal for students who in term acknowledge it as being more important. Similarly, designing labs that are in context of the student, particularly for non-majors, may help emphasize why certain faculty goals are important to them.

As the students put a large focus on the grade-oriented goal of "to earn an A or B", the students' strategies for completing this goal tended to focus on good student practices. The students tended to agree most, in likert scale responses, with achievement strategies of preparedness, reading the laboratory prior to arriving and coming prepared to laboratory, as a way of ensuring that they were prepared for class. Similarly the students acknowledged that they worked hard in laboratory, as another means of achieving their good grade.

While these are promising trends that students emphasized preparedness for their laboratory session, it also may make the fact that students are not taking away skills regarding glassware all the more troubling. Students have clearly placed preparing for their laboratory session as a top priority for achieving their goals of earning an A or B and learning in the laboratory activities, but despite reading the laboratories before their laboratory period, important goals such as comfort with glassware, designing experiments, learning chemical reaction and developing laboratory writing skills remained ranked near the bottom of the students goals at the end of the semester.

A second theme that arose from the achievement portion of the survey showed that students acknowledged what they were doing in their laboratory session. Students tended to agree more with statements about analyzing what they were doing and analyzing data. This shows that students are putting thought into what they are doing as they proceed through the laboratory activity so if emphasis on learning objectives could be made, students may be able to retain other goals, such as learning techniques or error analysis.

Implications for Research

The work by Bruck et al. (2010) and Bruck and Towns (2013) highlighted a list of objectives for teaching laboratories that faculty felt were most important. While this study only took place at two universities, we saw very little alignment between the two groups. While this study focused primarily on two Midwestern universities, the results will need to be explored in a national scale to confirm the discrepancies between the two groups. Similarly, a more in depth look at different student populations could provide good insight. This study focused primarily on first year engineering students and agriculture and HHS students. Looking closely at chemistry majors and a more in depth look at upper division students could lend better insight into what students find important and how that changes with time.

Similarly, this study relied solely on survey methods for data collection as compared to the qualitative interviews used by Bruck et al (2010). While the survey allows for easy collection from large amounts of participants, a follow up study with a focus from more of a qualitative approach may allow for a deeper understanding of what students believe about certain goals. Likewise, it may clarify how students read certain goals statements and give more insight to the trends seen in this study.

Implications for Teaching

This study provides faculty to better understanding of what students believe the objectives of laboratory activities are. Faculty may have little awareness that their goals for their laboratory curriculum are not evident to students, and so there was little alignment between the objectives of the students and the faculty from other studies

(Bruck et al, 2010, Bruck and Towns 2013, Hofstein and Lunetta, 1982, 2004, Kirschner and Meester, 1996), faculty can be aware of what expectations and emphasize the goals they believe are most important.

Likewise, placing more of an emphasis, in the laboratory manual and with the graduate teaching assistants, on teaching students technique and connecting the laboratory to the course material should help students place more emphasis on these goals. Reinforcing important faculty goals and ensuring that all facets of the course are consistent should help students be aware of key objectives.

Finally, removing time limitations for students on laboratory activities may allow students more time on task to focus on goals other than assignment completion. With limited amount of time to perform the laboratory activities and learn concepts and techniques, students will focus more on their main objective of earning a high score. As “finishing laboratory quickly” did not rank near the top of the list of important goals, students may be able to use the additional time to focus more on goals that were scored less important. Similarly, removing the requirement of completing all laboratory report work before the end of the three hour laboratory period would allow students to focus on laboratory outside of class. Additionally, if the laboratory report is completed outside of laboratory, the time spent in laboratory can be more directed at the task of completing and understanding the laboratory exercises, laboratory techniques and other goals faculty rank as more important rather than just completing the work to be turned in for a grade.

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APPENDIX

APPENDIX

End of Semester – year 1 goals questions

Please Indicate which goals you expected to achieve in this laboratory course and those that you are currently achieving.

