AFFORDANCES OF INSTRUMENTATION IN GENERAL CHEMISTRY LABORATORIES

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The purpose of this study is to find out what students in the first chemistry course at the undergraduate level (general chemistry for science majors) know about the affordances of instrumentation used in the general chemistry laboratory and how their knowledge develops over time. Overall, students see the PASCO™ system as a useful and accurate measuring tool for general chemistry labs. They see the probeware as easy to use, portable, and able to interact with computers. Students find that the PASCO™ probeware system is useful in their general chemistry labs, more advanced chemistry labs, and in other science classes, and can be used in a variety of labs done in general chemistry. Students learn the affordances of the probeware through the lab manual, the laboratory teaching assistant, by trial and error, and from each other. The use of probeware systems provides lab instructors the opportunity to focus on the concepts illustrated by experiments and the opportunity to spend time discussing the results. In order to teach effectively, the instructor must know the correct name of the components involved, how to assemble and disassemble it correctly, how to troubleshoot the software, and must be able to replace broken or missing components quickly. The use of podcasts or Web-based videos should increase student understanding of affordances of the probeware.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Statement of Problem

The Laboratory Experience and Instrumentation Usage

The laboratory experience is an essential component of chemistry coursework, and successful completion is required for a baccalaureate degree in chemistry. For other science majors and all engineering majors, laboratory experience is also an essential component of the degree. During the chemistry laboratory experience, instrumentation is used at all levels; the simpler forms of instrumentation such as electronic balances, calculators, simple spectrophotometers, and computer-based laboratory systems are used at the lower levels starting with general chemistry. More sophisticated instrumentation is introduced as the student takes more advanced courses that culminate in a specialized analytical chemistry class where instrumentation usage is directly studied.

Throughout the history of chemistry, instrumentation has been used in the universities, mostly for graduate students. As the undergraduate curriculum has been developed over the last 150 years, instrumentation has been introduced where the instructors deemed it important. Over time, technology usage has increased from using simple electronic balances, glass pipets, and stopwatches to computer-based laboratory systems (CBLs) for measurements and Internet-based lab simulations. As a long-time laboratory instructor, I have taught my students how to use technology that was available for them to use. Students who walked out of my classroom understood how to use the technology, what the instruments were used for, and had a foundational understanding of other potential uses for the technology beyond their own experience, or at least I thought they did.

Science educators, particularly chemistry educators take laboratory experiences for granted. Initial chemistry courses at the university level incorporate lab experiences for the purpose of teaching scientific techniques used in the research laboratory. As the science of chemistry grew, this purpose expanded very little to include training of students in the general university population on scientific techniques. Science departments and subsequently chemistry departments have improved and expanded the technologies used by undergraduate students to the point today where instrumentation is a fundamental component of every laboratory experience.

Technology and Affordances

For students majoring in the sciences, understanding of what technology is used for is crucial, not only in their own major subject, but in the other sciences. The science community is becoming more intertwined with each other in their research, and, more especially, the application of their research. Technology, particularly computer-based technology, is a critical component of research, industry, and education. Students must become familiar with the technology, understand the true uses of the technology, and imagine/predict future uses of the technology that go beyond what is currently done today.

Humans have taken the materials from the surrounding environments and fashioned tools since the beginning of their existence and have used imagination to create new uses for the tools or new tools altogether. When humans look at an object, they naturally create meaning and define a use for those objects based on what they see and do with the object. These uses are called affordances. The study of those uses has only recently begun in the late 20th century. This area of cognitive theory and education is growing and has focused primarily in the area of computer science and computer technology. Very little study has taken place in the sciences, and even less in chemistry. The reasons for the lack of research of affordances of instrumentation in chemistry are unknown. However, that does not take away from the need for this research.

Course Selected for this Study

In this study, I selected the general chemistry laboratory for science majors course at the University of North Texas (UNT), more specifically, the first semester course. All science majors are required to take this course to fulfill their degree requirements at UNT. Any science major that does not take this course at UNT fulfills this requirement by either completing an approved equivalent course at a different college or university or successfully completing the Advanced Placement® test (defined to be a score of either 4 or 5 on the AP Chemistry® test).

I chose this course because it introduces students to chemistry laboratory techniques and concepts that are used in subsequent chemistry courses and in other science and engineering courses. This lab also uses a computer-based laboratory probeware system, PASCO™ PASPORT™, which is new to most students in the general chemistry laboratory. This study is more powerful if the students have little to no prior experience using this particular system or any other similar system, so that I can track student growth in understanding and knowledge of affordances of this technology.

Purpose of this Study

In this research project, the intent of this two-phase, sequential mixed methods study will be to find out what students in the first chemistry course at the undergraduate level (General Chemistry for Science Majors) know about the affordances of instrumentation used in the general chemistry laboratory when they walk into the lab for the first time and how their knowledge develops over time. In the first phase, quantitative research questions or hypotheses will address the relationship of use of instrumentation with the development of knowledge of the affordances of the instrumentation over time. In the second phase, qualitative interviews and observation will be used to probe significant development of knowledge of affordances by exploring aspects of instrumental affordances with students in the general chemistry laboratory at the University of North Texas. The reason for the follow-up with qualitative research is to determine the specifics of where they get the understanding about affordances of the technology: does it come from the instructor, teaching assistant, experiences, discussions with fellow students, readings, or a combination of any or all of these possibilities?

Research Questions

The research questions are below. The instruments that were studied are the PASCO PASPORT™ system, and various probes and components of the PASPORT™ system.

- What do the students perceive as the identity of the instrument(s) in question?

- What do the students perceive as the affordances of the instrument(s) in question?
- What do the students perceive as the usefulness of the instrument(s) in question?

  (a) How can the instruments be used in chemistry beyond this class?

  (b) How can the instruments be used in other sciences?

Definitions of Key Terms

Affordance – the perceived or actual use of an object

Artifact – an object that has a defined purpose and meaning that is retained in the object

Distributed cognition – thinking and knowledge that is shared among a group of individuals that is developed and transmitted by direct communication between the members of the group

Phenomenography – a form of qualitative research that studies the language of a phenomenon; a branch of phenomenology

Significance of Study

This research project is important because students need to be able to apply what they learn in the laboratory to other situations such as advanced chemistry courses and chemistry research, other science courses taken at the undergraduate and graduate levels, and on the job. Students need to take each learning experience they have and apply it to other subjects and future experiences. The general chemistry laboratory is designed to give students foundational techniques and tools for future study in chemistry. What else and where else can the technology be used?

Prior research is scant and is limited to instrumentation used at the upper-level undergraduate courses. This project expands the research done on instrumentation in undergraduate labs. Only one other study exists that directly addresses this issue in chemistry at the undergraduate level. Uses of technology have been extensively studied within the computer sciences, but not with the classic sciences. Studies on the technology used in the general chemistry labs are limited to how well students adapt to the technology and how adept they are at using the technology. My research goes beyond that to the uses of the technology outside their current laboratory experience. How can this technology be used in other sciences such as biology and environmental science? How can this technology be used on the job?

This research project is limited to study of the PASCO system used in the general chemistry laboratory for science majors. The PASCO system is a computer-based laboratory system that incorporates several instruments for measuring into one data gathering system. The PASCO system is designed for ease of use, versatility, accuracy of measurement, and speed of data output. Similar computer-based laboratory systems exist (e.g., Vernier™) and are used in other secondary school and undergraduate laboratory settings.

The participants of this study are undergraduate students taking the General chemistry laboratory for science majors at the University of North Texas. These students tend to be at an early point in their undergraduate career. They also tend to have either declared a science or engineering major, or at the very least, know that they are going to major in one of the sciences or in engineering fields. Students in these laboratory courses must be at least 18 years old to participate in this study. This study does not discriminate based on gender, race, or handicapping condition.

This research project has the potential for a broad impact on pedagogy for undergraduate chemistry, because this study provides evidence of learning the uses of instrumentation in chemistry and the uses of instrumentation beyond the confines of the chemistry laboratory. This study also reinforces the need for instructors to ask students to apply what they are learning to other subjects, such as biology, environmental sciences, and physics. Finally, this study provides evidence that having students learn the uses of technologies will allow students to apply the technology appropriately in novel ways.

CHAPTER II

LITERATURE REVIEW

This chapter summarizes key studies regarding affordances of instrumentation and technology used in science laboratories and classrooms, explains key educational theories and models that are the foundation for this study, and provides a historical perspective on the purpose of the chemistry laboratory throughout the history of chemistry. The educational theories discussed include theory of affordances, theory of distributed intelligence, phenomenography, and the unified learning model. Studies include affordances of technology in chemistry and in other sciences.

Purpose of the General Chemistry Laboratory – A Historical Perspective

The development of the general chemistry laboratory at the university level follows the history of development of chemistry as a science. The first reported chemistry lab was started by a mathematician, Johannes Hartmann, in 1609. Hartman was commissioned to start this lab at the University of Marburg by the nobleman Moritz of Hessia. Hartman was given the title “Professor der Chymiatrie” (Lockemann & Oesper, 1953, p. 203). Hartmann allowed students to work in his laboratory for the purpose of “making of pharmaceutical preparations, using the procedures contained in his manual: ‘Praxis chymiatrica’” (Lockemann & Oesper, 1953, p. 203). In 1683, a similar laboratory was established at the University of Altdorf in Nürnburg, Germany by Johann Moritz Hoffman (Lockemann & Oesper, 1953). During the seventeenth century, the focus of chemistry instruction was on pharmaceuticals and compounding them from herbal and non-herbal sources.

As chemistry developed into a science that focused on analysis of substances and discovery of the elements in the eighteenth and nineteenth centuries, the study of chemistry at universities changed to include analysis and discovery. More universities across Europe and America began including chemistry as a subject of study in the late eighteenth century, but no analysis laboratory course for undergraduates was developed. Laboratory study was reserved for those working towards a medical or a philosophy degree. In the early nineteenth century, that began to change. In 1805-1806, Friedrich Stromeyer at the University of Göttingen in Germany offered the first analytical chemistry lab course for undergraduates "Privatissimis lectionibus Chemiae practicae cursum" (Lockemann & Oesper, 1953, p. 202) followed by "Analyseos chemiae Laboratorio academio instituiendi" (Lockemann & Oesper, 1953, p. 202) in 1810 and "Exercitatianes chemiae practices in Laboratorio academico" (Lockemann & Oesper, 1953, p. 202) in following years. The rough translations for each course title above are 'course for the private lecture in practical chemistry,' 'academic institutional laboratory for chemistry analysis,' and 'practical chemistry exercises in an academic laboratory.' All three of these courses were offered because Stromeyer had a fundamental principle "chemistry could only be really learned through laboratory practice and that the students must be given an opportunity to carry out analyses on their own" (Lockemann & Oesper, 1953, p. 202). Similar labs were established at University of Landshut in 1807 by J. N. Fuchs, and at University of Jena in 1811 by J. W. Fisher (Blick, 1955). In 1824, Justin von Liebig established an analytical chemistry lab for undergraduates at the University of Giessen (Lockemann & Oesper, 1953). All of the first established analytical chemistry laboratories for undergraduates were located in Germany.

In the United States, the teaching of chemistry began in the last half of the eighteenth century, but a laboratory course was not offered until 1825 when the Rensselaer Polytechnic Institute was established (Blick, 1955). Prior to 1825, instructors performed demonstrations with their lectures. At Resselaer Polytechnic Institute, students were required to perform labs and discuss their results to the class prior to the lecture, a very innovative teaching method for the time. As the country grew, so did the number of universities. The new universities were primarily land grant universities that emphasized practical sciences, especially agriculture. These practical sciences resulted in an increase in laboratory use at universities in the United States (Blick, 1955).

The establishment of the chemistry labs in Germany did have an influence on chemistry education in the United States (Siebring & Schaff, 1977). Two scientists in the mid-nineteenth century, Charles Eliot and Ira Remsen had great influence on chemistry education. Ira Remsen studied chemistry in Germany under Liebig at the University of Munich and had a strong enthusiasm for the chemistry laboratory. Remsen brought that enthusiasm back to the United States when he accepted a teaching position at Williams University then Johns Hopkins University. He wrote textbooks for chemistry and helped define how chemistry should be taught while he taught and led Johns Hopkins University in the 1870s through the early 1900s (Getman, 1939). In 1867, Charles Eliot, a professor of mineralogy at Massachusetts Institute of

Technology, published the first laboratory manual *A Manual of Inorganic Chemistry*. Eliot later became president of Harvard.

By the start of the twentieth century, the use of the undergraduate chemistry lab was well established across the United States and Europe. The pattern of at least one hour spent doing laboratory work per week with at least two hours of lecture per week was established in no part thanks to Ira Remsen. In addition, education was progressive; that is, education should include industrial training, agricultural education, and social education. Learning should be based on experiences rather than an authoritarian lecture. By the 1920s, opinions about labs for undergraduates, particularly students taking chemistry to fulfill a general education requirement, began to change. A long debate that spanned over 20 years took place in the chemistry community about the usefulness of individual laboratory experience versus teacher demonstration labs. In a teacher demonstration lab, the instructor would perform the experiment while the students would record and analyze the data. In 1935, Schlesinger argued the point of students doing experiments knowing the expense of doing chemistry labs during the Great Depression. He surveyed university professors and high school teachers across the United States to determine the objectives of teaching chemistry (Schlesinger, 1935, p. 525).

> Although my study of this question has not been exhaustive, I believe that I have gone far enough to justify the selection of the following as the aims of most teachers of high-school and general college chemistry:
> (1) To illustrate and clarify principles discussed in the classroom, by providing actual contact with materials.
> (2) To give the student a feeling of the reality of science by an encounter with phenomena which otherwise might be to him no more than words.
> (3) To make the facts of science easy enough to learn and impressive enough to remember.

(4) To give the student some insight into basic scientific laboratory methods, to let him use his hands, and to train him in their use.

In his conclusion, Schlesinger (1935, p. 528) writes:

> In conclusion, let me repeat that, in planning laboratory courses, it is essential to keep in sight the major objectives-training in observation, in thought, and in action. Although the illustration of principles and the clarification of difficulties by direct contact with the phenomena cannot be neglected, the main purpose must be achieved by selecting as the most significant part of the laboratory work, exercises the results of which the student cannot readily predict. These exercises should, as far as possible, demand the solution of some simple problem by experimental means …. To achieve this ideal in large classes without overstepping the bounds either of the student's mental abilities or the school's financial resources is a difficult task. It will require time, thought, imagination, and creative skill.

The debate between demonstration labs and individual lab work continued through the 1940s. One of the biggest arguments during the 1930s and 1940s against individual lab work was the expense of doing individual lab work (Adams, 1942). Chemistry laboratory work involved many consumable materials that were not needed in other sciences. After World War II and the passing of the G. I. Bill, funding for universities increased as veterans returned to complete a college education.

In the 1950s, the debate between demonstration lab and individual lab work waned, but a new debate was born: Are labs for learning skills and proving chemistry laws/theories using a deductive approach or are labs for gathering data and inductively arriving at general principles? Blick (1955, p. 265) argues that, “a proper balance in the use of inductive and deductive procedures is needed." Learning laboratory skills and techniques are an important part of general chemistry labs as are learning the nature of science applied to chemistry. This debate continued through the 1970s (Siebring & Schaff, 1977). Also, during this debate, a shift from mostly qualitative labs with a few quantitative labs to mostly quantitative labs with a few qualitative labs occurred as instrumentation such as the spectrophotometer was developed for use in the general chemistry lab (Siebring & Schaff, 1977).

In the 1970s, the quality and use of chemistry labs were in decline. Instructors began to question the need for the laboratory in chemistry education, especially if the labs themselves were poorly written or not updated to match current educational practices or scientific techniques. Money for labs became an issue again. According to Pickering, the biggest problem during this time and through the 1980s was a personnel problem – lack of quality people who know how to teach laboratories effectively, with little research experience, and with language barriers (Pickering, 1993). Pickering argues that, "… the teaching laboratory is a recruiting device. It is the excitement of the laboratory that draws people into science" (Pickering, 1993, p. 700). This motivation coupled with meaningful purpose for experiments, should provide a more satisfying learning experience for general chemistry students.

During the 1990s, research into effective chemistry teaching practices increased with the focus on inquiry-based learning as the most effective means for instructing students. This comes full circle with Schlesinger's statement about the main purpose of laboratory instruction: "training in thought, in observation, and in action … [and] … must be achieved by selecting as the most significant part of the laboratory work, exercises the results of which the student cannot readily predict" (Schlesinger, 1935, p. 528). The development of computer-based technology, microscale laboratory activities, incorporation of real-world applications in labs, and smaller scale instrumentation all contributed to the improvement of general chemistry laboratories.

Throughout the centuries, the development of the general chemistry lab has had several main goals: (1) train future scientists in laboratory techniques, (2) train students in the nature of inductive-deductive scientific inquiry, and (3) motivate students to pursue science, particularly chemistry, as a career. All along the way, instrumentation was introduced to the students as it was developed, but only one other person, Eric Malina, has actually stopped and asked the question ‘What do students see as the affordances of the instrumentation?’ His study is discussed later in this chapter.

The PASCO™ System and the General Chemistry Laboratory Experience at UNT

At the University of North Texas (UNT), the general chemistry laboratory courses use instrumentation from PASCO, Inc. The laboratory manual (Acree, 2005) is written to include specific instructions on how to use different components of the PASCO™ PASPORT™ system. The purpose of using the instrumentation is to introduce students to using instrumentation in chemistry labs at the undergraduate level, and to provide students with opportunities to do more inquiry-based laboratories rather than the typical ‘cookbook’ chemistry labs.

PASCO™ is a corporation based in Roseville, California that produces and sells computer-based laboratory systems. It is a competitor with Texas Instruments™ and Vernier™ in hand-held instrumentation for use in the secondary and undergraduate science labs. Their products (PASCO, 2008) include the PASPORT™ Probeware, software for data collection and analysis, curriculum for science courses grades K-12, lab equipment, labware, and other supplies needed to go with the PASPORT™ system and curriculum. Publications in peer-reviewed journals about the PASCO™ computer-based lab interfaces are limited to evaluations of the system (Boleman, 2008; Boyette &

Haase, 1996; McNairy & Mamola, 1996) or labs that use the PASCO™ system and its various components (Chebolu & Storandt, 2003, Choi & Wong, 2002; Choi, Wong, Yiu, & Mark, 2002; Nienart, 1994; Nyasulu & Barlag, 2009; Torres, 2006). Nothing in the literature currently exists regarding research on the PASCO™ system.

Educational Theories and Models that Support this Study

Affordances and Distributive Intelligence Theory

The educational theories this study is based upon are the theory of affordances (Gibson, 1979) and the distributive intelligence theory (Salomon, 1993). According to Gibson, an affordance is what an object or the environment provides to the observer in terms of what the object can be used for (Gibson, 1979). An affordance is based on the observer's visual perception of the object with careful reference to the environment where the object is used. For example, a thermometer is for measuring temperature and a pencil is used for writing down information on paper. Both thermometers and pencils could also be used to stir mixtures because of their long, slender, cylindrical structure. However, it is not good laboratory practice to do so. Affordances are neither good nor bad, nor are they used to classify objects. "You do not have to classify and label things in order to perceive what they afford" (Gibson, 1979, p. 134). I disagree with part of this statement because labels do carry the affordances within them, particularly for computer-based scientific equipment that usually is manufactured pre-labeled. Scientists attach meaningful names to their instruments. Using the example above, the word thermometer comes from two Greek words: *thermos*, meaning heat, and *meter*, meaning measure or measurement. Thus the use for a thermometer, measuring temperature (or change in heat) is built into its name.

According to distributive intelligence theory (Pea, 1993), construction of new knowledge is achieved by effective interaction between the learner and the environment. The environment can include other learners, the teacher, the physical environment, and the tools used in the learning experience. Distributed intelligence is a broader category of individual constructivism. Knowing is gained through activity. Passive observation may not result in learning. The setting in which the activity and interactions take place is a critical component of what the actions mean, and subsequently, the objects or tools used in the activity. The setting (such as a laboratory) may have some of the structured information needed by the individual or group to complete the activity. The overall cognitive process of the activity is distributed between the individual or group and the objects or tools used in the activity. Knowledge is an emergent property of an interacting system and is distributed across the interactive patterns of system elements.

Tools do contain an intrinsic intelligence because the inventor of the tools and the community that uses the tools define their uses and this contributes to the distributed intelligence of the larger community. The individual learner must pay close attention to the properties of the tools and the overall environment in order to contribute to the overall social distributed intelligence. The learner’s background experiences, the connections between the learner’s desire or goal, and the assimilation of the artifact as means towards that goal determine how easy it will be to show the learner how to form a system of distributed intelligence for completing the activity. These three items also determine how a student will complete the activity successfully (Pea, 1993).

Frequently, knowledge is socially constructed through collaborative efforts toward shared objectives and by dialogues and challenges brought about by differing perspectives of members of the group. Intelligence can also be distributed for use in designed artifacts. Artifacts include physical objects such as tools and control instruments, symbolic representations such as graphs, diagrams, and text, and the features of the physical environment. Humans have a natural desire to learn about, shape, and control their environment; they will invent artifacts to help them in their quest and will share the knowledge gained with others around them. Tools do contain an intrinsic intelligence because the inventor of the tools and the community that uses the tools define their uses and this contributes to the distributed intelligence of the larger community. The individual learner must pay close attention to the properties of the tools and the overall environment in order to contribute to the overall social distributed intelligence. The learner's background experiences, the connections between the learner's desire or goal and the assimilation of the artifact as means towards that goal, will determine how easy it will be to show the learner how to form a system of distributed intelligence for completing the activity and completing it successfully.

The Unified Learning Model (ULM)

The Unified Learning Model (ULM) has three components: working memory, knowledge, and motivation (Shell, et al., 2010). Each of the three components work together when learning takes place. According to the authors, "Learning occurs when the firing ability of a neuron is changed." (Shell et al., 2010). Neurons communicate with each other by firing neurotransmitters to each other based on the sensory input received by the neuron. The chemistry of neuron communication is complex. The change in the communication from one neuron to the next occurs when either the nature, duration of firing, or the concentration of the neurotransmitter changes.

The working memory is where sensory input goes for processing. Working memory is limited in its capacity to about 4-5 slots. When a learner is at the beginning stages, the working memory has small slots, but as the amount of knowledge stored in the brain increases, the slots can increase in capacity because of the brain's ability to chunk bits of information into categories for storage. An expert's working memory still has only about 4-5 slots, but the information in that working memory is chunked and very well connected to other information for faster processing. A chunk (Miller, 1956) is simply a connected grouping of information into a "single meaningful entity" (Shell et al., 2010).

Knowledge is both conceptual and procedural. Knowledge is what is stored long term, commonly called long-term memory. In order to build knowledge, a learner must practice and be repetitive in their practice so that the neural firings/communication occurs efficiently and effectively. Someone forgets knowledge because the neurons do not communicate with each other as they used to regardless of how long the neurons had communicated with each other. The more knowledgeable a person is the more connected the neurons are to each other, plus the neurons communicate with each other efficiently (Shell et al., 2010).

Motivation is the desire to learn and maintain effort in the work. Learning is both easy and difficult. Learning that is based on living in the world (episodic learning) is easy; learning abstract concepts and skills (semantic learning) is difficult. Motivation is based on how well the working memory works and how much knowledge we already have. If the working memory is limited because the knowledge we have is not well connected or missing, then much more motivation is needed to make the learning take place. Emotions, self-efficacy (the belief that I can do the task), and interest all play a part in motivation (Shell et al., 2010).