	Was this a goal for you in August?		Is this happening?	
	Yes	No	Yes	No
to earn an A or B.				
to prepare for the career I want to pursue.				
to develop my lab writing skills.				
to make connections between lecture material and the real world.				
to learn hands on.				
to develop lab skills.				
to learn chemistry.				
to make connections between lab and the real world.				
to confirm material I learned in lecture				
to learn how to be safe in the laboratory.				
to learn how research is done.				
to become more comfortable with lab techniques.				

to pass the course.

to learn to be efficient in lab.

to learn the scientific process.

to learn Organic Chemistry.

to connect chemistry to my major.

to join a research group.

to avoid injury in lab.

to enjoy chemistry more

to improve my confidence.

to meet people.

to improve my patience.

to gain interest in chemistry.

to connect lecture material with the labs.

to perform experiments.

select yes to both questions

to get to know the professor.

to survive the course.

to apply concepts learned to problems in lab.

to become a better chemistry student.

to better understand what a chemist does.

to gain lab experience.

to be more comfortable using glassware.

to learn chemical reactions.

to learn how chemistry affects me.
to work in a team
To learn error analysis procedures/calculations.

End of Semester - Year 1 – Achievement Strategies

Please indicate your agreement or disagreement with the following statements about techniques you employed to accomplish your goals in this course.

	Strongly Agree	Agree	Disagree	Strongly Disagree
I did not procrastinate.				
I had an open mind.				
I did not do lab work.				
I worked hard.				
I did not study.				
I did my best.				
I sought out help.				
I participated in analyzing data.				
I took detailed observations.				
I participated in collecting data.				
I did not manage my time.				
I read my notes.				
I did extra/more problems.				
I attended lab.				
I came to lab prepared.				
I read the assigned readings.				
I read the lab manual.				
I worked in groups.				
I discussed lab after class.				
I turned in the prelabs.				
I understood the lab reports.				
Select the response "Disagree".				
I stayed on task.				
I did not pay attention to detail.				
I took my time.				
I finished lab as quickly as I could.				

I was able to analyze what I was doing.
I took lab seriously.
I followed directions in the lab manual

Beginning of the Semester Survey – Year 2

Each of the following statements pertains to a learning goal for laboratory. Please indicate the importance of each goal to your learning as you complete experiments. The scale ranges from "Extremely Important" to "Not at all Important"

		Extremely Important (A)	Somewhat Important (B)	Neutral (C)	Not Very Important (D)	Not at all Important (E)
1	To earn an A or B.					
2	To prepare for the career I want to pursue.					
3	To develop my lab writing skills.					
4	To learn how to carry out experiments.					
5	To develop lab skills.					
6	To make connections between lab and the real world.					
7	To learn how research is done.					
8	To become more comfortable with lab techniques.					
9	To be efficient in lab.					
10	To connect chemistry to my major.					
11	To enjoy chemistry more.					
12	To connect lecture material with the labs.					
13	Please select "Somewhat Important" (B). if you are still reading					
14	To apply concepts learned to problems in the lab.					

15	To better understand what a chemist does.
16	To gain lab experience.
17	To be more comfortable with glassware.
18	To learn about chemical reactions.
19	To work as a team.
20	To learn error analysis procedures/calculations.
21	To learn how to design experiments.

Please indicate the level to which you agree with the following statements in terms of how you will go about accomplishing your goals in lab

		Strong Agree (A)	Agree (B)	Neither Agree or Disagree (C)	Disagree (D)	Strongly Disagree (E)
22	I will not procrastinate.					
23	I will work hard.					
24	I will seek out help.					
25	I will analyze data.					
26	I will take detailed observations.					
27	I will not manage my time.					
28	I will come to lab prepared.					
29	I will discuss lab after class.					
30	I will finish lab as quickly as I can.					
31	I will analyze what I					

am doing.

32 I will read the lab before my laboratory period.

End of Semester Survey – Year 2

Each of the following statements pertains to a learning goal for laboratory. Please think back to the chemistry labs you have done over the semester. Please indicate the importance of each goal to your learning as you completed experiments. The scale ranges from "Extremely Important" to "Not at all Important"

		Extremely Important (A)	Somewhat Important (B)	Neutral (C)	Not Very Important (D)	Not at all Important (E)
1	To earn an A or B.					
2	To prepare for the career I want to pursue.					
3	To develop my lab writing skills.					
4	To learn how to carry out experiments.					
5	To develop lab skills.					
6	To make connections between lab and the real world.					
7	To learn how research is done.					
8	To become more comfortable with lab techniques.					
9	To be efficient in lab.					
10	To connect chemistry to my major.					
11	To enjoy chemistry more.					
12	To connect lecture material with thelabs.					
13	Please select "Somewhat Important" (B). if you are still					

	reading					
14	To apply concepts learned to problemsin the lab.					
15	To better understand what a chemist does.					
16	To gain lab experience.					
17	To be more comfortable with glassware.					
18	To learn about chemical reactions.					
19	To work as a team.					
20	To learn error analysis procedures/calculations.					
21	To learn how to design experiments.					