ULM is supported by Gibson's theory of affordances and the theory of distributed intelligence, both of which are based on the theory of constructivism. ULM discusses how the brain constructs knowledge by making connections to prior learning and experiences just as constructivist theory does. ULM gives a biological and physiological basis for affordances. As information about the uses of a tool is put into working memory through visual and tactile perceptions, the brain works to make connections to procedural knowledge that the brain already has about that tool or similar tools. Thus, the brain develops procedural knowledge about the affordances of the tool in question. The brain can and does make incorrect connections (misconceptions), which takes time to undo. Distributed intelligence theory applies to the knowledge component and the motivation component of ULM. With distributed cognition, the procedural knowledge associated with a tool is gained through both episodic and semantic learning. Episodic learning occurs through the interaction between the learner and the tool in a natural setting and through interactions between the learner and other learners and between the learner and the instructor. Semantic learning involves the learner interacting with words, symbols, and ideas found on the page or coming directly from an expert to be memorized. With ULM, social interaction is a human drive that the brain needs. Hence, social interaction is important. When learning occurs in a natural setting, this also provides motivation for the learner and allows episodic learning to take place. Since episodic learning is easier than semantic learning, the human brain prefers episodic learning. The combination of social interaction and a proper learning setting increases interest in semantic learning by the student.

Biological Research Supporting Affordances

Recent research in neurophysiology (Gabarini, 2004) describes two classes of visuomotor neurons: canonical neurons and mirror neurons. Both types of neurons fire during tasks involving the execution of actions and pure observation. The canonical neurons respond to the presentation of a three-dimensional object in terms of its shape, size, and spatial orientation; in other words, they figure out how it looks. These neurons not only fire in response to the same object, but they will also fire when other objects with similar characteristics are presented. Mirror neurons are active during the execution of actions. Mirror neurons have the ability to fire during an observational task without any movement; however, they do not respond to the presence of objects, but to the observation of actions carried out by other individuals. So how does this pertain to affordances? Affordances directly couples perception and action. The visual control of the hands is inseparably connected with the visual perception of the objects used. Canonical neurons provide the reason for the existence of a mechanism in which object shape and function are paired and directly perceived by the observer. While observing an object, the neural system is activated as if the observer were interacting with it, simulating potential actions done with the object by the observer. The mirror neurons can create the meaning of the potential actions independent of the fact that the learner has yet to perform. This creation is a result of either just hearing about it or seeing it. In other words, seeing the object being used is learning how to operate it. Thus, the learner creates affordances that can be shared with the rest of the group.

Phenomenography

In order to get an accurate view of growth of student knowledge over time, this study will be a combination of quantitative and qualitative methods. The qualitative methodology has a theoretical basis in phenomenography (Akerlind, 2005; Bowden & Walsh, 2000; Marton, 1981). Phenomenography is a research technique that focuses on the student's experience of learning in his or her own words through interviews and self-reporting. The key part of phenomenography is the student's words. The goal is to describe how the learning is occurring and how the teaching and assessing affect the student's learning experience. Phenomenography studies the ways of experiencing a particular phenomenon; in this study the phenomenon is affordances of instrumentation. This leads to the expectation that different ways of experiencing use of instrumentation will be logically related through the common phenomenon of affordances. This form of research has occurred exclusively in higher education as my study does.

Phenomenography explores the range of meaning within the group of individuals as a group. Every interview is transcribed and the transcript is the focus for analysis. The analysis process looks for emerging meanings from commonalities of responses from the group and includes the structural relationships linking different ways of experiencing learning as expressed by the individuals in the interviews. Transcripts are read and re-read by the researcher who looks for the emerging similarities and differences between the participants' responses, then grouped and regrouped based on categories of description that result from those similarities and differences. Categories of description, which include the emerging meanings and structural relationships, represent a structured set that represent the full range of ways of experiencing the phenomenon in question by the individuals studied. In this study, the focus will be on what the uses of the instrumentation are and how they can be used. Also, focus will be on similarities and differences within and between categories and portions of transcripts that fit the categories.

Validity is accomplished through feedback from the population that was sampled, not necessarily the sample itself, or through feedback from the research community. Reliability is established through dialogic reliability check (Akerlind, 2005). In a dialogic reliability check, the researcher discusses categories seeking mutual critique of the data and of each researcher's hypotheses within the research community. The purpose of using the dialogic reliability check is to focus on the set of interviews as a group rather than the individual interviews. In this study the researcher will gain validity and reliability of the interview data through feedback from the research community and through a dialogic reliability check. Comparison of the qualitative data with the quantitative data will also reinforce categories generated from the interview data.

Prior Studies on Affordances of Instrumentation and Technology in Science Laboratories and Classes

Prior Studies on Affordances in Chemistry

A literature review by Pienta (2005) showed how undergraduate laboratory goals and focus have changed over the years. The original purpose of the laboratory was to provide students a hands-on experience doing chemistry, but has evolved over the years from seeing chemical principles in action to a "cookbook" approach of getting specific results with little connection to the lecture portion of the course. The chemistry lab is supposed to be an opportunity to learn problem solving and the scientific method as is done for apprentice graduate students. Decades of research show that there is no clear evidence of learning in the chemistry laboratory. In the last 10 years, that has changed with the development and implementation of computer technology and interface devices coupled with guided inquiry, cooperative learning, and the science writing heuristic. The technological gains have helped speed up the collection of data, improved visualization of the data, and allow students to manipulate research quality data. The technology also allows chemistry education researchers to better observe and measure effective teaching and learning in the laboratory. Pienta suggested studying the distributed cognition occurring in the laboratory, affordances of technology used in the chemistry laboratory, the framework of learning and interaction with the environment, student and teaching assistant perspectives, and alternative assessments for the laboratory course. Doing these things provides evidence of successful learning in the chemistry laboratory.

Nakhleh and Krajcik (1993, 1994) studied how technology affected conceptual development of acid-base theory for secondary chemistry students. They found that the use of technology in the form of microcomputer based labs and the type of instrumentation used (pH meters) had a strong influence on the understanding of the concepts taught. No undergraduate students were participants in the study and no study on how well the technology transferred to other courses or later chemistry courses was done. Neither was a study of the affordances of the available technology included.

A later study by Malina and Nakhleh (2003) addressed the need of study of affordances. In this study, they looked at how upper-level undergraduate students developed affordances of a CCD UV/Vis spectrophotometeter. For students, the graphical display of data had the most affordances, followed by time, and the probe. These artifacts helped develop conceptual learning in the laboratory; however, most conceptual lab learning occurs outside the laboratory experience after the lab. Both investigators stated that further study was needed on affordances that are common to all scientific instruments and more depth of study was needed.

A letter (Clark, 2004) to the editor of the *Journal of Chemical Education* questioned the use of the word affordance since it was "educationese" (Clark, 2004, p. 486) and not well defined. Malina's response addressed that issue by saying, "Unlike characteristics or physical properties, affordances cannot exist independently of the person perceiving the object and the context in which the object is perceived. "... The affordances of the CCD spectrophotometer are dependent upon a person's background (previous experience with the spectrophotometer, understanding of its designed purpose, etc.) and current need for the spectrophotometer" (Malina & Nakhleh, 2004, p. 486).

The article by Malina and Nakhleh (2003) is only a part of the bigger study by Malina (2002). In Malina's dissertation work, he studied upper level undergraduate students' development of affordances of the computer-interfaced Spectronic 20 spectrophotometer, the stand-alone Spectronic 20 spectrophotometer, and the CCD spectrophotometer. In this work, the focus was on how the affordances impacted the students' interpretation of data and understanding of chemistry concepts. Instructor objectives, experiment designs, instrument designs, and student objectives had an influence on the affordances perceived by the students. The affordances of each of the spectrophotometers were based upon how the data were recorded, how the data were displayed, and the nature of the data collected. Time also played an important role. Fast data acquisition kept students focused on procedural issues because of their objective to leave the lab as quickly as possible. On the other hand, data collection that was long and laborious decreased students' drive to complete the lab. Computer recording and graphical representation of data helped students stay motivated and provided visual representations of experimental data that supports abstract concepts taught in labs. Again, further study should involve more instrumentation and a more in-depth look at the affordances.

Prior Studies on Affordances in Other Sciences

In the field of biology, one study has taken place concerning affordances. This study (Ching, 2008) looked at elementary students in a collaborative project on marine biology. The authors studied the affordances of collaborative patterns among students for effective learning. They concluded that experienced students' effective, thoughtful, and strategic collaborations with less experienced students resulted in growth for the more experienced students as well as the less experienced students. This study clearly does not address affordances at the undergraduate level, nor did it address instrumentation.

In the field of physics, several studies have taken place concerning affordances in the laboratory. One study (Siorenta, 2008) examined physics teachers' beliefs and perceptions of laboratory and interactional computer technology (ICT) in physics instruction in the secondary classroom. Siorenta's study concluded that personal factors are strongly associated with teacher beliefs and perceptions, particularly with the application and use of modern technology in the laboratory. Two studies (Rolf, 1995; Rolf, Woszczyna, & Smith, 1998) looked at student learning in interactive computer environments in a high school physics class using the program, Interactive Physics™. One study showed students' learning occurred using the technology whether or not the teacher was present, because the computer's interface allowed effective student interaction with the microworld in the program and facilitated student discussion of the concepts. The other focused on the computer settings' affordances with student coordination of their interactions. Both positive and negative affordances were studied. This study concluded that the computer microworld as a tool limited students' sense making activities, yet contributed significantly to maintenance and coordination of students' physics conversations. As technology has improved, the negative affordances have decreased (Rolf, Woszczyna, & Smith, 1998). Both studies shed light on affordances of technology in the laboratory; however, they are limited to the secondary classroom and secondary students, not university students.

CHAPTER III

METHODOLOGY

Introduction

The purpose of this study is to determine what students in the first chemistry course at the undergraduate level (general chemistry for science majors) know about the affordances of instrumentation used in the general chemistry laboratory. The instrumentation used is the PASCO™ system. This study focused on the following:

- Student perception of the identity/meaning of the instrument(s)
- Student perception of the affordances of the instrument(s)
- Student perception of the usefulness of the instrument(s), including how the instrumentation could be used in other chemistry courses and other science courses

This study was also concerned with how students' knowledge of the affordances of the PASCO™ system expands and develops over time. In order to get an accurate view of growth of student knowledge over time, this two-phase sequential study incorporated a survey-based quantitative study in the first phase and an interview-based qualitative study in the second phase. The purpose for using both qualitative and quantitative research methods was to strengthen the results of both methods. The quantitative methods provide data on knowledge of affordances of the instrumentation from many students, while the qualitative data provide details on the affordances that a survey alone cannot offer. The theoretical basis for the quantitative part of the study is made available in cognitive psychology studies (Gall, Gall, & Borg, 2003). In cognitive psychology, structures and processes involved in mental activity and how those structures and processes mature over time are studied. To track the expansion of knowledge about the affordances of the instrumentation over time, assessments are given at the beginning of the course, midway through the course, and at the end of the course.

The theoretical basis for the qualitative part of the study is phenomenography (Akerlind, 2005; Bowden & Walsh, 2000; Marton, 1981). Phenomenography focuses on the student's experience of learning in his or her own words through self-reported accounts. Responses to short-answer questions on the surveys and interviews determine what they have learned about the instrumentation and how students learn from the instrumentation and from each other. The combination of the observations, interviews, and assessments provide triangulation of the data. The use of the interviews complements the results from the surveys and illustrates the results of surveys with deeper statements from the students about the instrumentation. Observations of student-student, student-teaching assistant, and student-instrumentation interactions will also support the results from the surveys and interviews. Using a combination of quantitative and qualitative methods provides reason for application of the results of this study to other similar university settings.

Description of Setting and Instrumentation

At the University of North Texas (UNT), the Laboratory Sequence for General Chemistry (CHEM 1430 and CHEM 1440, respectively) use the PASCO PASPORT™ probeware and data acquisition system (Version 1.9.0) for many of the laboratories. The probeware system is connected to a computer that contains the DataStudio™

software. This software is used for collecting, analyzing, and displaying real-time results in either graphical or numerical formats. The sensors used in the courses include pH probes, pressure transducers, drop counters, temperature sensors, colorimeters, and voltage sensors (W. E. Acree, personal communication, April 24, 2009). The lab manual used is *Modern General Chemistry Laboratory* (Acree, 2005). In this study, the focus is on the CHEM 1430 lab course, the first in the sequence. This class is chosen because almost all of the students that enroll in the course have no experience with the PASCO PASPORT™ system and because it is an off-sequence course (a first-semester course taken in the spring), the probability of having students under 18 years of age is minimal. Some students have possibly had some experience using similar technology in prior high school or college courses, but from the pilot study indications are that only a few experiences exist.

The components of the PASCO PASPORT™ system that are used in the CHEM 1430 lab are:

- PowerLink™ (Model PS-2001)
- Absolute Pressure Sensor™ (Model PS-2146)
- Temperature Sensor™ (Model PS-2125)

The Drop Counter™ (Model PS-2117) is a fourth component of this system that is included in this study and is used in the second semester of general chemistry laboratory. This component is included in this study to check for consistency of student responses.

The PowerLink™ has two main components: the PowerLink™ assembly and the USB cable assembly. The PowerLink™ is a three-sensor port. The USB links contain built-in general-purpose USB hubs and a PDA assembly; it is used for connecting various sensors, and multiple sensors, to the computer so that the DataStudio™ software can collect and graph the data in real-time (PASCO, 2005d).

The Absolute Pressure Sensor™ measures gas pressure. The range of measurement is from 0–700 kPa ±2 kPa. The sensor can also measure pressure in units of $N \cdot m^{-2}$, psi, atmosphere, and torr (PASCO, 2005a).

The Drop Counter™ measures the number of drops per sample of liquid or fine particulate that pass by the detector. The Drop Counter™ reports the data in either number of drops or as fluid volume in milliliters. The range of measurement is from 0–10 drops $\cdot$ s^{-1} (PASCO, 2005b).

The Temperature Sensor™ measures temperature in either degrees Fahrenheit, degrees Celsius or in units of kelvin. The range of measurement is -35–135 °C ±0.5 °C. The Sensor will measure accurately to the nearest 0.01 °C (PASCO, 2005c).

Pilot Phase of This Study

Data Collection Methods

A pilot study was conducted in fall 2009 to get some initial data for comparison with the full study and to establish the reliability of the instrumentation used in this study. First, approval of this project was obtained from the Institutional Review Board (IRB) at UNT. (IRB documentation can be found in Appendix A.) Second, information about this project was shared with the general chemistry lab sections on the first day of class with a letter detailing the purpose and methods of the project. Students were informed about the age restriction (being over 18 years old) before starting this project. No other restrictions were included. Participants were not discriminated against based on gender, race, or handicapping condition. Students were encouraged to participate in this study. Only volunteers were accepted in this study. Thirty-five students volunteered to participate from three lab sections, and of these, 33 student data sets were used. Two were not used because they dropped the course during this study.

After informing the students and obtaining consent to participate, an initial quantitative survey was given before the first lab started. This survey determined an initial level of knowledge about the affordances of the PASCO™ system and its various components and contained three sections:

Part 1: demographic data regarding age, gender, experience in chemistry laboratories, prior chemistry classes taken, and experience using technology in a lab setting

Part 2: a Likert scale for determining the level of understanding of the affordances of the instruments

Part 3: a set of short-answer questions regarding individual components of the PASCO™ system described above

A second survey that asked the same questions as the initial survey was given late in the semester. The purpose of giving the same survey again was to look for patterns and changes in understanding over time.

For the qualitative part of the pilot study, all students who participated in the quantitative study were invited late in the semester to participate. If students chose not to participate, other students who participated in the quantitative phase were invited to participate until a total of three agreed to participate. Only one interview occurred and was audio recorded. The interview was 45 minutes long. The interview consisted of a semi-structured set of questions about the probeware and about the labs that used the probeware. Questions covered the general purpose, uses, and usefulness of the PASCO™ system; and the purpose, uses, and usefulness of PASCO™ system and components in three specific laboratories.

The labs asked about in the interview were “Experiment 1A: Statistical Analysis on Different Types of Pennies” (Acree, 2005, pp. 1-12), “Experiment 7: Gas Laws – Verification of Boyle’s Law, Charles’ Law and Avogadro’s Law” (Acree, 2005, pp. 77-88), and “Experiment 10: Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water” (Acree, 2005, pp. 109-118). These labs were chosen because they correspond to timing of giving the survey (beginning, middle, and end of semester), and were assigned laboratories by the instructor. Experiment 1A was specifically chosen because it uses the DataStudio™ software component of the PASCO™ system. Experiment 7 was specifically chosen because this lab requires the use of three components: PowerLink™, Temperature Sensor™, and Absolute Pressure Sensor™. Experiment 10 was specifically chosen because this is the first of several labs that were completed before the end of the semester that uses the PASCO™ system and the Temperature Sensor™. In the subsequent labs, students were provided an option for using either a thermometer or the system with Temperature Sensor™. (See Appendix B for pilot study instrumentation.)

Pilot Study Data Analysis

After gathering the quantitative data, analysis of these data were statistically evaluated using SPSS 14.0 software looking for trends in the data for Part 2 (Likert scale for determining the level of understanding of the affordances of the instruments) through descriptive statistics and graph analysis. No correlational statistics were run because the purpose of the pilot study was to establish reliability and validity.

For Part 3 (short-answer questions regarding individual components of the PASCO™ system), student responses were quantified based on the words used (or in many cases not used) in the responses to two questions: “What is this device?” and “What is it used for?” The individual responses were tallied and graphed then the responses to the initial survey were compared graphically to the responses to the second survey. No coding system was developed during the pilot study for this part of the survey, because the tally of these responses provided a reason to code the responses in the main study the way that they were coded. Towards the end of the analysis of the question “What is it used for?” I developed a coding system to categorize the responses as there were numerous different answers that were difficult to quantify.

After gathering the qualitative data from the interview, patterns in the answers to interview questions were determined and compared to the results from the surveys to see if the interviews reinforce and elaborate on the results from the surveys. No coding was done on the interview. However, the responses to the questions on the interview were used to reinforce the data gathered in the quantitative portion of the pilot study.

Main Phase of This Study

Main Phase Participants

Participants in this study were volunteers enrolled in General Chemistry for Science Majors Laboratory (Chemistry 1430) during spring 2010. A large majority of students are in the age range of 18-22 and are fairly evenly distributed in numbers among freshmen, sophomores, and juniors. Participants were limited to being at least

18 years of age or older. Participants were not discriminated against based on gender, race, or handicapping condition. Fifty students volunteered to participate from seven lab sections and 34 student data sets were used. Sixteen were not used because they had either dropped the course during this study or did not complete at least one of the three surveys.

Data Collection Methods

Information about this project was shared with the students enrolled in Chemistry 1430 during the first laboratory recitations before the actual labs began. This allowed me the opportunity to gain access to a significantly large sample population for my study since all Chemistry 1430 students were required to attend this recitation on safety. As with the pilot study, a letter detailing the purpose and methods of the project was provided. Students were informed about the age restriction (being over 18 years old) before starting this project.

After informing the students and obtaining their signed consent to participate along with obtaining the necessary demographic information from Part 1 of the survey, an initial assessment of lab skills was used to obtained an assessment of knowledge on lab equipment used in their high school chemistry courses. In addition this assessment checked the validity of student responses to two demographic questions: “Did you take a chemistry class in high school?” and “If yes, did you do labs in your chemistry class in high school?”

Also administered was an initial quantitative survey that was very similar to the survey given during the pilot study. As discovered upon the evaluation of the pilot study, changes were made to Part 3 of the survey in order to improve student response rate for this section. This survey determined an initial level of knowledge about the affordances of the PASCO™ system and its various components. The three sections were as follows:

Part 1: Demographic data regarding age, gender, experience in chemistry laboratories, prior chemistry classes taken, and experience using technology in a lab setting

Part 2: A Likert scale for determining the level of understanding of the affordances of the instruments

Part 3: A set of short-answer questions regarding individual components of the PASCO™ system described above

In Part 3 of the survey, the pictures (see Appendix C) used for the components to be identified were improved upon for clarity. Also, as determined from the analysis of the pilot study a check box labeled “I don’t know” was added to the questions about the name of the component and the use of the component.

Two surveys that ask the same questions as the initial survey for Parts 2 and 3 were given. The second was given at mid-term; the third was given towards the end of the semester. The purpose of giving the same survey three times was to look for patterns and changes in understanding over time.

At mid-term, I went to the Chemistry 1430 labs and observed students as they used the PASCO™ system during two labs: “Experiment 10: “Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water” (Acree, 2005, pp. 109-118), and “Experiment 11A: “Calorimetry II – Determination of Heat of Chemical Reactions and Heat of Dissolution” (Acree, 2005, pp. 119-128). During the observations, I was looking at the social interactions between the students as they used the probeware of the PASCO™ system, the interactions between students and the teaching assistants when the students asked for help while using the probeware, and how the students used the system and interacted with the graphical interface of the system.

At mid-term, 48 students who agreed to participate in the quantitative part of this study and were still in the course were invited to participate in the qualitative part of this study. If students chose not to participate, other students were invited from the whole group until a group of ten students agreed to participate. Once students agreed to participate, interviews began late in the semester. A total of six interviews were conducted.

The interviews consisted of a semi-structured set of questions (see Appendix C.) about the probeware and about the labs that used the probeware. Questions covered the following topics:

(1) General purpose, uses, and usefulness of the probeware

(2) Purpose, uses, and usefulness of probeware and components in three specific laboratories

(3) Social interactions during lab in relation to the probeware and labs in general

The inclusion of the third topic of the questions addressed the social aspect of laboratories and how the students learned the affordances of the system. The labs asked about were "Experiment 1A: Statistical Analysis on Different Types of Pennies" (Acree, 2005, pp. 1-12), "Experiment 7: Gas Laws – Verification of Boyle's Law, Charles' Law and Avogadro's Law" (Acree, 2005, pp. 77-88), and "Experiment 10: Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and

Enthalpy of Fusion of Water" (Acree, 2005, pp. 109-118). These labs were chosen because they corresponded to timing of giving the survey (beginning, middle, and end of semester), and were assigned laboratories by the instructor. Experiment 1A was specifically chosen because it uses the DataStudio™ software component of the PASCO™ system. Experiment 7 was specifically chosen because this lab required the use of three components: PowerLink™, Temperature Sensor™, and Absolute Pressure Sensor™. Experiment 10 was specifically chosen because this was the first of several labs that were completed before the end of the semester that uses the Temperature Sensor™. In the subsequent labs, students were provided an option for using either a thermometer or the system with Temperature Sensor™. (See Appendix C for the instrumentation used in the main study.)

Reliability and Validity of the Instrumentation

In this study, validity was established through the completion of the pilot study. The pilot study contained at least thirty participants in the quantitative phase and one in the qualitative phase. Comparison of the results of the pilot study with the main study showed that the results are consistent from the pilot study to the main study.

The reliability of the results of the initial assessment of chemistry lab skills was accomplished through split-half correlation to find the coefficient of internal consistency (Gall, Gall, & Borg, 2003). The value of the coefficient of internal consistency was 0.85. This coefficient was corrected using the Spearman-Brown prophecy formula because the assessment was short, less than 30 questions. The Spearman-Brown prophecy formula helps account for the shortness of the assessment by predicting what the reliability would be if the number of questions were increased by a multiplier. The multiplier raises the number of questions to a statistically significant number. In this formula, $\rho^{*}_{xx'}$ is the predicted reliability, $\rho_{xx'}$ is the reliability of the current test and N is the multiplier for the number of replications of the test.

$$\rho^{*}_{xx'} = \frac{N\rho_{xx'}}{1 + (N-1)\,\rho_{xx'}}$$

For the survey, Cronbach's coefficient alpha was calculated to determine reliability of the survey. This alternative method is appropriate since the survey is not dichotomous and contains short answer questions (Gall, Gall, & Borg, 2003). The value for Cronbach's coefficient alpha for Part 2 of the survey is $\alpha = .67$.

In addition, for Part 3 of the survey, which contained short answer questions that needed to be quantified, an interrater reliability was conducted. A description of the process of establishing interater reliability is described below. I had 92% reliability in the Part 3 survey response, This reliability is considered acceptable (Borg, Borg, & Gall, 2003).

Main Phase Data Analysis

After gathering the quantitative data, analysis of these data were done using SPSS 14.0 software looking for trends in the data from Part 2 of the survey through simple statistical analysis. Patterns of growth were also assessed through graphical analysis. Correlations between demographic data and initial assessment results are also assessed through correlational statistics.

The coding schemes developed for Part 3 of the survey data with regards to the two questions: "What is this device?" and "What is it used for?" are found below in Tables 1 and 2.

Table 1

Coding Scheme for Survey Part 3 Question: "What Is This Device?"

Coding Value	Category for Coding
1	No answer given
2	I don't know/remember
3	Wrong answer given
4	Close to correct answer
5	Completely correct answer

Table 2

Coding Scheme for Survey Part 3 Question: "What Is It Used for?"

Coding Value	Category for Coding
1	No answer given
2	I don't know/remember
3	Wrong answer given
4	Close to correct answer
5	One correct use given when multiple uses
6	Completely correct answer

After gathering the qualitative data from the interviews and observations, I transcribed the raw data from the audio recording and hand-written observation notes into a readable form that can be easily analyzed. These transcribed data sources were the focus of the data analysis.

After reading the transcripts, patterns in answers to questions began to emerge. These patterns were also detected in the observation notes. A coding system was developed to correlate the interview data with the observation data and the survey data. The coding system was also matched to the research questions. (See Appendix D for the main phase interview-coding guide.) The survey questions and the interview questions overlapped frequently, so patterns were easy to spot.

Interrater Reliability

To establish the reliability of the coded data from the questions in Part 3 of the Survey, interviews, and observations, interrater reliability checks of the coded data were performed. A graduate student volunteered to assist me. The student was trained in the coding system for the interview and observation-coding scheme with one interview and one day of observation notes. She was also trained in the coding scheme for the Part 3 survey questions with one survey. These artifacts were selected because they had a high frequency of coded passages as well as high variability in the coding categories used. This allowed us to discuss the coding categories based on both definitions of the categories and examples from the texts.

During the training, the rater was provided a copy of the coding system with definitions and the coding system without definitions for clarity. Next, the rater was shown an example of a coded document. During the training, the rater and I discussed the system and I clarified any misunderstandings and answered questions until I was satisfied the rater could code on her own. Next, the rater was given an interview and one day of observation notes for her to code on her own. I was present in the room with her to answer any question she might have had while working through the two training passages. After she completed the coding, she explained to me her justifications for coding the way she did. During her explanation, I was comparing her codes to my own, and any differences were discussed. Clarification of definitions and category boundaries were also discussed.

Once common understandings of the coding categories were apparent, I gave her three sets of student surveys. These sets contained the responses from three different students over the course of the semester. She coded a total of nine surveys. These surveys were selected due to high frequency of coded passages and high variability in coding categories found. After she completed coding this set of surveys, we compared her assigned codes with my assigned codes. I recorded the number of passages that were coded identically and the number of passages coded differently. We then discussed differences in our codes. Any obvious coding error was identified and corrected. Any other coding that was different because of different interpretations was left unchanged. We had 92% reliability in the Part 3 survey response. This reliability is considered acceptable (Borg, Borg, & Gall, 2003).

I then gave her a second interview and two more days of observation notes. These passages were selected due to high frequency of coded passages and high variability in coding categories found. After she completed coding this second set of passages, we met to compare her assigned codes with my assigned codes. I recorded the number of passages that were coded identically, the number of passages coded differently, and the number of passages that one person had coded and the other had not. We then discussed differences in our codes. Any obvious coding errors were identified and corrected. Any other coding that was different because of different interpretations was left unchanged. We had an overall reliability of 83%, with 90% reliability in the interview passages and 76% reliability for the observation notes. All of these reliabilities are considered acceptable (Borg, Borg, & Gall, 2003). These values reflect the reliability of the coding systems created to categorize student responses to the questions in Part 3 of the survey, the interviews, and the observation notes.

CHAPTER IV

DATA ANALYSIS

In this chapter, results from the quantitative phase of this study and results from the qualitative phase of this study are discussed. The quantitative phase involved an initial survey of volunteer students before they began doing labs and an initial assessment of their high school chemistry laboratory experience, followed by two more surveys that occurred at mid-semester and again towards the end of the semester. The purpose of doing the same survey three times over the course of the spring 2010 semester was to track growth in student knowledge about the PASCO™ system over time. The qualitative phase involved audio-recorded interviews of individual students (with their permission) at the end of the semester and observations of student behaviors and interactions while using the PASCO™ system during their general chemistry laboratories.

Pilot Study Results

An investigative survey (Appendix B) was given twice during the fall 2009 semester for the pilot study. There are three parts to this survey. The first part asked for demographic data that are relevant to this study. Part 2 contained a series of statements about the probeware system as a whole that the students rank using a Likert scale. The Likert scale was 1 – *strongly disagree*, 2 – *disagree*, 3 – *I don't know*, 4 – *agree*, and 5 – *strongly agree*. Part 3 contained a set of questions about specific components of the probeware system asking if the students had used the component before, what the name of the component is, and what the component is used for.

Results of the first round of surveys show that students in general did not know the purpose or the uses of the PASCO™ system used in the general chemistry labs; nor did they know if the system would be useful outside of this chemistry lab, if it would be easy or difficult to use, or if it was portable. A few students were able to identify the Temperature Sensor™ initially (4 of 35 participants or 11%), as they had worked with that probe before, and correctly state the use of the Temperature Sensor™ (to measure temperature). However, no one knew the identity the PowerLink™, the Absolute Pressure Sensor™, or the Drop Counter™; nor did they know the uses of those three commonly used components of the PASCO™ system. Three of the components (PowerLink™, Temperature Sensor™, and Absolute Pressure Sensor™) were used during this semester; the fourth (Drop Counter™) was not and was part of the survey to help to ensure integrity of student responses. Most surveys only had Likert-scale questions answered; the short answer questions involving the four components were left blank (71%). One possible explanation for an omission is "I don't know," but a simple oversight is also feasible. Figure 1 illustrates the results from both initial and mid-term surveys for Part 2 questions. Figure 2 illustrates the results from both initial and mid-term surveys for Part 3, question 1.

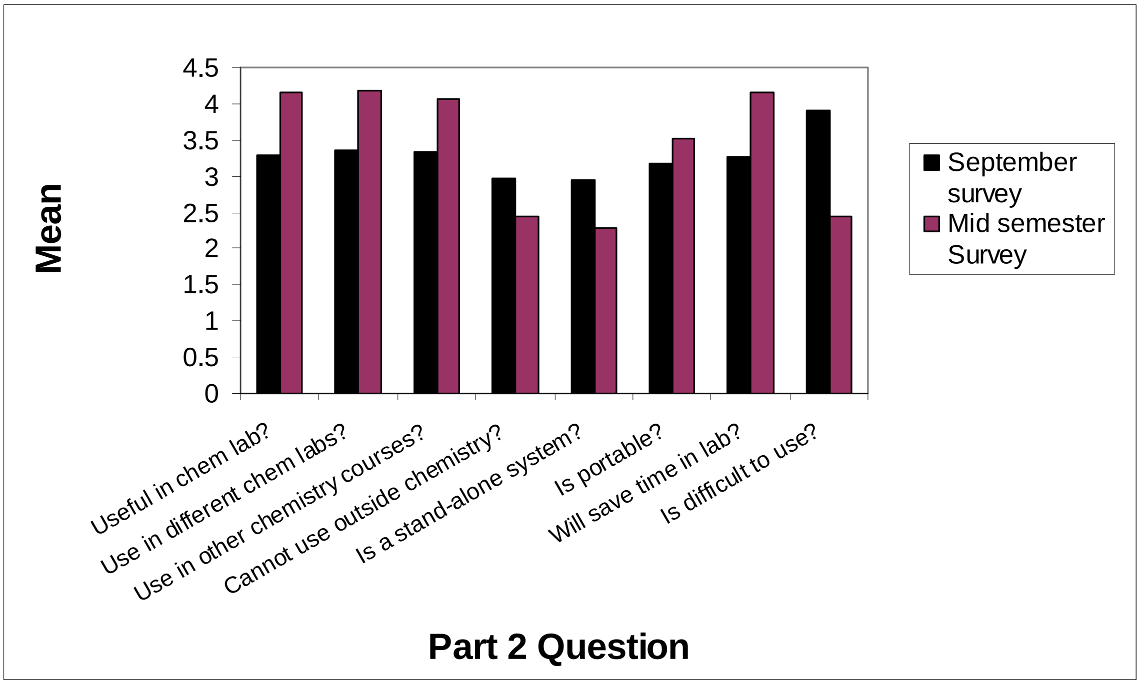

Figure 1. Pilot study survey comparisons of Part 2 results from first survey to second survey (1 = *strongly disagree*, 3 = *I don't know*, 5 = *strongly agree*) for determining the level of understanding of the affordances of the instruments.

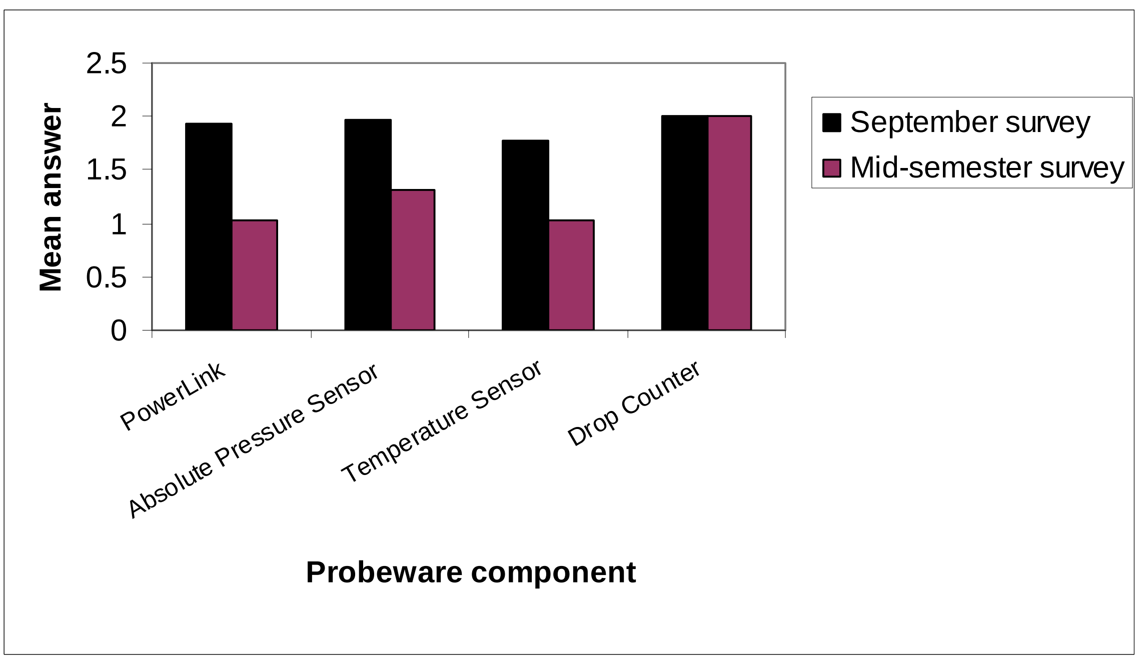

Figure 2. Pilot study survey result comparison of first and second surveys Part 3, question 1: "Have you ever used this device before?" about different components of the PASCO™ system (1 = *yes*, 2 = *no*).

Results from the second round of surveys showed the students did know the purpose of using the PASCO™ system in the general chemistry labs, but were still somewhat unsure if it would be useful outside of this chemistry lab, knew it was easy to use, and knew it wasn't portable. More short answer questions involving the four components were answered (at least 50%), even if not always correctly. This indicates that a greater number of the students did use the system and did learn some of the affordances of the components of the PASCO™ system. The temperature probe again was most correctly identified (50%) and its use was correctly identified more often (41%). The PowerLink™ and Absolute Pressure Sensor™ were correctly identified more often; however, the Drop Counter™ was not correctly identified. The questions for the Drop Counter™ still remained unanswered the most (81%).

Figures 1 and 2 show changes in student responses over time for Part 2 survey questions and for Part 3, question 1, "Have you used this device before?". From Figure 2, students do gain experience using the PowerLink™, the Temperature Sensor™, and the Absolute Pressure Sensor™, but not the Drop Counter™. From Figure 1, students' opinions about the probeware change over time from "I don't know" to a more defined opinion of agree or disagree. This is because students gained experience using the probeware.

Similar graphs for comparison of results for the identity and use of the four components of the probeware in the PASCO™ system can be found in Appendix E. The data from Appendix E gives the details regarding student names for the components asked about in Part 3 of the survey and results of an initial coding of the answers regarding usage of components asked about in Part 3 of the survey.

Demographic data for the pilot study can also be found in Appendix E. The data included in Appendix E allow the reader to compare the participant group in the pilot study with the participant group in the main study.

In the pilot phase of this study, patterns in the answers to interview questions were determined and compared to the results from the surveys to see if the interviews reinforce and elaborate on the results from the surveys. This process is described in Chapter 3 – Methodology. The pilot study does give some initial data that answers the research questions. Students can identify an instrument after using the instrument. While the name is not always correct, students can give the instrument a name that does reflect its primary use. They can also identify affordances of the instrument. Students do see the PASCO system as useful in the general chemistry lab because the system gives students accurate data in real-time, is easy to learn, and saves them time in lab. Students see the PASCO system as useful in other chemistry courses provided the system makes the measurements and collects the data that are needed in the lab. Students don't see it being used in other sciences; however, the interviewee could see it being used in a physics lab.

Main Study Results

Demographic Overview of Participants and Results of Initial Lab Assessment

In the study conducted in spring 2010, 50 students over the age of 18 volunteered to participate. All the volunteers were enrolled in Chemistry 1430, General Chemistry Laboratory for Science Majors at the University of North Texas. Of the 50 participants, 48 completed the initial survey, 46 completed both the initial and middle survey, and 34 completed all three surveys over the course of the semester. Therefore these 34 students are the focus of the quantitative phase of the study.

The participants were fairly evenly distributed between male and female: 16 male students and 18 female students (47.1% and 52.9%, respectively). Twenty-six were between the ages of 18 and 22, seven were between the ages of 23 and 28, and one was between the ages of 29 and 34 (76.5%, 20.6%, and 2.9%, respectively). No one was over the age of 34.

Almost all students took high school chemistry during their high school careers (94.1%). Only two students (5.9%) had not taken chemistry in high school: one was between the ages of 23 and 28 years old and the other was between the ages of 29 and 34. Of those who took high school chemistry, only two admitted they had not done labs in high school chemistry. Six students (17.6%) took college-level chemistry prior to this class. One student selected for interviews was enrolled in general chemistry I and II labs during spring 2010, the semester of the main study. The distribution of students reporting prior experience using technology in a lab setting was evenly distributed. Seventeen reported they had used technology before, while 16 reported never using technology before (51.5% and 48.5%, respectively). Only one person in the group did not report an answer to that question.

A question was raised during the course of the pilot study regarding the student responses to the demographic questions about having taken high school chemistry and doing labs in high school chemistry. I wanted to see if their experiences in high school would have an impact on their experiences in the general chemistry laboratory. The initial assessment of laboratory skills (found in Appendix C) was used to assess their memory of key skills and laboratory equipment that might have been used in an effective high school laboratory. Since laboratory experiences involve multiple modalities of learning, memory of the skills and correct equipment identification might be retained longer (Shell et al., 2010). The mean score for students who took high school chemistry (N = 32) was 71.44. The mean score for students who did not take high school chemistry (N = 2) was 64.00. A two-tailed *t*-test at the 95% confidence level was used to determine if completing high school chemistry had an effect on the initial assessment score. The *t*-test results indicate that the difference between the means was not statistically significant at the $\alpha = .05$ level ($t = 0.760$, $df = 32$, $p = .453$). The mean score for students who had experience in high school chemistry labs (N = 32) was 71.44. The mean score for students who did not have experience in high school chemistry labs (N = 2) was 64.00. Similarly, a two-tailed, *t*-test at the 95% confidence level was used to determine if doing high school chemistry labs has an effect on the initial assessment score. The *t*-test results indicate that the difference between the means was not statistically significant at the $\alpha = .05$ level ($t = 1.121$, $df = 32$, $p = .271$). Thus, taking high school chemistry and having prior high school lab experience has no effect on the scores on the initial assessment of laboratory skills. Table 3 shows the results of the *t*-test.

Table 3

Correlational statistics between initial assessment results and high school chemistry completion

Item	N	Mean	*Sd*	t_{obs}	*df*	*p*
High School Chemistry?						
Yes	32	71.44	13.26	0.760	32	.453
No	2	64.00	4.24			
High School Chemistry lab?						
Yes	32	71.44	13.26	1.121	32	.271
No	2	64.00	4.24			

Survey Results

Before starting the general chemistry labs, the participants took the survey in order to establish a baseline for comparison of student results over time. There were three parts to this survey. The first part asked for demographic data that are relevant to this study. Part 2 contained a series of statements about the probeware system as a whole that the students rank using a Likert scale. The Likert scale was 1 – *strongly disagree*, 2 – *disagree*, 3 – *I don't know*, 4 – *agree*, and 5 – *strongly agree*. Part 3 contained a set of questions about specific components of the probeware system asking if they had used the component before, what the name of the component is, and what the component is used for.

Results from the first round of the survey show that most students (79.4%) did not know if the probeware was useful in the general chemistry lab (but some students thought it could be), if it could be used for different labs in general chemistry, or if it could be used outside of chemistry. Most students (97.1%) did not know if the probeware was a stand-alone system or if it could interact with computers or other systems. Finally, most students did not know if the probeware would be portable (94.1%), if it would save them time in lab (85.2%) or would be difficult to use (88.2%). Most students had not used any of the four components listed below before beginning labs (greater than 80% for all components) and did not know what the names or the uses of the components were (greater than 85% for all components). The results from the first survey are shown below in Table 4. The mode for answers to questions in Part 2 was 3, “I don’t know.” The mode for answers to Part 3, Question 1 for all components was 1, “No.” The mode for answers to Part 3, Question 2 for all components was 2, “I don’t know.”

Midway through the semester, the participants completed the same survey again. At this point, students agreed that the probeware was useful in the general chemistry lab (73.5% agreed or strongly agreed, mode = 4), could be used for many different labs in general chemistry (76.4% agreed or strongly agreed, mode = 4), and could be used in other chemistry courses (73.5% agreed or strongly agreed, mode = 4). They disagreed with the statement that the system could not be used outside of chemistry (52.9% disagreed or strongly disagreed, mode = 2), but a significant percentage were still unsure (35.2%). They were also still somewhat unsure if the probeware was a stand-alone system that is unable to interact with computers (47.1%, mode = 3), and if the system was portable (47.1%, mode = 3). Some students were beginning to see that the probeware does interact with computers (35.2%) and is portable (38.2%). Students either agreed or strongly agreed that the system saved time in lab (79.4%, mode = 5).

They disagreed with the system being difficult to use (50%, mode = 2), but a number of students were still unsure (26.5%).

Table 4

First Round of Survey Results

Survey Question	Mean	Standard Deviation	Mode
The PASCO system is useful in the general chemistry lab.	4.17	0.62	3
The PASCO system can be used for many different labs in general chemistry.	3.23	0.49	3
The PASCO system can be used in other chemistry courses.	3.23	0.55	3
The PASCO system cannot be used outside of chemistry.	3.09	0.51	3
The PASCO system is a stand-alone system. That is, it cannot interact with computers or other PASCO	3.06	0.42	3
The PASCO system is portable.	2.97	0.38	3
The PASCO system will save me time in lab.	3.15	0.35	3
The PASCO system is difficult to use.	2.97	0.45	3
Regarding the PowerLink™:			
Have you ever used this device before?	1.94	0.24	2
What is this device?	2.00	0.64	2
What is it used for?	2.03	0.62	2
Regarding the Temperature Sensor™:			
Have you ever used this device before?	1.82	0.38	2
What is this device?	2.12	0.90	2
What is it used for?	2.12	1.07	2
Regarding the Absolute Pressure Sensor™:			
Have you ever used this device before?	2.00	0.00	2
What is this device?	1.88	0.32	2
What is it used for?	1.88	0.32	2
Regarding the Drop Counter™:			
Have you ever used this device before?	2.00	0.00	2
What is this device?	1.88	0.40	2
What is it used for?	1.85	0.35	2

By mid-semester, most students had used the PowerLink™ (85.3%), the Temperature Sensor™ (94.1%), and the Absolute Pressure Sensor™ (79.4%), but not the Drop Counter™ (88.2%). The mode for Part 3, Question 1 regarding if they had used these components before was 1, “Yes.” Most students did not name the PowerLink™ (61.8%) or the Absolute Pressure Sensor™ (82.4%). However, more students did name the Temperature Sensor™ (70.6%), leaving only 29.4% who did not name the Temperature Sensor™. Of those that did name the Temperature Sensor, only 26.4% did so completely correctly. Many students (52.9%) were able to at least get part of the uses correct for the PowerLink™. Some students did correctly state the use of the Temperature Sensor™ (32.3%), but more students did not answer this question (38.2%). Most students could state at least part of the use of Absolute Pressure Sensor™ (58.8%). Most students still did not use or know the name or use of the Drop Counter™ (52.9% and 52.9% respectively), if they answered the question (44.1% and 38.2% respectively. The results from the second round of the survey are shown in Table 5.

Close to the end of the semester, a third round of the survey was completed by the participants. At this point students agreed or strongly agreed (91.2%) that the probeware is useful in general chemistry labs, for many different general chemistry labs (94.1%), and in other chemistry courses (91.2%). The mode for these three questions was 5, “Strongly agree.” Some students disagreed with the statement that the system could not be used outside of chemistry (47.1%) but many were still unsure (41.2%). The mode for this question was 3, “I don’t know.” More students also thought the system could interact with computers (47.1%), but many were still unsure (44.1%). The mode for this question was 3, “I don’t know.” Students also agreed or strongly agreed that the system is portable (53%, mode = 5), but a significant number disagreed (23.5%). They still agreed or strongly agreed that the system saves them time in lab (91.2%, mode = 5). Students either disagreed or strongly disagreed with the system being difficult to use (76.5%). The mode for this question was 2 “disagree.”

Table 5

Second Round of Survey Results

Survey Question	Mean	Standard Deviation	Mode
The PASCO™ system is useful in the general chemistry lab.	4.06	0.78	4
The PASCO™ system can be used for many different labs in general chemistry.	3.94	0.81	4
The PASCO™ system can be used in other chemistry courses.	3.97	0.72	4
The PASCO™ system cannot be used outside of chemistry.	2.56	1.05	2
The PASCO™ system is a stand-alone system. That is, it cannot interact with computers or other	2.62	1.10	3
The PASCO™ system is portable.	3.35	0.98	3
The PASCO™ system will save me time in lab.	4.15	0.93	5
The PASCO™ system is difficult to use.	2.71	1.06	2
Regarding the PowerLink™:			
Have you ever used this device before?	1.15	0.36	1
What is this device?	2.32	1.57	1
What is it used for?	3.91	1.69	5
Regarding the Temperature Sensor™:			
Have you ever used this device before?	1.06	0.24	1
What is this device?	3.00	1.60	1
What is it used for?	3.24	2.04	1
Regarding the Absolute Pressure Sensor™:			
Have you ever used this device before?	1.21	0.41	1
What is this device?	1.65	0.92	1
What is it used for?	3.62	1.84	2
Regarding the Drop Counter™:			
Have you ever used this device before?	1.88	0.33	2
What is this device?	1.65	0.77	2
What is it used for?	1.79	0.95	2

By the end of the semester, all but two of the 33 students had used the PowerLink™ and the Absolute Pressure Sensor™. All students had used the Temperature Sensor™. The mode for these three questions was 1, “yes.” Only two students had used the Drop Counter™. The mode for this question was 2, “no.” Most students still didn’t name the PowerLink™ (61.8%) but could correctly identify the use of this component (50.0%). Many students could name the Temperature Sensor™ (50.0%), but did not state its use (44.1%). Those that did state the use of the Temperature Sensor™ did so correctly (32.4%). Many students did not name the Absolute Pressure Sensor™ (76.5%) or state its use (38.2%). Those who did state a use did so correctly (32.4%). Again, as before, students did not know the name (50.0% did not know; 41.2% did not answer.) or the use of the Drop Counter™ (50.0% did not know; 41.2% did not answer). The results of this survey are shown in Table 6.