Please indicate the level to which you agree with the following statements in terms of how you will go about accomplishing your goals in lab

		Strong Agree (A)	Agree (B)	Neither Agree or Disagree (C)	Disagree (D)	Strongly Disagree (E)
22	I did not procrastinate.					
23	I worked hard.					
24	sought out help.					
25	I analyzed data.					
26	I took detailed observations.					
27	I did not manage my time.					

28	I came to lab prepared.
29	I discussed lab after class.
30	I finished lab as quickly as I can.
31	I analyzed what I am doing.
32	I read the lab before my laboratory period.

Table A1: Results of McNemar's test

Prompt	χ^2 (McNemars test)	p
to earn A or B	92	<0.001
to prepare of the career I want to pursue	6	0.014
to develop my lab writing skills	63.2195122	<.001
to make connections between lecture and real world	5.555555556	0.018
to learn "hands on"	3.571428571	0.0588
to develop lab skills	16.33333333	<0.001
to learn chemistry	0	0.9999
to make connections between lab and the real world	10.90322581	<0.001
to confirm material I learned in lecture	0.590361446	0.4424
to learn how to be safe in the lab	71.73563218	<0.001
to learn how research is done	3.31372549	0.0687
to become more comfortable with lab techniques	15.68	<0.001
to pass the course	7.117647059	0.007
to be efficient in lab	0.444444444	0.505
to learn the scientific process	51.95522388	<0.001
to learn organic chemistry	1.6	0.059
to connect chemistry to my major	0.183673469	0.668
to join a research group	0.032258065	0.8575
to avoid injury in lab	36.1	<0.001
to enjoy chemistry more	16	<0.001
to improve my confidence	0.580645161	0.446
to meet people	82.17777778	<0.001
to improve my patience	29.34782609	<0.001
to gain interest in chemistry	0.373134328	0.5413
to connect lecture material with the labs	0.01369863	0.9068
to perform experiments	9.307692308	0.002
to get to know the proffessor	0.362318841	0.5472
to survive to course	1.5	0.2207
to apply concepts learned to problems in lab	0.609756098	0.4348
to become a better chemistry student	8	0.005
to better understand what a chemist does	15.05882353	<.001
to gain lab experience	8.047619048	0.004
to be more comfortable using glassware	74.71111111	<.001
to learn chemical reactions	14	<.001
to learn how chemistry affects me	3.072727273	0.0796
to work as a team	59.50704225	<.001
to learn error analysis procedures/calculations	49.47058824	<.001

Table A2: Year 1 Achievement statistics. Mann Whitney U test results * = p < 0.10, ** = p < .05, *** = p < .01. Italicize text means scoring was inverted for analysis

	Mean	**St. Dev.**
Did not procrastinate ***	2.38	0.853
Had an open mind ***	1.69	0.559
Did not work hard	1.24	0.550
Worked hard *	1.51	0.594
Did not study	1.68	0.753
Did my best ***	1.58	0.685
Sought out help ***	2.01	0.759
Analyzed data ***	1.51	0.536
Took Detailed observations	1.78	0.617
Collected data ***	1.40	0.534
Did not manage time ***	1.80	0.737
Read my notes ***	1.83	0.685
Did extra problems	2.67	0.847
Attended lab	1.20	0.452
Came prepared to lab	1.43	0.562
Read assigned readings **	1.99	0.836
Read lab manual***	1.43	0.539
Worked in groups	1.40	0.530
Discussed lab after class ***	2.18	0.880
Turned in prelab ***	1.28	0.484
Understood lab reports ***	1.80	0.678
Stayed on task **	1.54	0.568
Paid attention to detail ***	1.44	0.696
Took my time	1.78	0.678
Finished lab quickly ***	2.35	0.854
Analyzed what I was doing ***	1.77	0.604
Took lab seriously ***	1.50	0.608
Followed directions in lab manual	1.41	0.520

Table A3: Year 1 Achievement statistics. Wilcoxon signed rank test results * = p < 0.10, ** = p < .05, *** = p < .01. Italicize text means scoring was inverted for analysis.