Table 6

Third Round of Survey Results

Survey Question	Mean	Standard Deviation	Mode
The PASCO™ system is useful in the general chemistry lab.	4.47	0.66	5
The PASCO™ system can be used for many different labs in general chemistry.	4.38	0.70	5
The PASCO™ system can be used in other chemistry courses.	4.41	0.66	5
The PASCO™ system cannot be used outside of chemistry.	2.50	1.08	3
The PASCO™ system is a stand-alone system. That is, it cannot interact with computers or other	2.41	1.02	3
The PASCO™ system is portable.	3.53	1.26	5
The PASCO™ system will save me time in lab.	4.56	0.75	5
The PASCO™ system is difficult to use.	2.18	0.72	2
Regarding the PowerLink™:			
Have you ever used this device before?	1.06	0.23	1
What is this device?	2.03	1.49	1
What is it used for?	4.15	1.74	6
Regarding the Temperature Sensor™:			
Have you ever used this device before?	1.00	0.00	1
What is this device?	3.41	1.52	5
What is it used for?	3.32	2.17	1
Regarding the Absolute Pressure Sensor™:			
Have you ever used this device before?	1.18	0.39	1
What is this device?	1.88	1.41	1
What is it used for?	3.44	1.94	1
Regarding the Drop Counter™:			
Have you ever used this device before?	1.82	0.39	2
What is this device?	1.79	0.98	2
What is it used for?	1.68	0.68	2

Qualitative Analysis and Development of Themes

Data from the interviews and observation notes were analyzed according to a two-level protocol. The first level of analysis was the development of a coding system from the transcripts of the interviews and observation notes. Categories were developed with the goal of answering the research questions. The coding categories were developed based on recurring words and ideas found in the data by a constant comparative analysis (Gall, Gall, & Borg, 2003). These categories emerged as the data were examined and reexamined. The second level of analysis consisted of developing themes. These themes were ideas that were consistent across categories or were found within a category, and were based on the research questions.

Level 1 Analysis: Development of Coding Categories

To start the analysis of the qualitative data, I transcribed all audio recordings of interviews (see Appendix F). As stated in Chapter 3, student names were changed to protect their identity. As transcription was occurring, patterns of answers began to emerge. In addition, interview questions were written to allow for coding categories to emerge easily, and the interviews were structured so that patterns could emerge easily as well. In addition, I transcribed hand-written observations of student words and behaviors in the laboratory (See Appendix F). After transcription, I read and reread the interviews and created the coding system found in Appendix D. Establishment of reliability of the coding system is described in Chapter 3 – Methodology.

Beginning with the six interviews, I coded them using the categories in the coding system. Table 7 shows the fourteen coding categories along with the frequencies of each code appearing in all six interviews.

Table 7

Frequencies of Coding Categories for Interviews in Main Phase

Code	Category	Frequency Count
1	Time	30
2	Visual display	33
3	Ease-difficulty	46
4	Accuracy	19
5	Purpose	23
6	Learning	17
7	Future application	27
8	Unknowns	16
9	Procedures	32
10	Student-group	19
11	Student-system	26
12	Student-teaching assistant	15
13	Usefulness	39
14	Miscellaneous	3

After coding the interviews, I coded the observation notes using the same coding system. Table 8 shows the fourteen coding categories along with the frequencies of each code appearing in the data.

As I coded these data, I conducted a constant comparative analysis of the data to clarify, refine, and/or add categories as they emerged from the data. After completing the coding all the interviews and observation notes, no new categories emerged from the data. This confirmed that my coding system was correct and complete. During the entire coding process, I kept a record of themes that emerged from the data and were related to my research questions. This record was continually modified as new themes developed and/or existing themes needed updating. A detailed description of the coding scheme categories and their definitions is found in Appendix D.

Table 8

Frequencies of Coding Categories for Observation Notes in Main Phase

Code	Category	Frequency Count
1	Time	6
2	Visual display	20
3	Ease-difficulty	1
4	Accuracy	6
5	Purpose	0
6	Learning	1
7	Future application	0
8	Unknowns	0
9	Procedures	17
10	Student-group	5
11	Student-system	15
12	Student-teaching assistant	11
13	Usefulness	0
14	Miscellaneous	4

Level 2 Analysis: Emerging Themes from Coded Data

As I developed the coding categories, themes began to emerge from the data that were related to my research questions. After I completed coding, the categories were studied for additional themes or modification to themes that had emerged during coding. Data analysis reveals five themes. First, the students see the probeware's affordances as an accurate measuring tool that provides an easily read and interpreted visual display. Second, students gain understanding about the probeware from a combination of sources that include the lab manual, the teaching assistant, and interactions with their classmates. Third, the students see the probeware as easy to use. Fourth, the students see the probeware as useful for the general chemistry labs and future chemistry labs. Fifth, the students see the probeware as useful for other sciences.

Triangulation of themes across data sources

The themes described above were found from the survey question responses, the interviews, and the observation notes. Interview transcripts were analyzed in three stages. First, I examined them for instances that supported the five themes. Second, I examined them for instances that were contradictory to the five themes. Third, I examined them for new themes not seen in the survey question responses. Next, I repeated the analysis with the observation notes, and then compared the results of the analysis of the observation notes with the results of the analysis of the interviews. Finally, I examined the themes seen in the survey question responses and compared them to the themes in the interview transcripts and observation notes.

Table 9 summarizes the triangulation of the themes above (mainly from interview transcripts) with the observation notes and the survey question responses. The first column in Table 8 lists the five themes and the ideas within those themes. The second column shows data that supports each of the ideas within the themes. The third column indicates if each idea within a theme was observed, not observed, or contradicted by other data sources and how strongly the idea was supported or contradicted. All ideas are strongly supported across different data sources, and seen and heard consistently throughout the study.

Table 9

Summary of triangulation of themes

Ideas Within Themes	Triangulation Data	Results of Triangulation
Theme: Affordances of the Probeware		
Saves time in lab	Survey – part 2 question 7 results (91% agree or strongly agree) Interview – stated 30 times over 6 interviews Observations – seen 6 times	Observed
Visual display	Survey – not seen Interview – stated 33 times over 6 interviews Observations – seen 20 times	Observed
Accurate measuring tool	Survey – Part 2 Question 1 indirectly (91% agree or strongly agree in usefulness) Interviews – Accuracy stated 19 times; purpose stated 23 times over all 6 interviews Observations – Accuracy observed six times	Observed
Ability to be applied to different labs in general chemistry	Survey – part 2 question 2 (94% agree or strongly agree) Interviews – Purpose stated 23 times over all 6 interviews; future application stated 27 times over all six interviews.	Observed
Theme: Where students learn about affordances		
Lab manual	Interviews – learning stated 17 times over 6 interviews Observations – one time	Observed
Laboratory teaching assistant	Interviews – 15 times over 6 interviews Observations – 11 times	Observed
Trial and error	Interviews – learning stated 17 times over 6 interviews; student-system interactions stated 26 times over six interviews Observations – Student-system interactions seen 15 times	Observed
Other students	Interviews – Student-group interactions stated 19 times Observations – Student-group interactions seen 6 times	Observed

(continued)

Table 9. Summary of triangulation of themes (continued)

Theme: Ease of use of probeware		
Makes measure-ments easier	Survey – part 2 question 3 (76.5% disagreed with system being difficult to use) Interviews – Ease/difficulty stated 46 times over 6 interviews Observations – Ease/ difficulty seen once	Observed
Makes data collection easier	Survey – part 2 question 3 (76.5% disagreed with system being difficult to use) Interviews – Ease/difficulty stated 46 times over 6 interviews Observations – Ease/ difficulty seen once	Observed
Makes graphing easier	Survey – part 2 question 3 (76.5% disagreed with system being difficult to use) Interviews – Visual display stated 33 times over 6 interviews; ease/difficulty stated 46 times over 6 interviews Observations – Visual display seen 20 times; ease/ difficulty seen once	Observed
Set up and use of probeware is easy.	Survey – part 2 question 3 (76.5% disagreed with system being difficult to use) Interviews – Ease/difficulty stated 46 times over 6 interviews; procedures stated 32 times over 6 interviews; student-system stated 26 times over 6 interviews Observations – Ease/ difficulty seen once; procedures seen 17 times; student-system seen15 times.	Observed
Theme: Usefulness in chemistry labs		
Useful in other general chemistry experiments	Survey - part 2 question 2 (94% agreed or strongly agreed) Interviews – Usefulness stated 39 times Observations – none	Observed
Useful in other chemistry courses	Survey – part 2 question 3 (91% agreed or strongly agreed) Interviews – Usefulness stated 39 times; future application stated 27 times	Observed
Theme: Usefulness in other science labs		
Useful in other sciences like biology and physics	Survey – part 2 question 4 (47% disagreed or strongly disagreed) Interviews – Usefulness stated 39 times; future application stated 27 times	Observed

In general, the ideas within the themes were seen in all the data sources unless the context of the data source did not allow the theme to be observed. For example, the theme of usefulness in other science labs was not seen in the observation notes, but was observed in the interviews and the surveys. With themes established and triangulated across data sources, I address all the research questions directly in the next five sections.

What Students Perceive As The Identity Of The Instrument(s)

Before students could tell me the identity of the components of the probeware system, I had to find out if they had used the components. Figure 3 illustrates how students' responses to the question "Have you ever used this device before?" found in Part 3 of the survey. Most students had not used the components of the probeware before at the beginning with the exception of five students having already used something like the Temperature Sensor™. As students progressed through the course, all students had used the PowerLink™ and the Temperature Sensor™, thirty-one students had used the Absolute Pressure Sensor™, but they had not use the Drop Counter™. This is expected because the Drop Counter™ is not used in this course but is used in the next course.

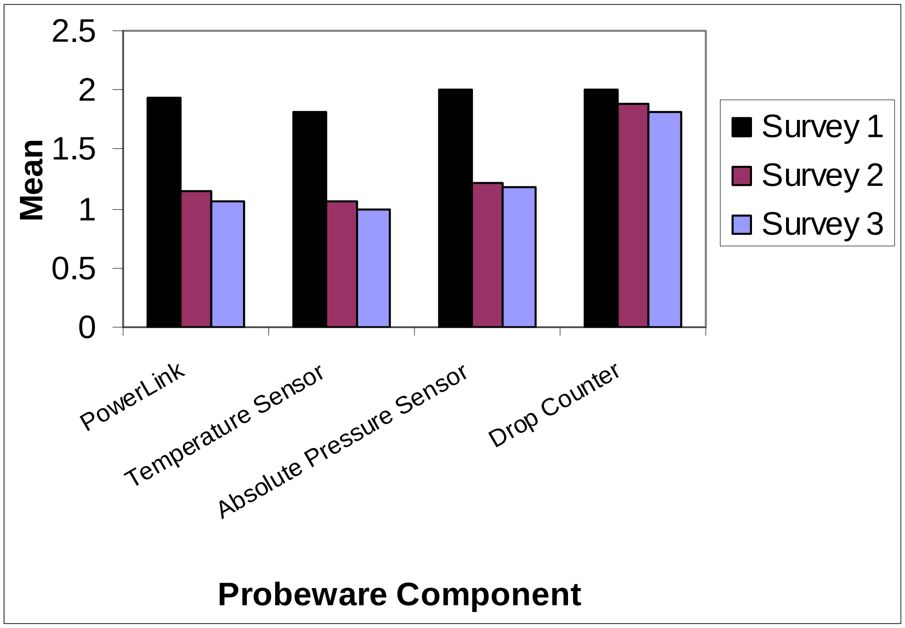

Figure 3: Comparison of results over time for survey Part 3, question – "Have you ever used this device before?" (1 = *yes*, 2 = *no*).

Once I found out if the students had used the probeware, I turned my attention to what they name the components of the probeware. Figures 4 – 7 illustrate how the responses to the question about the name of each component asked about in Part 3 of the survey changed over time. Consistently, the number of "I don't know" responses decreased over time even though the number of non-responses varied. For the PowerLink™, the number of "I don't know" responses decreased from 28 in the first survey to two in the third survey, while the number of non-responses increased from four in the first survey to 21 in the third survey. For the Temperature Sensor™, the number of "I don't know" responses decreased from 28 in the first survey to one in the third survey, while the number of non-responses changed from six in the first survey, to ten in the second survey and finally to seven in the third survey. For the Absolute Pressure Sensor™, the number of "I don't know" responses decreased from 29 in the first survey to 17 in the third survey, while the number of non-responses increased from four in the first survey to 22 in the third survey. For the Drop Counter™, the number of "I don't know" responses decreased from 29 in the first survey to 18 in the third survey, while the number of non-responses increased from five in the first survey to 14 in the third survey. Because the students have been provided the check box for indication of "I don't know," it cannot be inferred that students who did not answer the question do not know the information requested only that they failed to respond to the item.

In Figure 4 students were asked the name of the PowerLink™. In the beginning, 28 out of 34 students did not know what the name of this component was, one student had answered incorrectly, and one had given a correct answer. Four students did not answer this question. By the end of the semester, only two did not know what the name of this component was, four students answered incorrectly, four had answers that were close to correct, and three had correct answers. Twenty-one students did not answer this question.

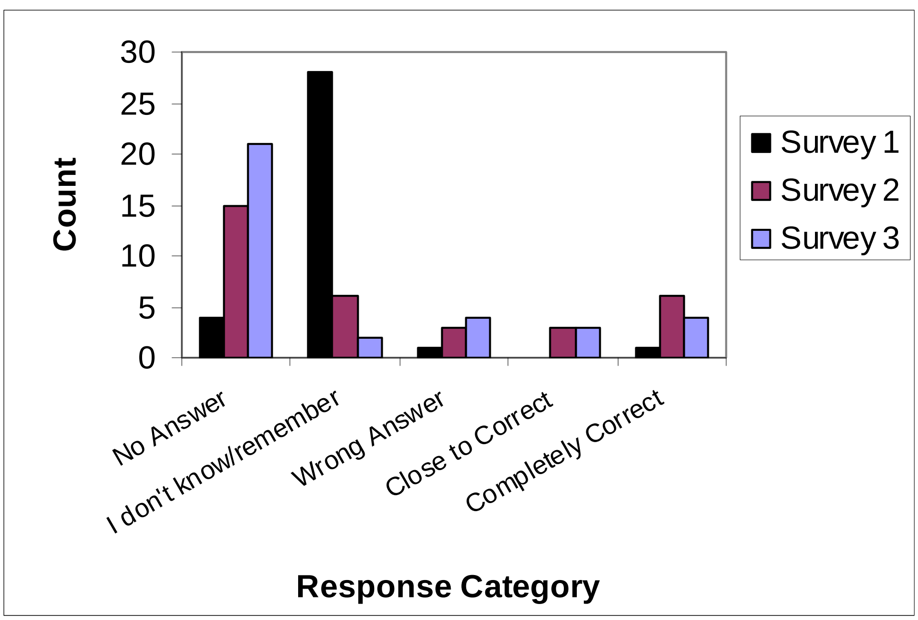

Figure 4. Comparisons by count of responses over time for name of PowerLink™.

In Figure 5, students were asked the name of the Temperature Sensor™. In the beginning, 28 out of 34 students did not know what the name of this component was. Six students did not answer this question. By the end of the semester, only one student did not know what the name of this component was, no students answered incorrectly, five had answers that were close to correct, and 12 had correct answers. Six students did not answer this question.

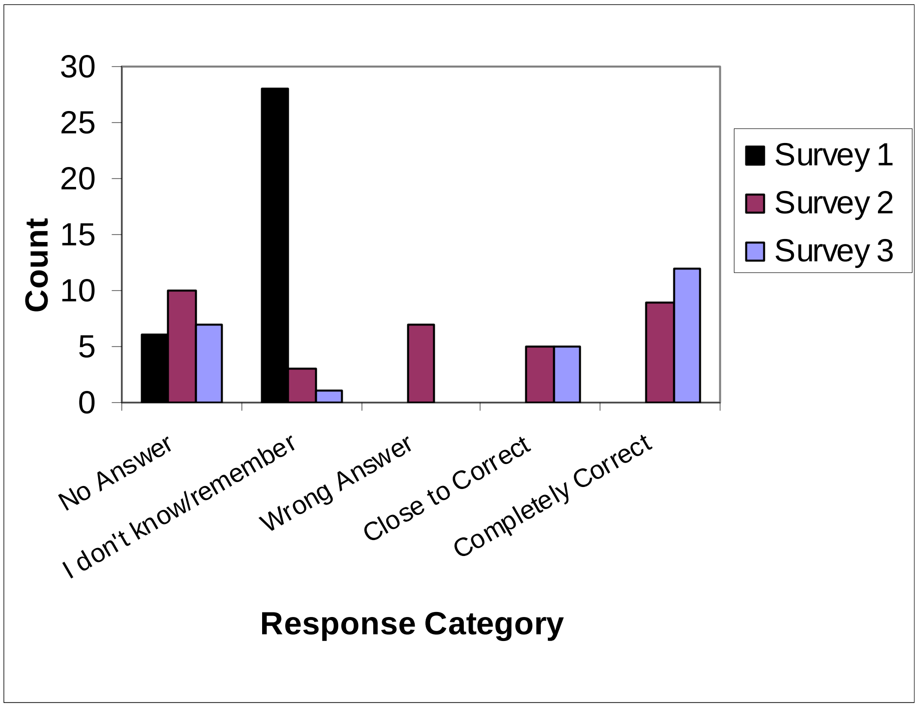

Figure 5. Comparisons by count of responses over time for name of Temperature Sensor™.

In Figure 6, students were asked the name of the Absolute Pressure Sensor™. In the beginning, 30 out of 34 students did not know what the name of this component was. Four students did not answer this question. By the end of the semester, only four students did not know what the name of this component was, one student answered incorrectly, four had answers that were close to correct, and three had correct answers. Twenty-two students did not answer this question.

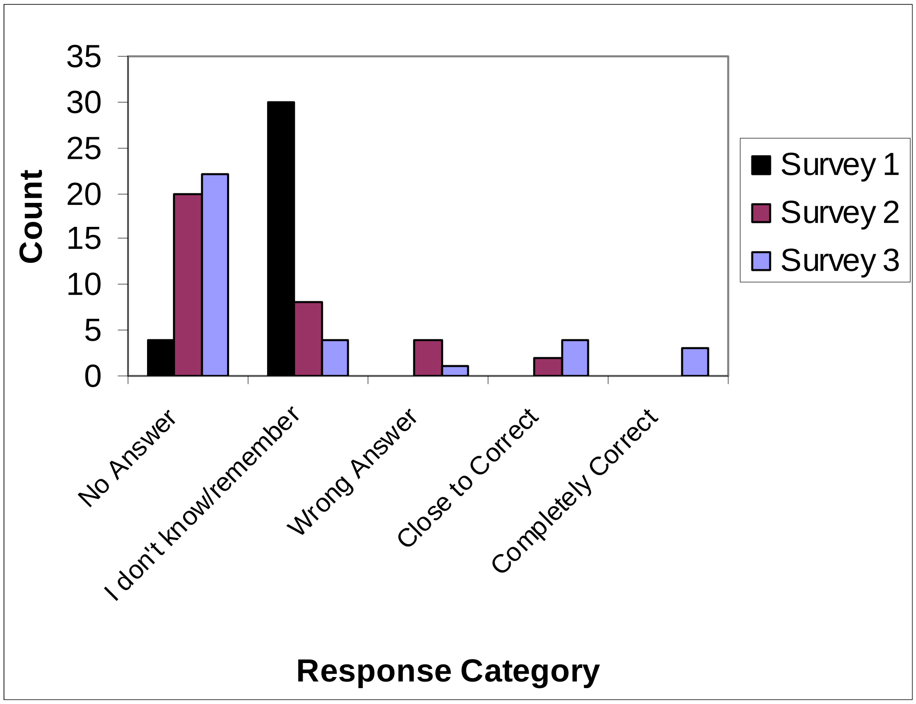

Figure 6. Comparisons by count of responses over time for name of Absolute Pressure Sensor™.

In Figure 7, students were asked the name of the Drop Counter™. In the beginning, 29 out of 34 students did not know what the name of this component was. Five students did not answer this question. By the end of the semester, 17 did not know what the name of this component was, one student answered incorrectly, and two had correct answers. Fourteen students did not answer this question.

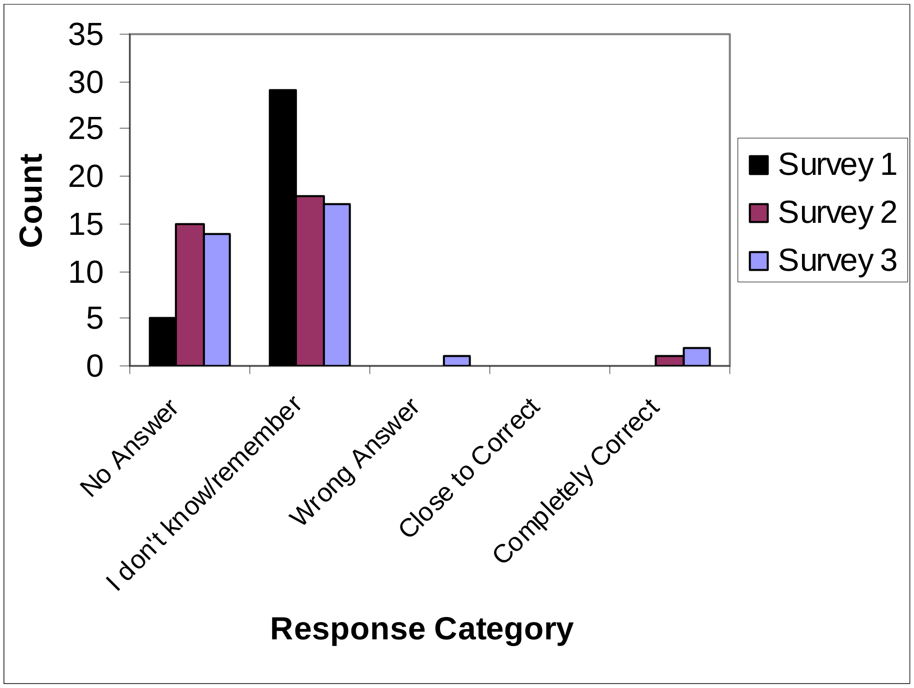

Figure 7. Comparisons by count of responses over time for name of Drop Counter™.

What the Students Perceive as the Affordances of the Instrument(s)

Once I found out what the students know about the names of the components of the probeware, I turned my attention to the affordances of the probeware. Figure 8 illustrates the students' change in perceptions of potential affordances of the probeware system as a whole over the course of the semester. In the beginning students did not know if the probeware was a stand-alone system (mean = 2.98), or if the probeware was portable (mean = 3.02). By the end of the semester, many students disagreed or strongly disagreed with the idea that the probeware was a stand-alone system (47%), but many students were still not sure (42%). The mean response for this question was 2.53 reflecting the dichotomy of the responses of the students to this question. Also by the end of the semester, students did not necessarily agree with each other on the portability of the system. Fifty-three percent of students either agreed or strongly agreed that the system is portable. However, 23.5% of students either disagreed or strongly disagreed that the system is portable, and 23.6% of students were still not sure. The mean response to this question was 3.44. At the beginning of the semester, students did not know if the probeware saved them time in lab (mean = 3.15), or if it was difficult to use (mean = 2.98). By the end of the semester students either agreed or strongly agreed that the probeware save them time in lab (mean = 4.62). They either disagreed or strongly disagreed that the system was difficult to use (mean = 1.93). Figure 8 illustrates these results.