	Mean	**St. Dev.**
Did not procrastinate ***	2.38	0.853
Had an open mind ***	1.69	0.559
Did not work hard ***	1.24	0.550
Worked hard ***	1.51	0.594
Did not study ***	1.68	0.753
Did my best ***	1.58	0.685
Sought out help	2.01	0.759
Analyzed data ***	1.51	0.536
Took Detailed observations ***	1.78	0.617
Collected data ***	1.40	0.534
Did not manage time ***	1.80	0.737
Read my notes***	1.83	0.685
Did extra problems ***	2.67	0.847
Attended lab ***	1.20	0.452
Came prepared to lab ***	1.43	0.562
Read assigned readings	1.99	0.836
Read lab manual***	1.43	0.539
Worked in groups ***	1.40	0.530
Disscussed lab after class ***	2.18	0.880
Turned in prelab ***	1.28	0.484
Understood lab reports ***	1.80	0.678
Stayed on task ***	1.54	0.568
Paid attention to detail ***	1.44	0.696
Took my time ***	1.78	0.678
Finished lab quickly ***	2.35	0.854
Analyzed what I was doing ***	1.77	0.604
Took lab seriously ***	1.50	0.608
Followed directions in lab manual ***	1.41	0.520

Table A4: Year 2 Goal Statement Results. Mann Whitney U results * = $p < 0.10$, ** = $p < .05$, *** = $p < .01$.

Statement	Mean	St. Dev.
To get an A or B	1.10	.311
To prepare for the career I want to pursue.	1.69	1.002
To connect lecture material with the labs. ***	1.76	.742
To be efficient in lab. ***	1.77	.849
To connect chemistry to my major. ***	1.79	1.078
To work as a team. **	1.79	.863
To make connections between lab and the real world.	1.89	.870
To learn how research is done.	1.90	.868
To become more comfortable with lab techniques. **	1.92	.878
To learn error analysis procedures/calculations.	1.94	.900
To learn how to carry out experiments.	1.97	.848
To develop lab skills.	1.97	.885
To learn about chemical reactions.	2.03	.894
To apply concepts learned to problems in the lab. ***	2.05	.888
To gain lab experience. ***	2.05	.971
To learn how to design experiments	2.11	.948
To develop my lab writing skills.	2.25	.893
To enjoy chemistry more. ***	2.30	1.013
To better understand what a chemist does. ***	2.48	1.058
To be more comfortable with glassware. ***	2.65	1.128

Table A5: Year 2 Goal Statement Results. Wilcoxon Signed Rank Test * = $p < 0.10$, ** = $p < .05$, *** = $p < .01$.

Statement	**Mean**	**St. Dev.**
To get an A or B. ***	1.10	.311
To prepare for the career I want to pursue. ***	1.69	1.002
To develop my lab writing skills. ***	2.25	.893
To learn how to carry out experiments. ***	1.97	.848
To develop lab skills. ***	1.97	.885
To make connections between lab and the real world. **	1.89	.870
To learn how research is done. ***	1.90	.868
To become more comfortable with lab techniques. ***	1.92	.878
To be efficient in lab. **	1.77	.849
To connect chemistry to my major. ***	1.79	1.078
To enjoy chemistry more. ***	2.30	1.013
To connect lecture material with the labs. *	1.76	.742
To apply concepts learned to problems in the lab. ***	2.05	.888
To better understand what a chemist does. ***	2.48	1.058
To gain lab experience. ***	2.05	.971
To be more comfortable with glassware. ***	2.65	1.128
To learn about chemical reactions. ***	2.03	.894
To work as a team.	1.79	.863
To learn error analysis procedures/calculations. ***	1.94	.900

Table A6: Year 2 Achievement Statement Results. Wilcoxon Signed Rank Test * = p < 0.10, ** = p < .05, *** = p < .01.