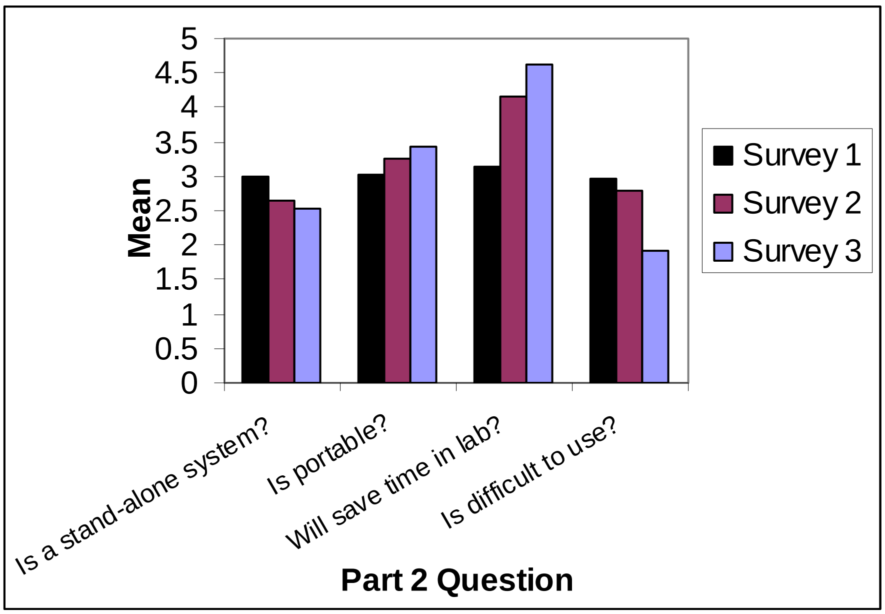

Figure 8. Comparisons using a Likert scale (1 = *strongly disagree*, 3 = *I don't know*, 5 = *strongly agree*) of means of Part 2 question about potential affordances of probeware from the three surveys given at the beginning, middle and end of the semester.

Figures 9 – 12 illustrate how the responses to the question about the use of each component asked about in Part 3 of the survey changed over time. Consistently, the number of "I don't know" responses decreased over time even though the number of non-responses increased. Because the students have been provided the check box for indication of “I don’t know,” it cannot be inferred that students who did not answer this question do not know the information requested only that they failed to respond.

In Figure 9, students were asked the use of the PowerLink™. In the beginning, 27 out of 34 students did not know what the use of this component was, one student had answered incorrectly, and one had given a correct but incomplete answer. Four students did not answer this question. By the end of the semester, only two did not know what the use of this component was, seven students answered incorrectly, four had answers that were close to correct, six had correct but incomplete answers, and three had correct and complete answers. Four students did not answer this question.

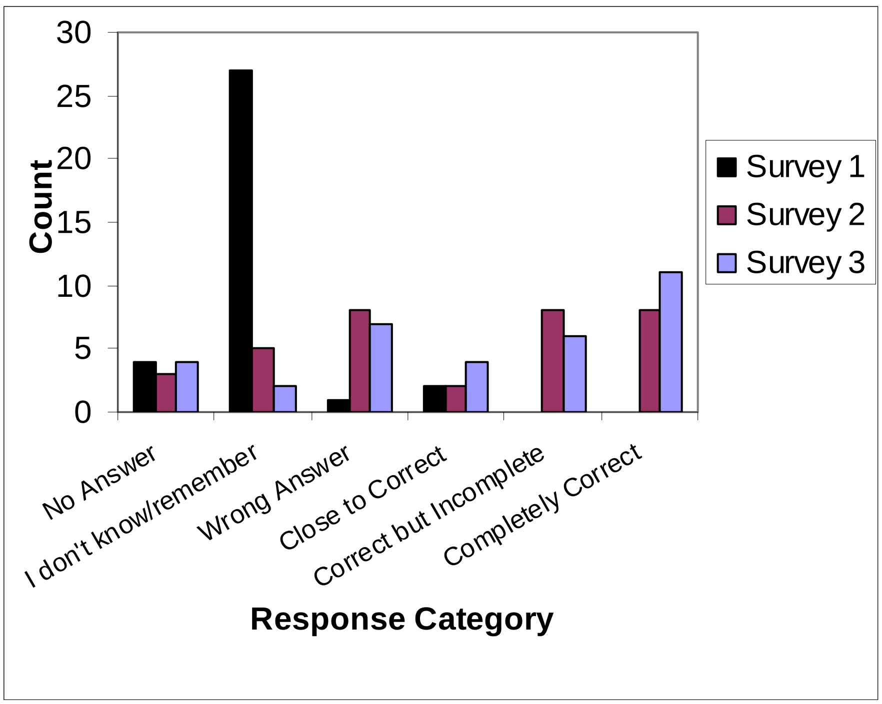

Figure 9. Comparisons by count of responses over time for use of PowerLink™.

In Figure 10, students were asked the use of the Temperature Probe™. In the beginning, 23 out of 34 students did not know what the use of this component was, eight had given an answer that was close to correct, one had given a correct but incomplete answer, and one had given a correct and complete answer. Seven students did not answer this question. By the end of the semester, only one did not know what the use of this component was, no students answered incorrectly, eight had answers that were close to correct, one had correct but incomplete answers, and ten had correct and complete answers. Fourteen students did not answer this question.

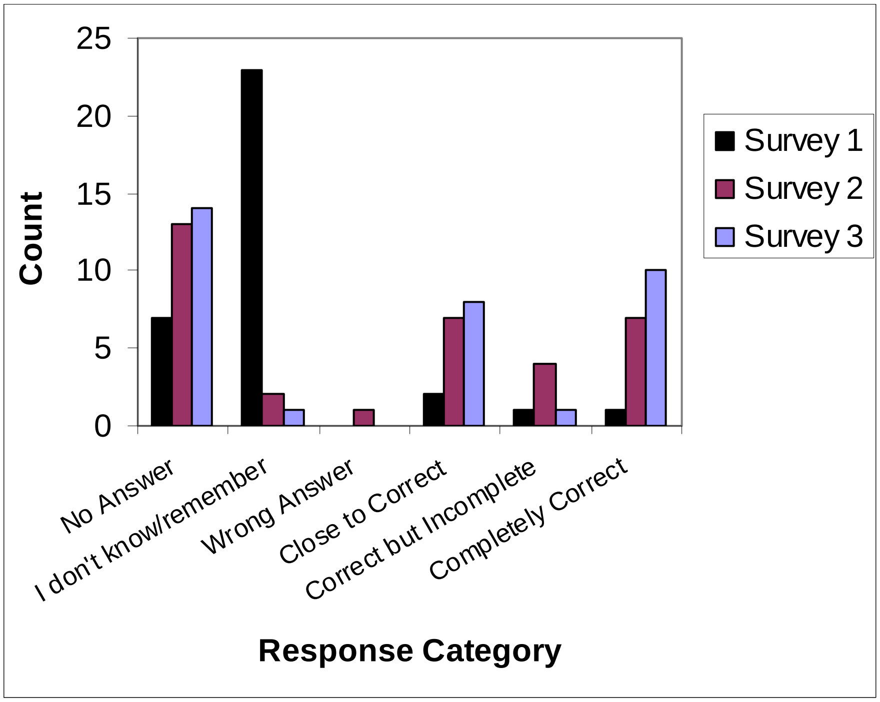

Figure 10. Comparisons by count of responses over time for use of Temperature Sensor™.

In Figure 11, students were asked the use of the Absolute Pressure Sensor™. In the beginning, 30 out of 34 students did not know what the use of this component was. Four students did not answer this question. By the end of the semester, only four did not know what the use of this component was, three students answered incorrectly, seven had answers that were close to correct, three had correct but incomplete answers, and eight had correct and complete answers. Nine students did not answer this question.

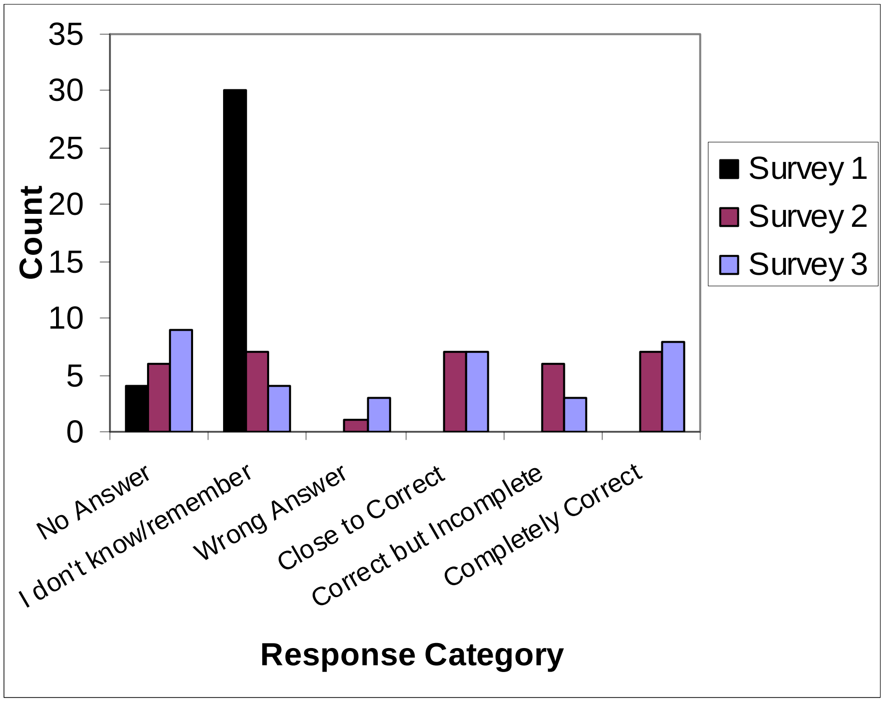

Figure 11. Comparisons by count of responses over time for use of Absolute Pressure Sensor™.

In Figure 12, students were asked the use of the Drop Counter™. In the beginning, 29 out of 34 students did not know what the use of this component was and five students did not answer this question. By the end of the semester, 18 did not know what the use of this component was, one student answered incorrectly, one had answers that were close to correct, and no one had correct and complete answers. Fourteen students did not answer this question.

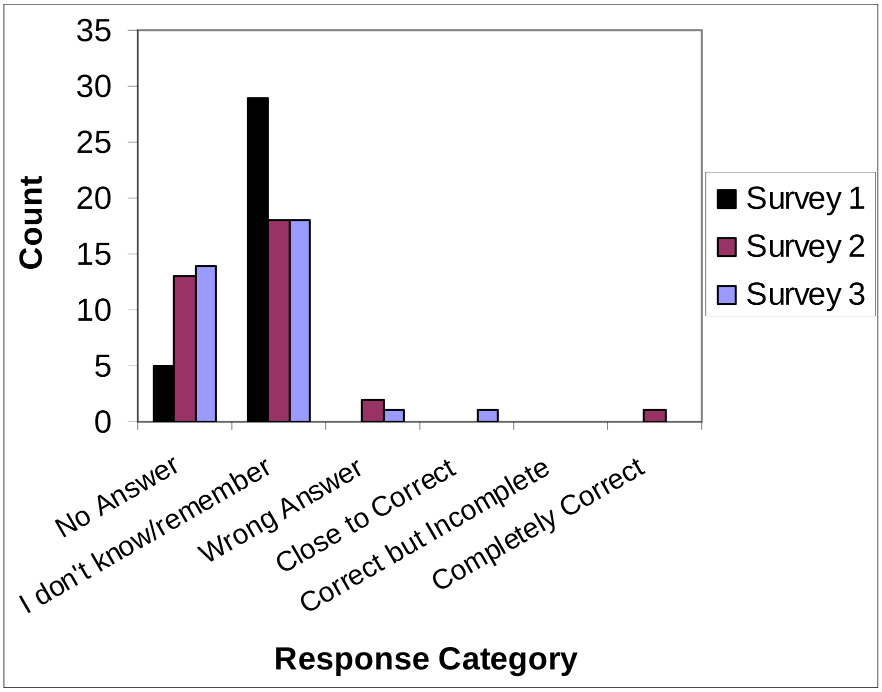

Figure 12. Comparisons by count of responses over time for use of Drop Counter™.

After comparing the quantitative results from the surveys, I then turned my attention to the qualitative results for an overall picture. Students see the probeware's affordances as time, the visual display, a measuring tool, and ability to be applied to different labs in general chemistry. With regards to time, students saw the probeware as a device that saves them time in lab. This affordance was seen throughout the pilot study phase and again throughout the main study. Riley saw the system would give students more efficient results (Appendix F, Riley interview, lines 19-20) and save them time (Appendix F, Riley interview, line 31). Lisa also saw the system would give results faster and would not require a lot of time (Appendix F, Lisa interview, line 84). When Riley was provided the option of using a thermometer rather than the Temperature Sensor™ during Experiments 11 and 12, she chose the Temperature Sensor™ because the thermometer would have been more time consuming. As she said, "We get out as soon as we're done, so why take the option that takes longer?" (Appendix F, Riley interview, lines 205-206). Mickey and Ron made similar comments about the choice of the temperature probe over the thermometer for Experiments 11 and 12. Mickey appreciated the time saving ability of the visual display of the graphs. "It's very efficient … it instantly graphs it and we know that graphing and working out and all of that takes so much time doing it by hand. It's like instantaneous feedback." (Appendix F, Mickey interview, lines 130-132). During an observation of "Experiment 10, Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water" (Acree, 2005), one group of students was measuring the temperature of the water in the calorimeter. One partner used the thermometer, while the other used the temperature probe. The student who used the temperature probe obtained the measurement faster than his partner who used the thermometer. Finally, as students used the probeware over time, they found that the system saved them time in the lab.

A second affordance the students found to be very important was the visual display. As I observed the students in the lab, the visual display took the form of mostly graphs of measurements over time, either pressure or temperature, as those were the measurements made by the system during the experiments done during this semester. The visual display could also be in a numerical format. In the numerical format, data are displayed to the nearest 0.01 with the base unit of kPa for pressure and °C for temperature. Students could also have both displays showing on the computer monitor if they wished.

Students found the visual display to be very helpful in the lab, particularly the graphs. Ron thought that the system gave them a nice graph that made it easy to find their end results, particularly for the temperature measurements (Appendix F, Ron interview, lines 115-116). Lisa also found it helpful for the pressure measurements. "It drew the graph for us and we got to see the different pressure points for each gas that we were measuring for that lab" (Appendix F, Lisa interview, lines 74-75). Mickey said "Well you can't really see the changes, so it gave me a visual of what was happening when the probe was inside" (Appendix F, Mickey interview, lines 94-95). Pat was able to see the differences between pre-1982 pennies and post-1982 pennies when having the graphs of the masses on the monitor during Experiment 1 (Appendix F, Pat interview, lines 41-42).

The third affordance of the probeware and system was it was an accurate measuring tool. Chantal said "It helped measure more accurately" (Appendix F, Chantal interview, line 46), and "Gave us an accurate reading of the temperature" (Appendix F, Chantal interview, line 86). Riley used the Absolute Pressure Sensor™ in Experiment 7 to measure the pressure of natural gas. She filled the syringe with 10 mL increments of natural gas and measured the pressure each time she added the gas (Appendix F, Riley interview, lines 122-125). Ron used the probeware for measuring temperature and pressure and thought the system took a lot of guesswork out of some calculations (Appendix F, Ron interview, line 94). Ron also stated that the probes had to be calibrated in the beginning (Appendix F, Ron interview, line 72). When asked about the accuracy of the system, Ron said "I'd say it's pretty close, but if you calibrate it right then yeah, it would be better" (Appendix F, Ron interview, line 171). During observations, students were observed calibrating their Temperature Sensors™ before beginning making measurements with the sensor. This was done every time they used the Temperature Sensor™. Students were also observed watching the graphical display to determine when a constant temperature was reached. Some students would switch to the numerical display to get an accurate reading of the temperature to the nearest 0.01 °C. Then, they would round that measurement to the nearest 0.1 °C to increase the significance of the last digit in their measurement. Lisa stated, “Well the PASCO system was a lot more accurate. The thermometer was hard to read: 24 could be 25? The PASCO, you could just see it on the computer so that made it a lot more accurate, like it would give you like 24.8” (Appendix F, Lisa interview, lines 140-142).

The fourth affordance is the ability to be applied to different labs in general chemistry. All the interviewees saw that the system could be used for measuring temperature in different labs and for graphing results. Ron also saw that the system could be used for titration labs using the Drop Counter™. Ron was in the second semester lab for general chemistry at the same time as the first semester lab, so he had more experience with the system than the rest of the students (Appendix F, Ron interview, lines 13-24). Students were observed using the system during all labs that were assigned to use the probeware, especially Experiments 9, 10, and 11 (Acree, 2005). From the survey, students were asked if the probeware could be used for many different labs in general chemistry. As the students learned about the system over the course of the semester, their answers changed from “I don’t know” to “agree/strongly agree.”

Where Students Learn About the Affordances

Students learn about the affordances of the PASCO™ system from a variety of sources: the lab manual, their laboratory teaching assistant, trial and error, and each other. Riley stated that she learned how to use the system through trial and error and reading the instructions, which weren't always clear. "Once we did it the first time, we found out what we were doing right and wrong by the TAs, and then we knew what to do" (Appendix F, Riley interview, lines 302-303). Ron learned how from the lab book. "It showed you how to calibrate it and it gave pretty good step-by-step instructions, how to graph different things" (Appendix F, Ron interview, lines 216-217). When Lisa had questions, she asked her teaching assistant. "When you don't know something, asking someone helps" (Appendix F, Lisa interview, line 217). Mickey followed directions in the lab manual. When he had problems, he or his partner would ask their lab teaching assistant to help (Appendix F, Mickey interview, lines 226-227). Pat stated that Experiment 8 (really Experiment 7) went into detail on how to manipulate and maneuver around the system. Pat also said that practicing was another method for learning (Appendix F, Pat interview, lines 256-259).

One student was observed instructing the group next to her how to calibrate the temperature probe. She provided step-by-step guidance to the group while she was calibrating her own temperature probe. All observed students asked their laboratory teaching assistant for help when the DataStudio™ program froze, how to zoom in on the graph when the graphical display was too large in scale, or when sensors were not working properly. The students were also observed looking in their lab manuals for the step-by-step instructions and discussing the procedure with their partners in order to use the probeware correctly.

Student Perception of Usefulness of the Instrument(s)

After determining the affordances of the probeware, I then determined if the students found the probeware useful and determined the usefulness of the probeware. Figure 13 illustrates the change in student perception of the usefulness of the probeware over the course of the semester. At the beginning, the students did not know whether it would be useful in the chemistry lab (mean = 3.25), or whether it could be used in different chemistry labs (mean 3.23). As the semester progressed, students saw the usefulness of the probeware system. By the end of the semester, students agreed or strongly agreed that the probeware is useful in the chemistry lab (mean = 4.5) and is useful in different general chemistry labs (mean = 4.5).

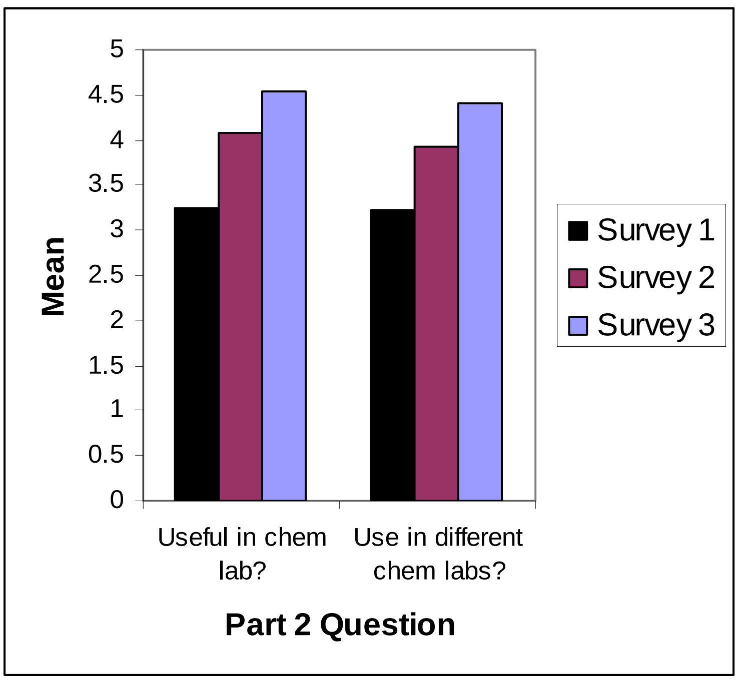

Figure 13. Comparisons using a Likert scale (1 = *strongly disagree*, 3 = *I don't know*, 5 = *strongly agree*) of means of Part 2 questions about usefulness of probeware from the three surveys given at the beginning, middle and end of the semester.

Ease of use of the probeware

The strong opinions of the students by the end of the semester are based on their experience in using the probeware. Interviews showed why the students found it useful. Students found that the probeware was easy to use and made calculations and measurements easier. From the survey results, students not only found the PASCO™ system useful, but also did not find it difficult to use. At first, the students were not sure if it would be easy to use, but as they used the system over the course of the semester, they definitely thought it was easy to use. Mickey said, "The more I use it, the more comfortable I would get [with the system]" (Appendix F, Mickey interview, lines 187-188).

In the interviews, students saw that the system made measurements, data collection, and graphing data easier. According to Lisa, the system made it easier to gather information (Appendix F, Lisa interview, line 11) and get data together to do calculations (Appendix F, Lisa interview, lines 116-117). According to Chantal, the temperature and pressure probes were easy to use (Appendix F, Chantal interview, lines 127-128). Riley said, "… it does it for you. As simple as picking it up and putting it in a cup. It does it for you" (Appendix F, Riley interview, lines 190-191).

Setting up and using the system was easy to do. Student groups observed over the course of several weeks became smoother in their operation of the probeware and more sophisticated. They became more adept at modifying the graphical display to read the graph accurately and were able to show the graphical display and the numerical display at the same time. The students also did not have to ask as many questions of their laboratory teaching assistant as they became more comfortable with the system. According to Chantal, the system was simple to set up (Appendix F, Chantal interview, line 36). The temperature and pressure probes were easy to use and made the labs easier to complete (Appendix F, Chantal interview, lines 127-128).

Usefulness in other chemistry courses

Students in this study saw the probeware system as useful in other chemistry courses. Figure 14 shows how the students' opinions changed over time as they gained experience with the system. At the beginning, students did not know if it could be used in other chemistry courses (mean = 3.23). At the end of the semester, students agreed or strongly agreed that it could be used in other chemistry courses (mean = 4.44).