Statement	Mean	St. Dev.
I will not procrastinate ***	1.73	.821
I will work hard ***	1.26	.493
I will seek out help ***	1.54	.496
I will analyze data ***	1.54	.673
I will take detailed observations ***	1.55	.646
I will not manage my time	1.65	.979
I will come to lab prepared ***	1.30	.525
I will discuss lab after class ***	2.28	.884
I will finish lab as quickly as I can ***	2.50	1.099
I will analyze what I am doing ***	1.57	.604
I will read the lab before my laboratory period ***	1.47	.619

Table A7: Year 2 Goal Statement Results. Mann Whitney U results * = $p < 0.10$, ** = $p < .05$, *** = $p < .01$.

Statement	**Mean**	**St. Dev.**
To get an A or B	1.22	.488
To be efficient in lab.**	1.95	.912
To work as a team.	2.02	.960
To prepare for the career I want to pursue.	2.07	1.099
To gain lab experience.**	2.10	1.141
To become more comfortable with lab techniques.	2.13	.940
To connect lecture material with the labs.	2.13	.900
To develop lab skills.	2.17	.943
To learn how to carry out experiments.	2.19	.910
To learn error analysis procedures/calculations.	2.19	.951
To make connections between lab and the real world.	2.21	.947
To learn about chemical reactions.*	2.21	.948
To learn how research is done.*	2.25	.954
To apply concepts learned to problems in the lab.*	2.27	.905
To connect chemistry to my major.	2.32	1.132
To learn how to design experiments	2.43	1.053
To develop my lab writing skills.	2.57	1.033
To enjoy chemistry more.**	2.57	1.075
To be more comfortable with glassware.**	2.65	1.141
To better understand what a chemist does.***	2.67	1.102

Table A8: Year 2 Goal Statement Results. Wilcoxon Signed Rank Test * = p < 0.10, ** = p < .05, *** = p < .01.

Statement	Mean	St. Dev.
To get an A or B ***	1.22	0.488
To prepare for the career I want to pursue. ***	2.07	1.099
To develop my lab writing skills. ***	2.57	1.033
To learn how to carry out experiments. ***	2.19	0.910
To develop lab skills. ***	2.17	0.943
To make connections between lab and the real world. ***	2.21	0.947
To learn how research is done. *	2.25	0.954
To become more comfortable with lab techniques. ***	2.13	0.940
To be efficient in lab. ***	1.95	0.912
To connect chemistry to my major.	2.32	1.132
To enjoy chemistry more. ***	2.57	1.075
To connect lecture material with the labs. ***	2.13	0.900
To apply concepts learned to problems in the lab. ***	2.27	0.905
To better understand what a chemist does. ***	2.67	1.102
To gain lab experience.	2.10	1.141
To be more comfortable with glassware. ***	2.65	1.141
To learn about chemical reactions. ***	2.21	0.948
To work as a team. ***	2.02	0.960
To learn error analysis procedures/calculations. ***	2.19	0.951
To learn how to design experiments. ***	2.43	1.053

Table A8: Year 2 Achievement Statement Results. Wilcoxon Signed Rank Test * = p < 0.10, ** = p < .05, *** = p < .01.

Statement	**Mean**	**St. Dev.**
I did not procrastinate ***	2.15	1.052
I worked hard ***	1.65	.698
I sought out help	1.99	.935
I analyzed data ***	1.77	.687
I took detailed observations **	1.93	.793
I did not manage my time *	1.94	1.00
I came to lab prepared ***	1.56	.694
I discussed lab after class ***	3.12	1.10
I finished lab as quickly as I could ***	2.22	.988
I analyzed what I did ***	1.84	.724
I read the lab before my laboratory period ***	1.66	.841

Table A9: Goals Results Comparison Across Year 2 . Mann Whitney U * = p < 0.10, ** = p < .05, *** = p < .01. +/- indicates direction of the shift.