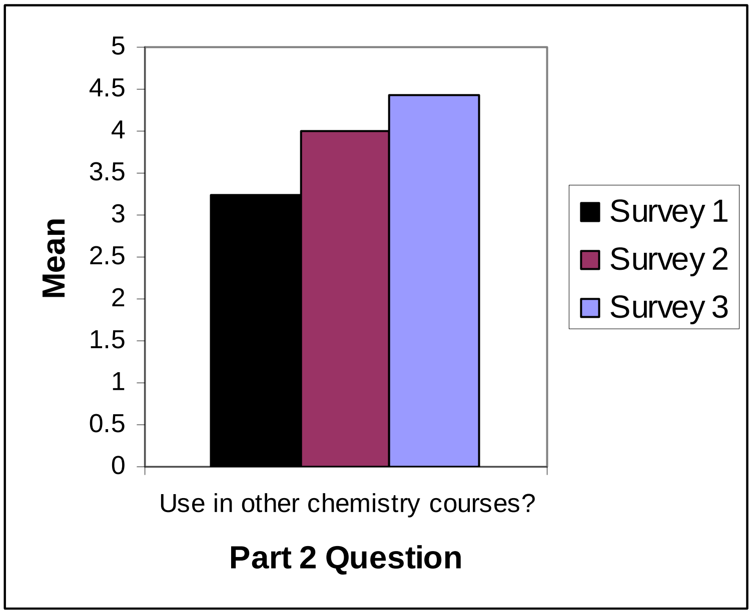

Figure 14. Comparison using a Likert scale (1 = *strongly disagree*, 3 = *I don't know*, 5 = *strongly agree*) of means of Part 2 question about usefulness of probeware in other chemistry courses from the three surveys given at the beginning, middle and end of the semester.

Interviews provided details about the usefulness of the probeware in other chemistry courses. Pat thought it could be used in general chemistry II, organic chemistry, and other chemistry courses (Appendix F, Pat interview, lines 197-198). Mickey thought it could be used in the next chemistry course, but was not sure (Appendix F, Mickey interview, lines 185-186).

Usefulness in other sciences

While students in the study saw the probeware system useful in other chemistry courses, they were not as sure about the usefulness in other sciences. Student survey responses initially were "I don't know" to the statement "The PASCO system cannot be used outside of chemistry" (mean = 3.00), then as time passed, students disagreed with that statement (mean = 2.47), but a number of students were still not sure (41.2%). Figure 15 illustrates this.

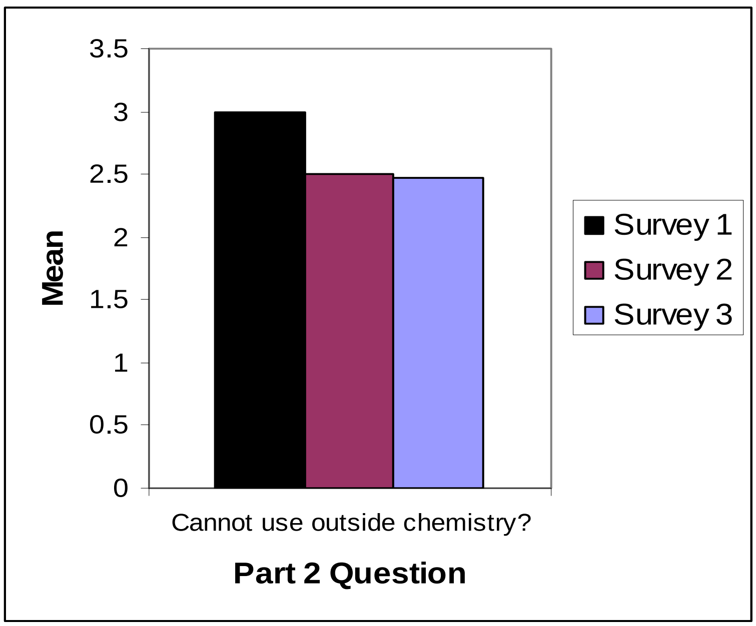

Figure 15. Comparison using a Likert scale (1 = *strongly disagree*, 3 = *I don't know*, 5 = *strongly agree*) of means of Part 2 questions about usefulness of probeware in other sciences from the three surveys given at the beginning, middle and end of the semester.

Interviews confirm the findings shown by the survey results. According to Ron, "Biology has some things that deal with temperature and pressures. Maybe some physics. I haven't taken a lot of physics so I don't really know what the exact use would be in that lab" (Appendix F, Ron interview, lines 185-187). According to Chantal, the probeware system would be very useful in physics. "A lot of it (physics) had to do with the similar things: temperature, pressure, and volume. And it could have helped with the accuracy in those labs" (Appendix F, Chantal interview, lines 175-176). Mickey wasn't sure if it could be used in other sciences but he could see the possibility of using it (Appendix F, Mickey interview, line 194).

In this chapter, data gathered about student demographics and results on the initial assessment are presented. Qualitative data were also coded, and themes emerged from the qualitative data. Finally, data about the affordances of the probeware system, where students learn about the affordances of the probeware system, ease of use of the probeware system, and the usefulness of the probeware system in chemistry and other sciences are presented. In the next chapter, conclusions and limitations to this study are presented. Implications for educators and for future research are presented, too.

CHAPTER V

CONCLUSIONS

Introduction

The purpose of this study is to find out what students in the first chemistry course at the undergraduate level (general chemistry for science majors) know about the affordances of instrumentation used in the general chemistry laboratory when they walk into the lab for the first time and how their knowledge develops over time. Students enrolled in the first semester of general chemistry laboratory were the participants in this study. Students were initially assessed on their prior knowledge about laboratory skills and equipment that are commonly used in high school chemistry classes. Then, an initial survey was given to set a baseline for knowledge of the PASCO PASPORT™ system and the affordances of this system. The same survey was given a second time at mid-semester and a third time towards the end of the semester. The purpose of giving the same survey three times was to track growth of knowledge over time. To get the details about the affordances of the probeware and how they learn about the affordances, I observed the students as they used the probeware in the labs and interviewed participants at the end of the semester.

Instrumentation was incorporated into university chemistry laboratories as soon as they were developed but general use was primarily at the graduate level of study. Some instrumentation was even developed at universities. If the purpose of the general chemistry laboratory is to develop skills and techniques that are used in chemistry, apply the concepts learned in class, and develop an appreciation for scientific work, then incorporation of appropriate instrumentation in general chemistry is a must (Schlesinger, 1935; Blick, 1955; Siebring & Schaff, 1977). The use of probeware systems, such as the PASCO PASPORT™ system or the Vernier™ system, accomplishes such purposes. The PASCO PASPORT™ system is appropriate for general chemistry laboratory use because it can be connected to a computer or used as a stand-alone system, it contains multiple forms of instrumentation (as probes) that measure a variety of properties of substances, and has a relatively easy student-system interface that quickly provides feedback to the students. These characteristics of the probeware system allow the student to focus on the laboratory skills and techniques, and the concepts being reinforced by the laboratory. The probeware also allows students the opportunity to appreciate the nature of scientific work.

The theories of affordances (Gibson, 1979) and distributed intelligence (Salomon, 1993; Pea, 1993) provide a theoretical basis for this study. An affordance is the actual or perceived use of an object. With scientific instrumentation, the use is predefined and tends to correspond with the name of the instrument. Distributed intelligence is a form of constructivism that focuses on the effective interaction between learner and the environment, where effective interaction is successful learning by the learner. Distributed intelligence supports this idea of a predefined use of instrumentation because the instrumentation was defined carefully by the inventor(s) and shared with the scientific community at large through direct instruction and written manuals. For students using a probeware system, the environment for learning includes the lab manual, the manual for the instrumentation, the instructor, and other students who are successfully using the probeware.

There are eight sections in this chapter. The first five sections address the answers to the research questions. The sixth section discusses the limitations of this study. The seventh and eighth sections discuss the implications of this research to education and implications for future research.

What Do Students Perceive as the Identity/Meaning and Use of Instrument(s) in Question?

Overall, students see the PASCO™ system as a useful and accurate measuring tool for their general chemistry lab. They see the probeware as easy to use, portable, and able to interact with computers. The system was designed to be easy to use by novice chemistry students and accurate if the probeware is operated properly.

The PowerLink™ was identified as a hub for the probes that interfaced with the computer. Students saw that the probes plugged in to the PowerLink™ and the PowerLink™ was plugged in directly to the computer. When the probes were plugged into the PowerLink™, the DataStudio™ software responded immediately by opening either a graphical display or numerical display ready to begin making the appropriate measurements.

The Temperature Sensor™ was identified as a temperature probe. This name is commonly used for the component across different probeware systems and is virtually identical in shape, structure, and size as other temperature probes across different probeware systems. The students also correctly identified the use for the temperature probe as measuring temperature. The students also knew that this component had to be calibrated before using it in order to increase the accuracy of the measurements. The students preferred to have a graphical display when using this component as it showed them how the temperature changed over time and when an equilibrium temperature was reached. They would read the graph for the equilibrium temperature or switch the display to a numerical mode to get accurate decimal places. They preferred to use a temperature probe over a thermometer because the temperature probe required no estimation of decimals and gave them the temperatures quicker than a thermometer.

Students identified the Absolute Pressure Sensor™ in a variety of ways. Two examples are pressure sensor and pressure gauge. Students could correctly identify the use of this sensor as measuring the pressure of gases. They could also correctly describe how to operate the pressure sensor. The students said this component was somewhat difficult to operate. Asking for help from their laboratory teaching assistant and practicing reduced the difficulty of operation.

Students could not identify the Drop Counter™ nor state its use. This is expected because the students did not use this component in the first semester of general chemistry. One student in the study did use the Drop Counter™ because he was enrolled in both the first and second semesters of the general chemistry lab. This student did correctly identify the component and the use of the component in titrations, a lab technique that is taught in the second semester lab.

What Do Students Perceive as the Usefulness of Instrument(s) in Question?

Students find that the PASCO™ probeware system is useful in their general chemistry labs and can be used in a variety of labs done in general chemistry primarily for measuring temperature and graphing results. The usefulness of the probeware system is increased by the affordance of saving time in lab/efficiency, and the visual display of data in real time. The speed of measuring and recording the data by the system is greatly appreciated by all students. The students could see the measurements change over time via either a graph of the measurement versus time or through a numerical display. The numerical display also provided a level of accuracy not seen by a gauge or meter (as on a thermometer). The digital numerical display could give values for the measurements to the nearest 0.01 units, a level of accuracy that is not usually seen with an analog device that requires estimating to the nearest 0.1 or nearest 0.05 depending on the gauge or meter. Overall, the students found the system and the components useful for their labs.

How Can the Instruments Be Used in Chemistry Beyond this Class?

Students could see the PASCO™ probeware system being used in other courses besides general chemistry labs. Students thought that the probeware could be useful not only in their general chemistry lab, but also in more advanced chemistry courses such as organic chemistry. This is important because it shows that the students can apply the skills they learn in general chemistry in future chemistry courses. They recognized that pressure and temperature are measured in many different chemistry courses and the probeware can be a useful tool for those courses.

How Can the Instruments Be Used in Other Sciences?

Most students (31 of 34 students, or 91.2%) recognized the potential use of the PASCO probeware in advanced chemistry courses, but only some (16 of 34 students or 47.1%) realized the potential use in other sciences such as biology and physics. In chemistry, the skills and techniques learned in the general chemistry lab can be used in other sciences. Some students recognized that sciences like biology and physics make pressure, temperature, and other measurements such as pH. A few students even reported that the probeware could used in the workplace such as environmental testing firms, medical labs, and other places that use basic chemistry laboratory techniques taught in general chemistry. For these few, their appreciation for scientific work increased over the span of the semester.

How Students Learn the Affordances

The scope of this study also went beyond finding the affordances of the probeware system. It also examined at how students learned the affordances. The primary method for learning was by reading the lab manual. If the instructions in the lab manual were not clear to the students, they would employ other methods for learning such as trial and error, asking the laboratory teaching assistant, or asking other nearby students. If the students ran into trouble with the system, they would tend to ask their laboratory teaching assistant or each other for help. Students learned how to use the system using a variety of methods in various combinations depending on the situation. Once students learned how to use the system, their operation of the system becomes more fluid and faster.

One strategy for teaching how to use technology was markedly absent. The method of modeling was not observed and only briefly mentioned in interviews. In modeling, the instructor shows students how to use the technology by utilizing the technology while the students watch and explaining the process while using the technology. In my observations, the laboratory teaching assistant would either do it for them without explaining to the students, or would just tell the students what to do without showing them. Also, during interviews, students did not mention that the laboratory teaching assistant modeled the affordances of the technology. Modeling is an important teaching strategy and will be discussed further in the implications section below.

This study built on the research about affordances of instrumentation used in chemistry laboratories. Prior studies have focused on either high school laboratory use or upper-level undergraduate use. This study's focus on the first chemistry lab taken by university students supports prior work (Malina, 2002) on the upper-level undergraduate use. This study supports the affordances of saving time, accurate measurements, and ease of use as potentially common affordances of all instrumentation. Other affordances that were found in this study were the visual display and the ability to be used in a variety of labs.

Limitations to this Study

The findings presented in this research are based on the data collected during this study and therefore may be limited in their application. This study constitutes a small collection of data about one specific form of instrumentation, namely the PASCO PASPORT™ system. The affordances found in this study may or may not be applicable to other similar systems or to more advanced instrumentation. Additionally, not all of the components of the system were studied. Other components such as the colorimeter, the dissolved oxygen sensor, pH meter and voltage sensor were not studied, nor was the DataStudio™ software that accompanies the PASPORT™ system. Investigating other components of this probeware system, other similar probeware systems, or other instrumentation may produce findings that differ from those presented in this study.

The sample size for this study is also a limitation to this study. This limitation is due to the National Institutes of Health (NIH) requirement that participation in research involving human subjects must be on a voluntary basis. While the initial number of volunteers in the main study was larger than the number of participants in the pilot study, those numbers fell due to waning attendance as the semester progressed. The statistical methods employed in this study allowed me to draw the conclusions of this study. The statistical significance is enough ($n > 30$) to establish validity and reliability of this study.

Implications for Educators

Instrumentation probeware are valuable tools not only for chemists but also for educators. Probeware systems are great introductory instrumentation for first-year undergraduate students and are designed to be used by educators in the science laboratories. The use of probeware systems provides lab instructors the opportunity to focus on the concepts being illustrated by the experiments and the opportunity to spend time discussing the results and helping students make effective connections between the theories and concepts used in the classroom with what they are doing in the lab. The probeware's ease of use, speed in providing accurate data, and the visual display are the affordances that allow these opportunities for instructors.

Conversely, the instructor needs to be very familiar with the names and workings of the probeware and all its components. The students that take general chemistry have little to no experience using this kind of instrumentation or any instrumentation, but do have experience using computers. When students have trouble operating the system, the instructor will have to teach them how to fix the problem whatever the problem may be.

The instructor should model how to use the probeware before the students use the probeware. The modeling should include how to connect the probe(s) to the appropriate data input devices such as the PowerLink™ and to computers as needed. The instructor should model how to turn on the software and operate the software effectively using sample data. The instructor should model how to correctly operate the various probe(s) used in the lab by doing a short practice run on the lab the students will do that day. Finally, the instructor should model how to disassemble the probeware. While this may take some time at first, this modeling should reduce the amount of student errors in using the probeware, should reduce the number of questions asked by the students on how to use the probeware, and should reduce the amount of time the students spend completing the lab.

In order to teach and model effectively, the instructor must know the correct name of the components involved, how to assemble and disassemble it correctly, how to troubleshoot the software, and must be able to replace broken or missing components quickly. More importantly, the instructor must have a good command of the language that is tied with the probeware system being used in the lab. This can be a challenge for an instructor, especially early in the semester when students are learning how to use it. However, when the modeling of new skills is effectively done using the correct terminology, those skills are retained better and learned quicker than if the teaching is poorly done or incomplete.

New instructors, inexperienced instructors, instructors who have difficulty speaking English will have inherent issues with teaching students how to use the probeware system effectively. In addition, it is impossible for instructors to effectively address questions from all students who are having issues using this system (or any probeware system) at one time or over a very short period of time. Because of these issues, the foundation is laid for developing podcasts (Powell, 2010) or other easily accessible videos for instructors and students. These videos can illustrate the proper use of the probeware, correct pronunciation of key words and names of components. The videos for the students and instructors should have clearly stated, step-by-step instructions regarding basic operation procedures for the probeware system and for the software associated with the probeware system. Videos should be made available on how to correctly use individual probes. Finally videos should be made that give students and instructors tips and instructions on how to troubleshoot the probeware system. These videos would encourage development of correct affordances of the probeware by the students.

Videos that model how to use the probeware and the various components would also encourage effective student-student interaction (Powell, 2010). Students already interact in terms of dividing up the tasks for a lab and sharing data. The videos will allow students to talk about the probeware system and develop understanding of the affordances of the probeware together so that they can not only use the probeware correctly but also discuss the probeware using accurate terminology. Students can then construct accurate affordances of the probeware, because they have a common language and common usage of the probeware (Pea, 1993). In addition, when students learn how to use the probeware using multiple modalities including experiential learning techniques, they create more effective chunks of knowledge that are retained longer and recalled faster than if the student used just their written lab instructions alone or trial and error alone (Shell, et al., 2010). Laying the foundation and encouraging more student-student interactions should increase teamwork and promote the potential of greater depth of knowledge.

There are three recognized approaches to learning: deep, strategic, and surface (Entwistle & Ramsden, 1983). Instructors would prefer students to attain a deep understanding of the instrumentation they are using, but this understanding is dependent on the student's approach to learning and how the students are taught. To accomplish a higher cognitive experience concept integration, demonstrated by explaining, applying, and relating concepts, must become part of the laboratory where active pedagogy is taking place. This is demonstrated by successful operation of the instrumentation, collection of accurate data from the instrumentation, few errors in either accuracy or precision of measurements, and little to no need to ask for assistance when a problem with the instrumentation arises. A student who chooses to adopt a surface approach will not learn deeply or meaningfully and is a strong predictor of failure (Mewhinney, 2009). Surface learning is demonstrated by avoiding tasks that seem to be “difficult,” passively watching laboratory activities, continued questioning of classmates to operate the instrumentation for them, and doing just enough lab work so that they can leave lab quickly. If the desired goal of education is achievement and a greater depth of understanding, then the learning approach has to turn to more strategic and deeper understanding.

Finally, it is important for the instructor to realize that the students will construct perceived affordances of the instrumentation that may or may not be the same as the actual affordance. It is important for the instructor to determine what those affordances are from the students' perspectives. Instructors should assess the impact of the experiments on students' understandings by observing the students working in the laboratory and asking key probing questions regarding the names and uses of the components of the probeware. Small, subtle changes in the instructions or nature of the experiment can be missed if the instructor considers only lab reports and exams. For example, a student's data value for the temperature of a substance from the graphical display on the PASCO™ probeware system can be in error by a significant amount if they are obtaining the value from a poorly scaled graph. Giving complete instructions on how to set an effective scale for reading temperature from the graph (like on a podcast or other easily accessible video) will improve the accuracy of the student's data value reading. Similarly, instructing students to switch the display from graphical to numeric will also improve the accuracy of the student's data value.

Overall, the affordances provided by the probeware system and how the students learn the affordances will influence student understanding of both the skills and concepts taught in the lab. It will also help their interpretation of data and will prepare them for more advanced course work in the sciences. Therefore, instructors must be very aware of their objectives for having students use the probeware and choose experiments and components of the probeware that are consistent with their objectives.

This study has implications for instrument developers and manufacturers. Based on the results of this study, clear and concise written instructions as well as training for instructors who use this system or other similar probeware systems is critical for successful usage of the products they sell. Providing web-based videos or podcasts of how to use the probeware would also be a useful item for both instructors and students.

Implications for Future Research

This research focused on students enrolled in the first semester of the first year general chemistry lab. This study also focused on the students interactions with the instrumentation, with the instructor, and with each other both in the laboratory setting and in interviews. The findings presented in this study could be specific to this particular setting. Thus, students in different sciences that use this type of instrumentation could be studied to see if the affordances of the probeware they see in chemistry lab are the same or different in other science labs. The affordances of time and visual display might be common for other sciences, but are there other affordances of the system in general that would be different for physics or biology, for example?

Also, other components of the probeware system can be studied for their affordances. Maybe the other components like the colorimeter and the voltage sensor have similar affordances as the temperature probe that allow students to “see” what is not apparent to them in the reaction container (Appendix F, Mickey Interview, lines 94-95). Similar systems to the PASCO PASPORT™ can be studied to see if their affordances are the same as the PASPORT™ system or if new ones are found in the other systems.

Other instrumentation that is used at upper division undergraduate level chemistry courses and in graduate level laboratories can also be studied for their affordances. General chemistry laboratory is a gateway course for future studies in chemistry and provides foundational lab skills used in upper level courses. One prior study (Malina, 2002) shows that there might be some common affordances between probeware and more advanced instrumentation, such as time and visual display. What other affordances does probeware have in common with more advanced instrumentation? What new affordances are learned as students advance in learning instrumentation? Ultimately, a collection of affordances that are common to all instrumentation might be determined.

APPENDIX A

IRB APPROVAL AND STUDENT CONSENT FORMS

UNT
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Discover the power of ideas.

OFFICE OF THE VICE PRESIDENT FOR RESEARCH AND ECONOMIC DEVELOPMENT

August 11, 2009

Kristin Sherman
Department of Chemistry
University of North Texas

Re: Human Subjects Application No. 09308

Dear Ms. Sherman:

As permitted by federal law and regulations governing the use of human subjects in research projects (45 CFR 46), the UNT Institutional Review Board has reviewed your proposed project titled "Affordances of Instrumentation Used in the General Chemistry Laboratory." The risks inherent in this research are minimal, and the potential benefits to the subject outweigh those risks. The submitted protocol is hereby approved for the use of human subjects in this study. **Federal Policy 45 CFR 46.109(e) stipulates that IRB approval is for one year only, August 11, 2009 to August 10, 2010.**

Enclosed is the consent document with stamped IRB approval. Please copy and use this form only for your study subjects.

It is your responsibility according to U.S. Department of Health and Human Services regulations to submit annual and terminal progress reports to the IRB for this project. The IRB must also review this project prior to any modifications.

Please contact Shelia Bourns, Research Compliance Administrator, or Boyd Herndon, Director of Research Compliance, at extension 3940, if you wish to make changes or need additional information.

Sincerely

Patricia L. Kaminski, Ph.D.
Associate Professor
Chair, Institutional Review Board

PK:sb

CC: Dr. Diana Mason

1155 Union Circle #305250 | Denton, Texas 76203-5017 | TEL 940.565.3940 | FAX 940.565.4277
TTY 940.369.8652 | www.unt.edu

UNT™
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OFFICE OF THE VICE PRESIDENT FOR RESEARCH AND ECONOMIC DEVELOPMENT
Research Services

March 4, 2010

Diana Mason
Department of Chemistry
University of North Texas

Re: Human Subjects Application No. 10036

Dear Dr. Mason:

As permitted by federal law and regulations governing the use of human subjects in research projects (45 CFR 46), the UNT Institutional Review Board has reviewed your proposed project titled "Affordances of Instrumentation Used in the General Chemistry Laboratory." The risks inherent in this research are minimal, and the potential benefits to the subject outweigh those risks. The submitted protocol is hereby approved for the use of human subjects in this study. **Federal Policy 45 CFR 46.109(e) stipulates that IRB approval is for one year only, March 4, 2010 to March 3, 2011.**

Enclosed is the consent document with stamped IRB approval. Please copy and **use this form only** for your study subjects.

It is your responsibility according to U.S. Department of Health and Human Services regulations to submit annual and terminal progress reports to the IRB for this project. The IRB must also review this project prior to any modifications.

Please contact Shelia Bourns, Research Compliance Administrator, or Boyd Herndon, Director of Research Compliance, at extension 3940, if you wish to make changes or need additional information.

Sincerely,

Patricia L. Kaminski, Ph.D.
Associate Professor
Chair, Institutional Review Board

PK:sb

1155 Union Circle #305250 | Denton, Texas 76203-5017 | TEL 940.565.3940 | FAX 940.565.4277

University of North Texas Institutional Review Board

Informed Consent Form

Before agreeing to participate in this research study, it is important that you read and understand the following explanation of the purpose, benefits and risks of the study and how it will be conducted.

Title of Study: Affordances of Instrumentation Used in the General Chemistry Laboratory

Principal Investigator: Kristin Sherman, a graduate student in the University of North Texas (UNT) Department of Chemistry.

Purpose of the Study: You are being asked to participate in a research study that will determine if college-level students taking general chemistry laboratory can identify uses for various instrumentation used in the general chemistry laboratory beyond what they use them for in the chemistry lab.

Study Procedures: You will be asked to complete an initial survey at the beginning of the semester that will take about 10-15 minutes of your time. You will also be asked to complete two more surveys during the semester, at mid-semester and again at the end of the semester, that will take about 5-10 minutes of your time. You may also be invited to participate in an interview at the end of the semester that will take 45-60 minutes. If you agree to be surveyed, you are not obligated to participate in the 45-60 minute interview.

Foreseeable Risks: No foreseeable risks are involved in this study.

Benefits to the Subjects or Others: We expect the project to benefit you by focusing on what the instrumentation is used for and thinking about what the instrumentation could be used for beyond general chemistry. Interviewees will benefit greatly from the interview and discussion of their ideas in the interview. All subjects will gain understanding in instrumentation use in chemistry and other courses and careers.

Procedures for Maintaining Confidentiality of Research Records: All surveys, audio recordings of interviews, and transcriptions of the interviews will be maintained and locked in the Principal Investigator's office. Anyone who transcribes the audio recordings other than the Principal Investigator will sign a confidentiality agreement prior to transcribing the audio recordings. All survey participants will be coded using a randomly generated number system not based on any personally identifiable number. The interview participants' names will be changed to protect their identity. Any personally identifiable data will be kept for the duration of three years past the end of the study for the purpose of contacting interviewees. The confidentiality of your individual information will be maintained in any publications or presentations regarding this project as well as the doctoral dissertation.

Questions about the Study: If you have any questions about the study, you may contact *Kristin Sherman* at telephone number (940) 565-2265, or the faculty advisor, Dr. Diana Mason, UNT Department of Chemistry, at telephone number (940) 565-2491.

Review for the Protection of Participants: This research study has been reviewed and approved by the UNT Institutional Review Board (IRB). The UNT IRB can be contacted at (940) 565-3940 with any questions regarding the rights of research subjects.

Research Participants' Rights: Your signature below indicates that you have read or have had read to you all of the above and that you confirm all of the following:

- Kristin Sherman has explained the study to you and answered all of your questions. You have been told the possible benefits and the potential risks and/or discomforts of the study.
- You understand that you do not have to take part in this study, and your refusal to participate or your decision to withdraw will involve no penalty or loss of rights or benefits. The study personnel may choose to stop your participation at any time.
- Your decision to participate in this study or to withdraw from this study will have no effect on your standing in this course or your course grade.
- You understand why the study is being conducted and how it will be performed.
- You understand your rights as a research participant and you voluntarily consent to participate in this study.
- You have been told you will receive a copy of this form.

____
Printed Name of Participant

______________________________ ____________
Signature of Participant Date

For the Principal Investigator: I certify that I have reviewed the contents of this form with the participant signing above. I have explained the possible benefits and the potential risks and/or discomforts of the study. It is my opinion that the participant understood the explanation.

______________________________ ____________
Signature of Principal Investigator Date

APPROVED BY THE UNT IRB
FROM 8/11/09 TO 8/10/10

University of North Texas Institutional Review Board

Informed Consent Form

Before agreeing to participate in this research study, it is important that you read and understand the following explanation of the purpose, benefits and risks of the study and how it will be conducted.

Title of Study: Affordances of Instrumentation Used in the General Chemistry Laboratory

Principal Investigator: Kristin Sherman, a graduate student in the University of North Texas (UNT) Department of Chemistry.

Purpose of the Study: You are being asked to participate in a research study that will determine if college-level students taking general chemistry laboratory can identify uses for various instrumentation used in the general chemistry laboratory beyond what they use them for in the chemistry lab.

Study Procedures: You will be asked to participate in an interview that will last 45-60 minutes. This interview is a follow-up to the surveys you agreed to take this semester. This interview will be between you and the Principal Investigator. This interview may be audio recorded so that the data gathered during the interview will be accurate.

Foreseeable Risks: No foreseeable risks are involved in this study.

Benefits to the Subjects or Others: We expect the project to benefit you by focusing on what the instrumentation is used for and thinking about what the instrumentation could be used for beyond general chemistry. Interviewees will benefit greatly from the interview and discussion of their ideas in the interview. All subjects will gain understanding in instrumentation use in chemistry and other courses and careers.

Procedures for Maintaining Confidentiality of Research Records: All surveys, audio recordings of interviews, and transcriptions of the interviews will be maintained and locked in the Principal Investigator's office. Anyone who transcribes the audio recordings other than the Principal Investigator will sign a confidentiality agreement prior to transcribing the audio recordings. All survey participants will be coded using a randomly generated number system not based on any personally identifiable number. The interview participants' names will be changed to protect their identity. Any personally identifiable data will be kept for the duration of three years past the end of the study for the purpose of contacting interviewees. The confidentiality of your individual information will be maintained in any publications or presentations regarding this project as well as the doctoral dissertation.

Questions about the Study: If you have any questions about the study, you may contact *Kristin Sherman* at telephone number (940) 565-2265, or the faculty advisor, Dr. Diana Mason, UNT Department of Chemistry, at telephone number (940) 565-2491.

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Research Participants' Rights: Your signature below indicates that you have read or have had read to you all of the above and that you confirm all of the following:

- Kristin Sherman has explained the study to you and answered all of your questions. You have been told the possible benefits and the potential risks and/or discomforts of the study.
- You understand that you do not have to take part in this study, and your refusal to participate or your decision to withdraw will involve no penalty or loss of rights or benefits. The study personnel may choose to stop your participation at any time.
- Your decision to participate in this study or to withdraw from this study will have no effect on your standing in this course or your course grade.
- You understand why the study is being conducted and how it will be performed.
- You understand your rights as a research participant and you voluntarily consent to participate in this study.
- You have been told you will receive a copy of this form.

____
Printed Name of Participant

________________________________ ____________
Signature of Participant Date

For the Principal Investigator: I certify that I have reviewed the contents of this form with the participant signing above. I have explained the possible benefits and the potential risks and/or discomforts of the study. It is my opinion that the participant understood the explanation.

____ ____________
Signature of Principal Investigator Date

APPROVED BY THE UNT IRB
FROM 8/11/09 TO 8/10/10

University of North Texas Institutional Review Board

Informed Consent Form

Before agreeing to participate in this research study, it is important that you read and understand the following explanation of the purpose, benefits and risks of the study and how it will be conducted.

Title of Study: Affordances of Instrumentation Used in the General Chemistry Laboratory

Principal Investigator: Diana Mason, University of North Texas (UNT) Department of Chemistry.

Key Personnel: Kristin Sherman, University of North Texas (UNT) Department of Chemistry

Purpose of the Study: You are being asked to participate in a research study that will investigate if college-level students taking general chemistry laboratory can identify uses for various instrumentation used in the general chemistry laboratory beyond what they use them for in the chemistry lab.

Study Procedures: You will be asked to complete an initial survey at the beginning of the semester that will take about 10-15 minutes of your time. You will also be asked to complete two more surveys during the semester, at mid-semester and again at the end of the semester, that will take about 5-10 minutes of your time. You will also be observed up to four (4) times during this study while working in the lab by Kristin Sherman. Kristin will take notes while you are working, and she will not interfere with your lab work in any way. Kristin will also follow all lab safety procedures while making observations. You may also be invited to participate in an interview towards the end of the semester that will take 45-60 minutes. If you agree to be surveyed, you are not obligated to participate in the 45-60 minute interview.

Foreseeable Risks: No foreseeable risks are involved in this study.

Benefits to the Subjects or Others: For the field of study, chemistry education, understanding of how students learn to use instrumentation will help instructors provide more effective instruction to their students. With the growth of use of computer-based laboratories and instrumentation at the lowest level of undergraduate chemistry courses, more students will use this technology. Instructors need to know what students see as the usefulness of the instrumentation and the uses of the instrumentation so that their instruction can be more effective.

Procedures for Maintaining Confidentiality of Research Records: All surveys, lab observation notes, audio recordings of interviews, and transcriptions of the interviews will be maintained and locked in the Principal Investigator's office. Anyone who transcribes the audio recordings other than the Principal Investigator or Kristin Sherman will sign a confidentiality agreement prior to transcribing the audio recordings. All survey participants will be coded using a randomly generated number system not based on any personally identifiable number. The interview participants' names will be changed to protect their identity. Any personally identifiable data will be kept for the duration of three years past the end of the study for the purpose of contacting interviewees. The confidentiality of your individual information will be maintained in any publications or presentations regarding this project as well as the doctoral dissertation.

Questions about the Study: If you have any questions about the study, you may contact *Diana Mason* at telephone number *940-565-2491* or *Kristin Sherman* at telephone number *940-565-2265*.

Review for the Protection of Participants: This research study has been reviewed and approved by the UNT Institutional Review Board (IRB). The UNT IRB can be contacted at (940) 565-3940 with any questions regarding the rights of research subjects.

Research Participants' Rights:

Your signature below indicates that you have read or have had read to you all of the above and that you confirm all of the following:

- *Diana Mason or Kristin Sherman* has explained the study to you and answered all of your questions. You have been told the possible benefits and the potential risks and/or discomforts of the study.
- Your decision to participate or to withdraw from the study will have no effect on your standing in this course or your course grade.
- You understand why the study is being conducted and how it will be performed.
- You understand your rights as a research participant and you voluntarily consent to participate in this study.
- You have been told you will receive a copy of this form.

____
Printed Name of Participant

________________________________ ____________
Signature of Participant Date

APPROVED BY THE UNT IRB
FROM 3/4/10 TO 3/3/11

For the Principal Investigator or Designee:

I certify that I have reviewed the contents of this form with the subject signing above. I have explained the possible benefits and the potential risks and/or discomforts of the study. It is my opinion that the participant understood the explanation.

________________________________ ____________
Signature of Principal Investigator or Designee Date

University of North Texas Institutional Review Board

Informed Consent Form

Before agreeing to participate in this research study, it is important that you read and understand the following explanation of the purpose, benefits and risks of the study and how it will be conducted.

Title of Study: Affordances of Instrumentation Used in the General Chemistry Laboratory

Principal Investigator: Diana Mason, University of North Texas (UNT) Department of Chemistry.

Key Personnel: Kristin Sherman, University of North Texas (UNT) Department of Chemistry

Purpose of the Study: You are being asked to participate in a research study that will investigate if college-level students taking general chemistry laboratory can identify uses for various instrumentation used in the general chemistry laboratory beyond what they use them for in the chemistry lab. This study is a part of dissertation work by Kristin Sherman and supervised by the Principal Investigator, Diana Mason.

Study Procedures: You will be asked to participate in an interview that will last 45-60 minutes. This interview is a follow-up to the surveys you agreed to take this semester. This interview will be between you and the Principal Investigator. This interview may be audio recorded so that the data gathered during the interview will be accurate.

Foreseeable Risks: No foreseeable risks are involved in this study.

Benefits to the Subjects or Others: For the field of study, chemistry education, understanding of how students learn to use instrumentation will help instructors provide more effective instruction to their students. With the growth of use of computer-based laboratories and instrumentation at the lowest level of undergraduate chemistry courses, more students will use this technology. Instructors need to know what students see as the usefulness of the instrumentation and the uses of the instrumentation so that their instruction can be more effective.

Procedures for Maintaining Confidentiality of Research Records: All surveys, lab observation notes, audio recordings of interviews, and transcriptions of the interviews will be maintained and locked in the Principal Investigator's office. Anyone who transcribes the audio recordings other than the Principal Investigator or Kristin Sherman will sign a confidentiality agreement prior to transcribing the audio recordings. All survey participants will be coded using a randomly generated number system not based on any personally identifiable number. The interview participants' names will be changed to protect their identity. Any personally identifiable data will be kept for the duration of three years past the end of the study for the purpose of contacting interviewees. The confidentiality of your individual information will be maintained in any publications or presentations regarding this project as well as the doctoral dissertation.

Questions about the Study: If you have any questions about the study, you may contact *Diana Mason* at telephone number *940-565-2491* or *Kristin Sherman* at telephone number *940-565-2265*.

Review for the Protection of Participants: This research study has been reviewed and approved by the UNT Institutional Review Board (IRB). The UNT IRB can be contacted at (940) 565-3940 with any questions regarding the rights of research subjects.

Research Participants' Rights:

Your signature below indicates that you have read or have had read to you all of the above and that you confirm all of the following:

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- Your decision to participate or to withdraw from the study will have no effect on your standing in this course or your course grade.
- You understand why the study is being conducted and how it will be performed.
- You understand your rights as a research participant and you voluntarily consent to participate in this study.
- You have been told you will receive a copy of this form.

____
Printed Name of Participant

______________________________ ____________
Signature of Participant Date

APPROVED BY THE UNT IRB
FROM 3/4/10 TO 3/3/11

For the Principal Investigator or Designee:

I certify that I have reviewed the contents of this form with the subject signing above. I have explained the possible benefits and the potential risks and/or discomforts of the study. It is my opinion that the participant understood the explanation.

______________________________ ____________
Signature of Principal Investigator or Designee Date

APPENDIX B

PILOT STUDY INSTRUMENTS

Lab Technology Survey

In this survey you will be asked some questions that you may or may not know the answers to. If you don't know the answers, don't worry; this will not affect your grade in the course. Please respond honestly and as completely as you can. Thank you for your cooperation!

Part 1: Tell me about yourself.

Male Female

Age: 18-22 23-28 29-34 35-40 41 and older

Did you take a chemistry class in high school? YES NO

If yes, did you do labs in your chemistry class in high school? YES NO

Did you take a college-level chemistry class prior to this one? YES NO

If yes, did you take the matching lab course? YES NO NOT OFFERED

Do you have experience using technology in a lab setting? YES NO

If so, what was your experience?____________________________________

What is your major? __________________________

Part 2: Please rank the following statements according to the following scale:

- 5 – strongly agree
- 4 – agree
- 3 – I don't know
- 2 – disagree
- 1 – strongly disagree

1. The PASCO system is useful in the general chemistry lab. 5 4 3 2 1
2. The PASCO system can be used for many different labs in general chemistry. 5 4 3 2 1
3. The PASCO system can be used in other chemistry courses. 5 4 3 2 1
4. The PASCO system cannot be used outside of chemistry. 5 4 3 2 1
5. The PASCO system is a stand-alone system. That is, it cannot interact with computers or with

other PASCO systems.	5	4	3	2	1
6. The PASCO system is portable.	5	4	3	2	1
7. The PASCO system will save me time in lab.	5	4	3	2	1
8. The PASCO system is difficult to use.	5	4	3	2	1

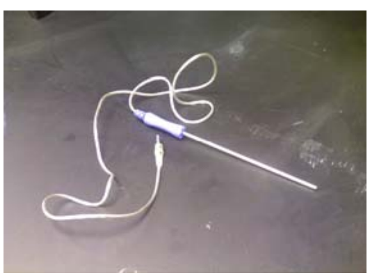
<u>Part 3</u>: Look at the pictures below. Answer the questions that follow to the best of your ability:

A) 

1. Have you ever used this device before? YES NO

2. What is this device?

3. What is it used for?

B) 

1. Have you ever used this device before? YES NO

2. What is this device?

3. What is it used for?

C) 

1. Have you ever used this device before? YES NO

2. What is this device?

3. What is it used for?

D) 

1. Have you ever used this device before? YES NO

2. What is this device?

3. What is it used for?

Interview Script for Study

Introduce myself… "You can call me Kris" to help put them at ease.

"This interview should take about one hour."

"There are no right or wrong answers to the questions I will ask you. I am interested in your understandings and opinions."

"I will be taking notes throughout the interview to help me remember."

"I will also be audio taping the interview so I don't forget anything we say."

"Just a reminder: Everything is confidential. Only my advisor and I will have access to the notes and tapes that will be kept out of sight in a locked office. The tapes will be kept for three years after the interviews along with any personally identifiable information if I need to follow up on anything after the interview. After the three years, the tapes will be destroyed."

"Your grade cannot and will not be affected."

"Anything used to report findings will be under an alias to protect your identity."

"You have the option to not answer any question or end this interview at any time."

"Do you have any questions about what we are doing today?" [Answer any and all questions]

"You will have a chance to ask questions at the end."

"I have paper, pens, and pencils available for you if you would like to write or draw anything. I also have a copy of the lab manual here if you would like to look at it."

[Begin interview questions – start on next page]

[After the interview:]

"This concludes the interview. Do you have any questions for me at this point?"

“Thank you for participating in this interview. Again, everything is confidential. Only my advisor and I will have access to the notes and tapes that will be kept out of sight in a locked office. The tapes will be kept for three years after the interviews along with any personally identifiable information if I need to follow up on anything after the interview. After the three years, the tapes will be destroyed.”

Interview Questions

1. In your opinion, what is/are the purpose(s) of general chemistry laboratories?
2. What do you think is the purpose of using the PASCO system in the General Chemistry lab? Please elaborate.
3. Did you physically use the PASCO system? If so, what did you use it for?
4. Describe how you used the PASCO system in the lab “Statistical Analysis on Different Types of Pennies.”
    a. What was the purpose of using the PASCO system in this lab?
    b. How did this system work for you in this lab?
    c. How did you physically use it? Describe the techniques.
    d. Did you find the system useful for this lab? Please elaborate.
    e. Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.
    f. Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.
5. Describe how you used the PASCO system in the lab “Gas Laws – Verification of Boyle’s Law, Charles’ Law, and Avogadro’s Law.”
    a. What was the purpose of using the PASCO system in this lab?

b. How did this system work for you in this lab? How did the probe(s) help?
c. How did you physically use it? Describe the techniques.
d. Did you find the system useful for this lab? Please elaborate.
e. Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.
f. Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.

6. Describe how you used the PASCO system in the lab “Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water.”
   a. What was the purpose of using the PASCO system in this lab?
   b. How did this system work for you in this lab? How did the probe help?
   c. How did you physically use it? Describe the techniques.
   d. Did you find the system useful for this lab? Please elaborate.
   e. How did using the PASCO system for this lab compare to using a thermometer in the calorimetry labs that follow?
   f. Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.
   g. Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.
7. Consider the PASCO system from your perspective/experience in an overall sense:
   a. What components of the system were most helpful in conducting experiments?

b. What components of the system were least helpful or even a hindrance in conducting experiments?
c. What components of the system were most helpful for interpreting data?
d. What components of the system were least helpful for interpreting data?
e. Do you think the PASCO system gives you accurate data? Why or why not?
f. With regards to other Chemistry courses beyond General Chemistry, do you see this system as useful? If so, how and for which ones? If not, why not?
g. With regards to other science courses, do you see this system as useful? If not, why not? If so, which sciences do you see this system as applicable? How can they be applied?
h. Do you think there are any applications of the PASCO device beyond the classroom? If not, why not? If so, where can this be used and how?
i. Are there parts of the PASCO system that you still do not understand fully? Why?
j. Do you have any questions for me?

8. In your opinion, is there better instrumentation available for the general chemistry laboratory at UNT? If so, what are they? Why do you think so?

APPENDIX C

MAIN STUDY INSTRUMENTS

Lab Technology Survey

In this survey you will be asked some questions that you may or may not know the answers to. If you don't know the answers, don't worry; this will not affect your grade in the course. Please respond honestly and as completely as you can. Thank you for your cooperation!

Part 1: Tell me about yourself.

Male Female

Age: 18-22 23-28 29-34 35-40 41 and older

Did you take a chemistry class in high school? YES NO

If yes, did you do labs in your chemistry class in high school? YES NO

Did you take a college-level chemistry class prior to this one? YES NO

If yes, did you take the matching lab course? YES NO NOT OFFERED

Do you have experience using technology in a lab setting? YES NO

If so, what was your experience?____

What is your major? ___________________________

Part 2: Please rank the following statements according to the following scale:

- 5 – strongly agree
- 4 – agree
- 3 – I don't know
- 2 – disagree
- 1 – strongly disagree

1. The PASCO system is useful in the general chemistry lab. 5 4 3 2 1
2. The PASCO system can be used for many different labs in general chemistry. 5 4 3 2 1
3. The PASCO system can be used in other chemistry courses. 5 4 3 2 1
4. The PASCO system cannot be used outside of chemistry. 5 4 3 2 1
5. The PASCO system is a stand-alone system. That is, it cannot interact with computers or with

other PASCO systems. 5 4 3 2 1

6. The PASCO system is portable. 5 4 3 2 1

7. The PASCO system will save me time in lab. 5 4 3 2 1

8. The PASCO system is difficult to use. 5 4 3 2 1

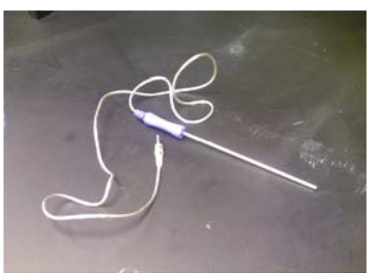
Part 3: Look at the pictures below. Answer the questions that follow to the best of your ability:

A) 

1. Have you ever used this device before? YES NO

2. What is this device? What is it used for?

☐ I don't know (Please explain)

B) 

1. Have you ever used this device before? YES NO

2. What is this device? What is it used for?

☐ I don't know (Please explain)

C) 

1. Have you ever used this device before? YES NO

2. What is this device? What is it used for?

☐ I don't know (Please explain)

D) 

1. Have you ever used this device before? YES NO

2. What is this device? What is it used for?

☐ I don't know (Please explain)

Interview Script for Study

Introduce myself… “You can call me Kris” to help put them at ease.

“This interview should take about one hour.”

“There are no right or wrong answers to the questions I will ask you. I am interested in your understandings and opinions.”

“I will be taking notes throughout the interview to help me remember.”

“I will also be audio taping the interview so I don’t forget anything we say.”

“Just a reminder: Everything is confidential. Only my advisor and I will have access to the notes and tapes that will be kept out of sight in a locked office. The tapes will be kept for three years after the interviews along with any personally identifiable information if I need to follow up on anything after the interview. After the three years, the tapes will be destroyed.”

“Your grade cannot and will not be affected.”

“Anything used to report findings will be under an alias to protect your identity.”

“You have the option to not answer any question or end this interview at any time.”

“Do you have any questions about what we are doing today?” [Answer any and all questions]

“You will have a chance to ask questions at the end.”

“I have paper, pens, and pencils available for you if you would like to write or draw anything. I also have a copy of the lab manual here if you would like to look at it.”

[Begin interview questions – start on next page]

[After the interview:]

“This concludes the interview. Do you have any questions for me at this point?”

“Thank you for participating in this interview. Again, everything is confidential. Only my advisor and I will have access to the notes and tapes that will be kept out of sight in a locked office. The tapes will be kept for three years after the interviews along with any personally identifiable information if I need to follow up on anything after the interview. After the three years, the tapes will be destroyed.”

Interview Questions

1. In your opinion, what is/are the purpose(s) of general chemistry laboratories?
2. What do you think is the purpose of using the PASCO system in the General Chemistry lab? Please elaborate.
3. Did you physically use the PASCO system? If so, what did you use it for?
4. Describe how you used the PASCO system in the lab “Statistical Analysis on Different Types of Pennies.”
    a. What was the purpose of using the PASCO system in this lab?
    b. How did this system work for you in this lab?
    c. How did you physically use it? Describe the techniques.
    d. Did you find the system useful for this lab? Please elaborate.
    e. Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.
    f. Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.
5. Describe how you used the PASCO system in the lab “Gas Laws – Verification of Boyle’s Law, Charles’ Law, and Avogadro’s Law.”
    a. What was the purpose of using the PASCO system in this lab?

b. How did this system work for you in this lab? How did the probe(s) help?

c. How did you physically use it? Describe the techniques.

d. Did you find the system useful for this lab? Please elaborate.

e. Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.

f. Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.