Statement	Beginning	End
To get an A or B ***	1.10	1.22
To prepare for the career I want to pursue. ***	1.69	2.08
To develop my lab writing skills. ***	2.26	2.57
To learn how to carry out experiments. ***	1.99	2.20
To develop lab skills. ***	1.99	2.17
To make connections between lab and the real world. ***	1.91	2.21
To learn how research is done. ***	1.89	2.26
To become more comfortable with lab techniques. ***	1.95	2.15
To be efficient in lab. ***	1.72	1.93
To connect chemistry to my major. ***	1.97	2.30
To enjoy chemistry more. ***	2.36	2.59
To connect lecture material with the labs. ***	1.73	2.13
To apply concepts learned to problems in the lab. ***	1.99	2.25
To better understand what a chemist does. **	2.56	2.70
To gain lab experience. ***	1.93	2.08
To be more comfortable with glassware.	2.74	2.67
To learn about chemical reactions. ***	2.03	2.23
To work as a team. ***	1.77	2.01
To learn error analysis procedures/calculations. ***	1.96	2.19
To learn how to design experiments. ***	2.13	2.44

Table A10: Goals Results Comparison Across Year 2 . T-test * = p < 0.10, ** = p < .05, *** = p < .01. +/- indicates direction of the shift.

Statement	Beginning	End
To get an A or B	1.11	1.09
To prepare for the career I want to pursue.	1.67	1.85
To develop my lab writing skills.	2.23	2.45
To learn how to carry out experiments.	1.90	1.97
To develop lab skills. **	1.87	2.27
To make connections between lab and the real world. **	1.75	2.12
To learn how research is done.	1.94	1.97
To become more comfortable with lab techniques.	1.70	1.85
To be efficient in lab.	2.12	2.33
To connect chemistry to my major.	2.27	2.56
To enjoy chemistry more. *	1.91	2.13
To connect lecture material with the labs.	2.00	2.03
To apply concepts learned to problems in the lab.	2.51	2.58
To better understand what a chemist does.	1.88	2.00
To gain lab experience. **	2.93	2.45
To be more comfortable with glassware.	1.99	2.18
To learn about chemical reactions.	2.01	1.88
To work as a team.	1.97	2.18
To learn error analysis procedures/calculations. **	1.82	2.21
To learn how to design experiments	1.93	2.09

Table A11: Goals Results Comparison Across Year 2 . T-test results * = p < 0.10, ** = p < .05, *** = p < .01. +/- indicates direction of the shift.

Statement	Beginning	End
To get an A or B. ***	1.10	1.22
To prepare for the career I want to pursue. ***	1.69	2.07
To develop my lab writing skills. ***	2.25	2.57
To learn how to carry out experiments. ***	1.98	2.19
To develop lab skills. ***	1.97	2.17
To make connections between lab and the real world. ***	1.89	2.21
To learn how research is done. ***	1.90	2.25
To become more comfortable with lab techniques. ***	1.92	2.13
To be efficient in lab. ***	1.76	1.95
To connect chemistry to my major. ***	2.00	2.32
To enjoy chemistry more. ***	2.31	2.57
To connect lecture material with the labs. ***	1.76	2.13
To apply concepts learned to problems in the lab. ***	2.05	2.27
To better understand what a chemist does. ***	2.48	2.67
To gain lab experience.	2.04	2.10
To be more comfortable with glassware.	2.65	2.65
To learn about chemical reactions. ***	2.02	2.21
To work as a team. ***	1.79	2.02
To learn error analysis procedures/calculations. ***	1.94	2.19
To learn how to design experiments. ***	2.11	2.43

VITA

VITA

Anyone who meets Taylor Owings will quickly learn that he is a huge St. Louis Cardinals fan, devoted to his friends and family, and passionate about teaching and coaching. During his time at Purdue, Taylor has not only spent his time taking courses, researching what college chemistry students hope to learn from their courses, and what motivates them to learn, but also been a teaching assistant, supervisor, and student teacher. Taylor is a passionate, enthusiastic, animated, hard-working, and innovative person and these qualities come out in everything he does; especially in his teaching. As a teacher, Taylor strives to inspire, motivate, and give his students the tools and support they need to reach their full potential and develop an interest in chemistry.

Aside from teaching and research, Taylor is also an active member of his church, a board game enthusiast, and a dedicated follower of his favorite sports teams. At his church, Taylor plays on the softball team, runs sound for the services on Sunday mornings, and leads a Sunday school class. In his spare time, Taylor enjoys spending time reading, playing board games with his friends, contributing to a sports blog that he and his two best friends from college created, and watching the Cardinals, Pacers, Colts, Everton, and Indy Eleven sports teams. After completing his degree at Purdue, Taylor looks forward to starting his teaching and coaching career at North Montgomery High School in Crawfordsville, IN.