6. Describe how you used the PASCO system in the lab “Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water.”

   a. What was the purpose of using the PASCO system in this lab?

   b. How did this system work for you in this lab? How did the probe help?

   c. How did you physically use it? Describe the techniques.

   d. Did you find the system useful for this lab? Please elaborate.

   e. How did using the PASCO system for this lab compare to using a thermometer in the calorimetry labs that follow?

   f. Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.

   g. Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.

7. Consider the PASCO system from your perspective/experience in an overall sense:

   a. What components of the system were most helpful in conducting experiments?

b. What components of the system were least helpful or even a hindrance in conducting experiments?

c. What components of the system were most helpful for interpreting data?

d. What components of the system were least helpful for interpreting data?

e. Do you think the PASCO system gives you accurate data? Why or why not?

f. With regards to other Chemistry courses beyond General Chemistry, do you see this system as useful? If so, how and for which ones? If not, why not?

g. With regards to other science courses, do you see this system as useful? If not, why not? If so, which sciences do you see this system as applicable? How can they be applied?

h. Do you think there are any applications of the PASCO device beyond the classroom? If not, why not? If so, where can this be used and how?

i. Are there parts of the PASCO system that you still do not understand fully? Why?

j. Do you have any questions for me?

8. In your opinion, is there better instrumentation available for the general chemistry laboratory at UNT? If so, what are they? Why do you think so?

9. How did you go about learning how to use the various parts of the PASCO system during this semester?

10. Describe how you and your lab partner (or rest of your lab group) worked through labs. Who did the most work? What were the roles of each person?

11. Describe discussions you had with your lab partner (or rest of your lab group) about how to work with the PASCO system.

12. Describe discussions you had with your lab TA (teaching assistant) about how to work with the PASCO system.

APPENDIX D

MAIN STUDY INTERVIEW CODING GUIDE

MAIN STUDY INTERVIEW CODING GUIDE

1. Time – This includes any comments regarding the idea of time. This includes any comment regarding speed of obtaining data, speed of completion of labs, any comparisons between the time it takes to operate the instrument compared with traditional instrumentation.
2. Visual display – This includes any comments about visual displays of data that include graphs, tables, or charts displayed on computer monitor
3. Ease-difficulty – This includes comments regarding components that were helpful or a hindrance to using the system, understanding the lab procedure, or data analysis.
4. Accuracy – This includes comments regarding accuracy of data output and display with regards to the system, the accuracy of the results of the lab, and any reasons that would be related to the accuracy or loss of accuracy regarding their data.
5. Purpose– This includes the students' comments regarding the purpose of the entire system, the individual components of the system, or the laboratory.

   NOTE: This does not include comments regarding ease-difficulty or accuracy.
6. Learning – This includes comments or actions that pertain to or show some indication of learning. This includes learning taking place prior to or during data collection
7. Future Application – This includes comments regarding applications in advanced chemistry courses, in other science courses, or in other areas such as the work place.
8. Unknowns – This includes comments regarding what aspects of the system and/or the components that they still do not understand fully.

9. Procedures – This includes comments or observations about laboratory procedures, procedures for using the instrumentation, procedures for changing the display, procedures for analyzing the data, or procedures for calibrating the instrumentation.
10. Student-Group – This includes comments and observations about how the student interacted with the rest of the group during lab
11. Student-System – This includes comments and observations about how the student interacted with the instrumentation.
12. Student-Teaching Assistant – This includes comments and observations about how the student interacted with the lab teaching assistant.
13. Usefulness – This includes any comments and observations about how the students perceive the usefulness of the system and any of the components of the system. NOTE: This does not include any comments regarding ease-difficulty or accuracy.
14. Miscellaneous – This includes any comments and observations that do not fit into any of the above categories but seem important to include.

APPENDIX E

ADDITIONAL PILOT STUDY DATA

Demographic Overview of Participants

In the study conducted in fall 2009, 35 students who were over the age of 18 volunteered to participate. All the volunteers were enrolled in Chemistry 1430, General Chemistry Laboratory for Science Majors at the University of North Texas. Of the 35 participants, 35 completed the initial survey, and 32 had completed both the initial and mid-semester surveys over the course of the semester.

The participants were fairly evenly distributed between male and female: 20 male students and 15 female students (57.1% and 42.9%, respectively). Twenty-seven were between the ages of 18 and 22, seven were between the ages of 23 and 28, and one was between the ages of 29 and 34 (77.1%, 20.0%, and 2.9%, respectively). No one was over the age of 34.

Most students took high school chemistry during their high school careers (88.1%). Four students (11.4%) had not taken chemistry in high school: three were between the ages of 18 and 22 years of age, and one was between the ages of 23 and 28 years old. Of those who took high school chemistry, only three admitted they had not done labs in high school chemistry. Only one person in the group did not report an answer to that question.

Ten students (28.6%) took college-level chemistry prior to this class. The distribution of students reporting prior experience using technology in a lab setting was evenly distributed. Nineteen reported they had used technology before, while 16 reported never using technology before (54.3% and 45.7%, respectively).

Results from Survey Part 3 Question 2 “What Is This Device?”

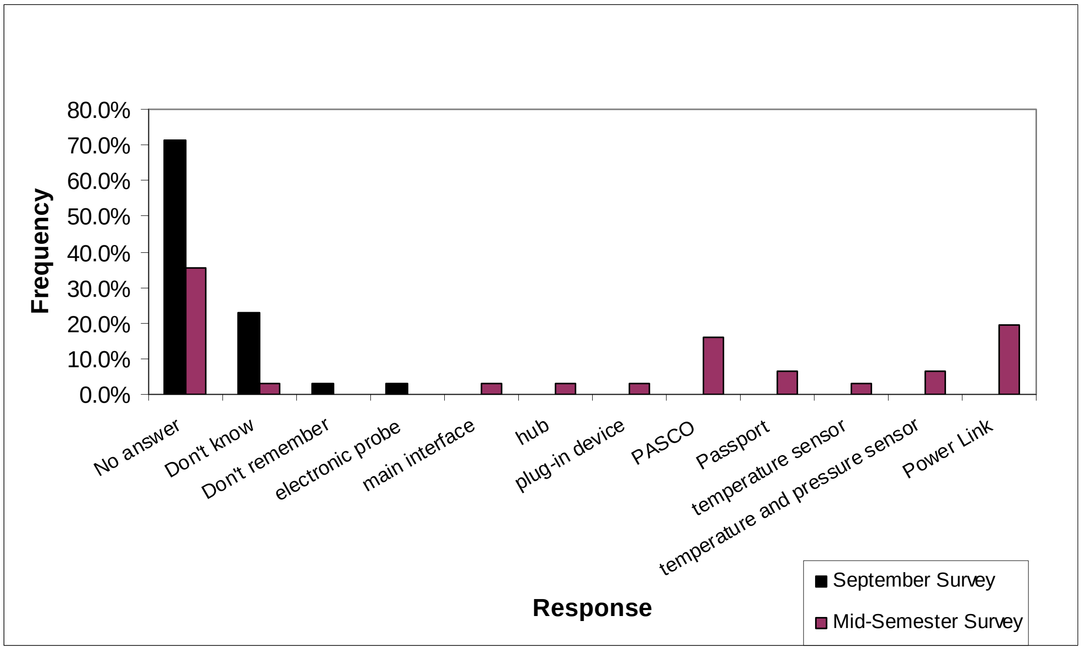


Figure E1. Responses to “What is this device?” about PowerLink™.

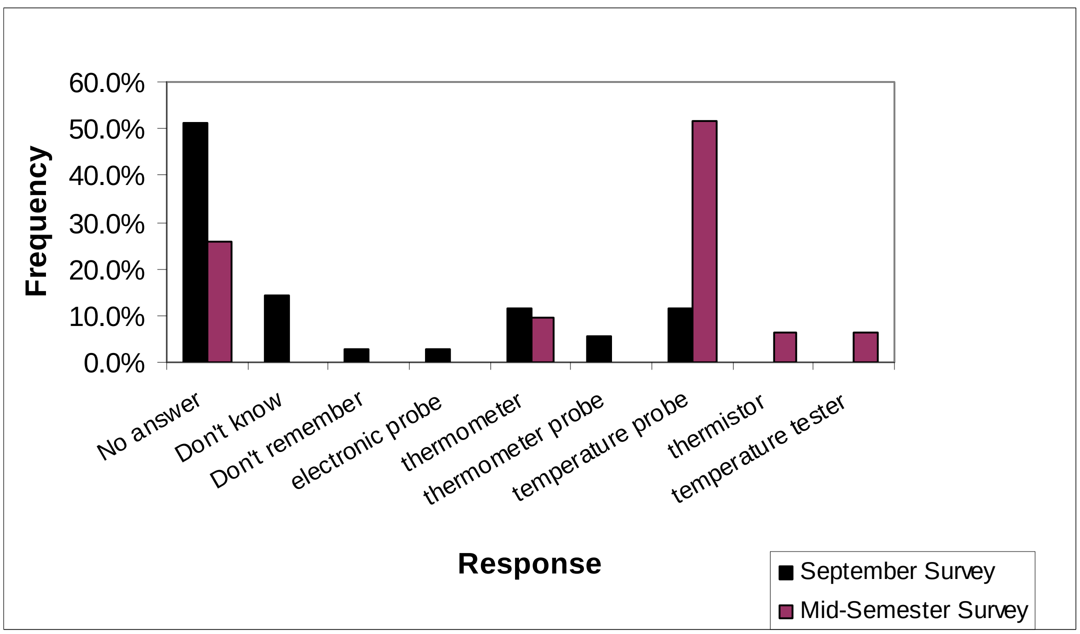


Figure E2. Responses to “What is this device?” about Temperature Sensor™.

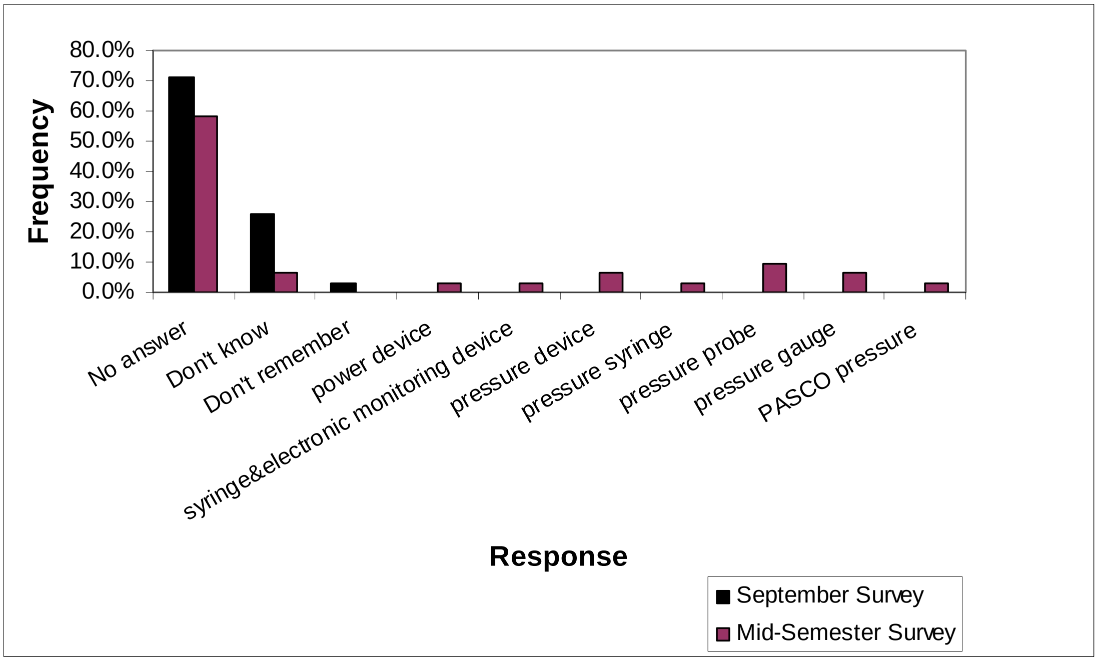
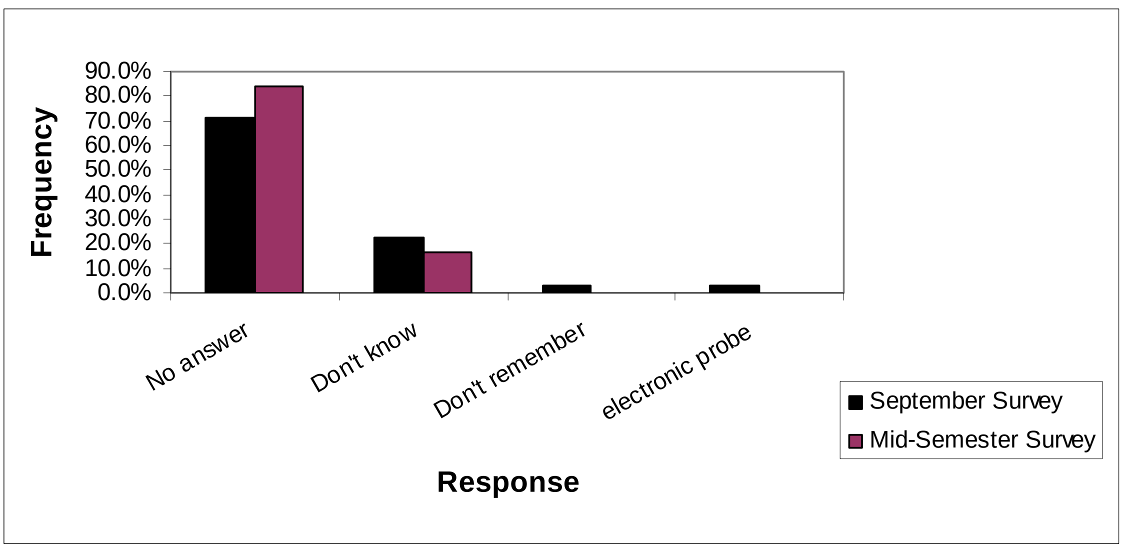


Figure E3. Responses to "What is this device?" about Absolute Pressure Sensor™.



FigureE4. Responses to "What is this device?" about Drop Counter™.

Results from Survey Part 3 Question "What Is It Used for?"

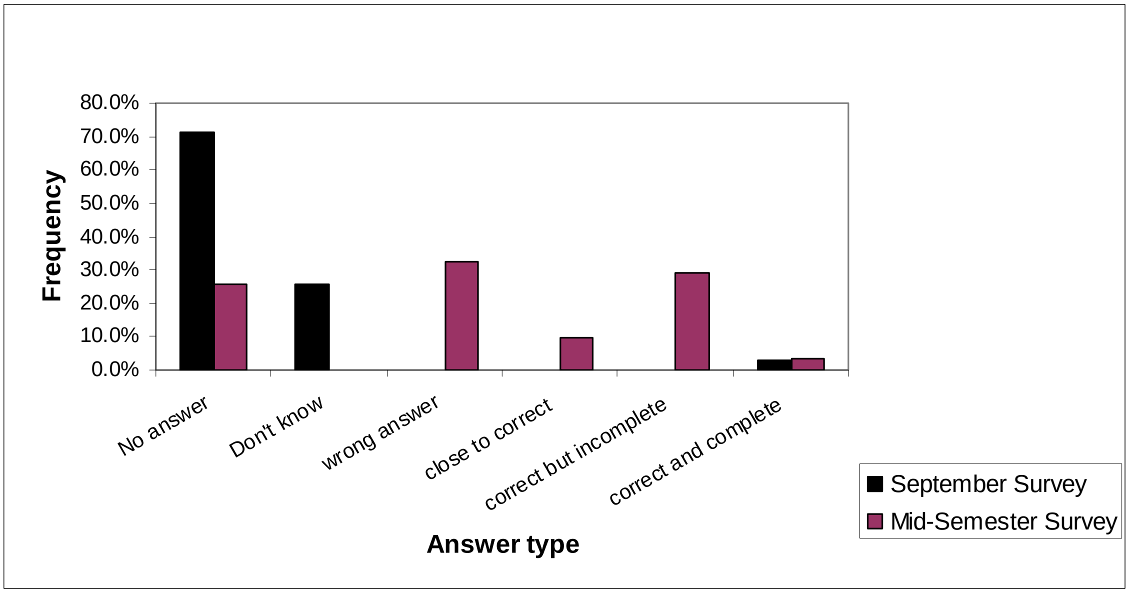


Figure E5. Categories of responses to "What is it used for?" about PowerLink™.

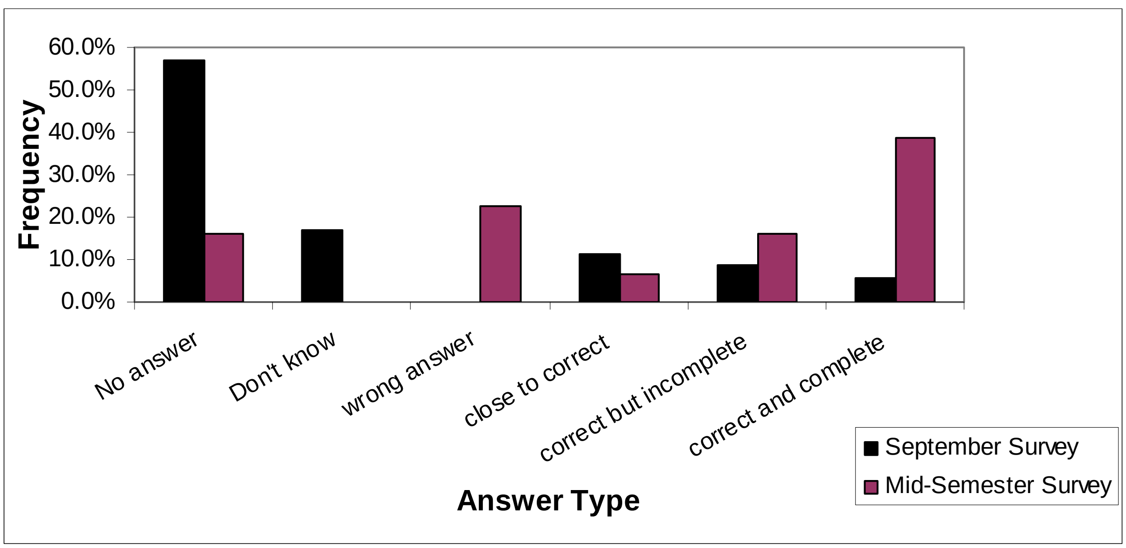


Figure E6. Categories of responses to "What is it used for?" about Temperature Sensor™.

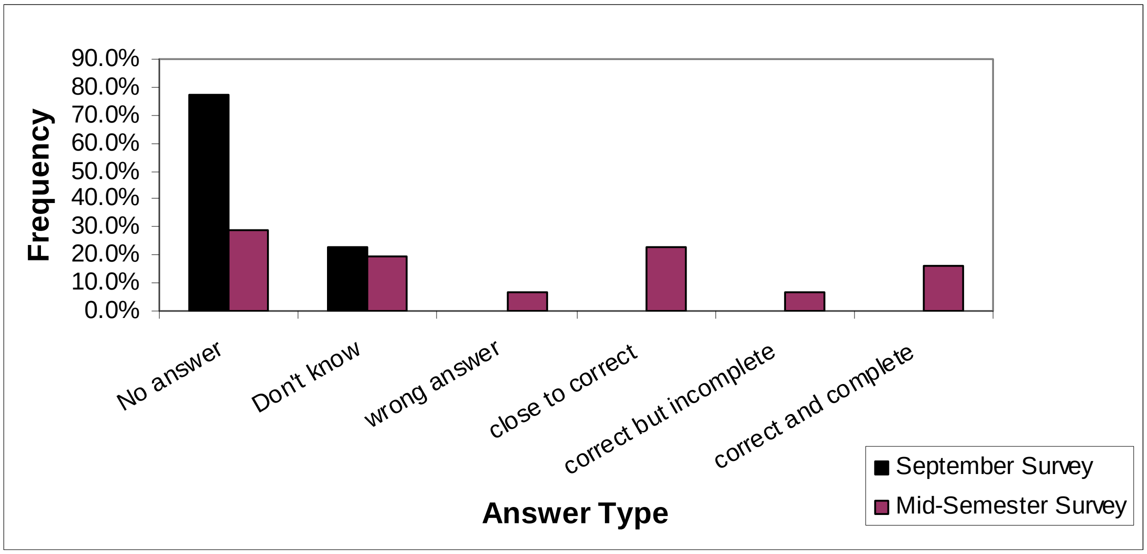


Figure E7. Categories of responses to “What is it used for?” about Absolute Pressure Sensor™.

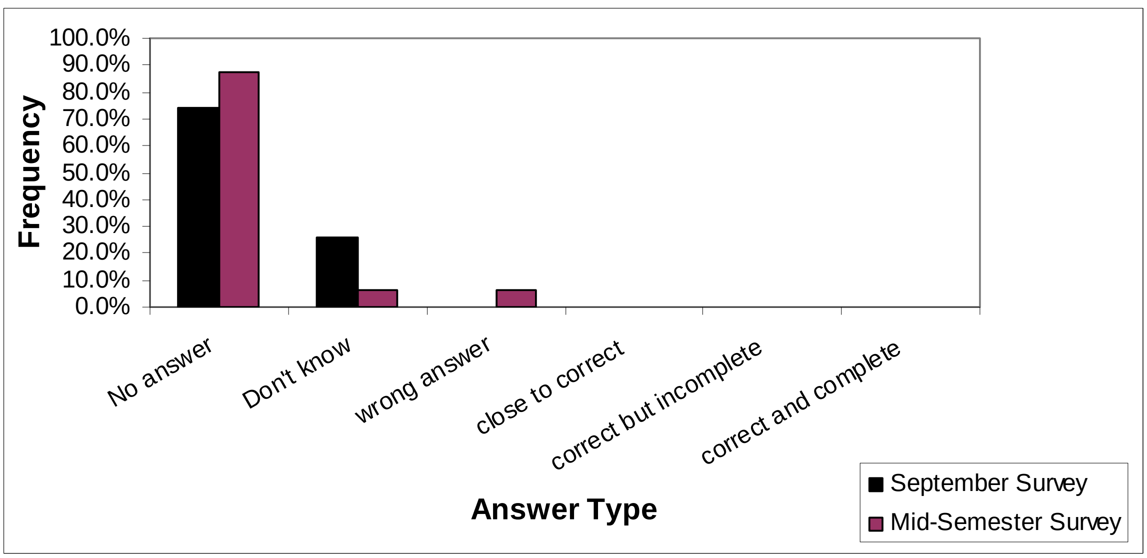


Figure E8. Categories of responses to “What is it used for?” about Drop Counter™.

APPENDIX F

INTERVIEW TRANSCRIPTS

Sherman: First of all, in your opinion, what is the purpose, or purposes, of the chemistry laboratories that you have done so far?

Riley: I guess, I would say that its guide, like kinda a guide, a guide that helps you physically do what you're learning in class, so it always helps things make more sense if you're physically doing with your hands than reading about it…pretty good so you hope you understand it?

Sherman: What do you think is the purpose of using the Pasco System in the General Chemistry Lab?

Riley: To help us get better results I guess, I mean, it's the product itself you're talking about, Right? Like the temperature probe and like the materials?

Sherman: Yes, yes. Really right now the whole system.

Riley: Well, we only use a couple of things in Chem I, like the titrations and stuff would be used in Chem II, I mean, for us, its probably used to help us get more efficient results. Help us with our experiments and stuff. I mean without it, we would have to do everything with thermometers and stuff. Otherwise the measurements too?

Sherman: What would be different about doing it the other way rather than using the Pasco System?

Riley: With the temperature probes you can just kinda stick it in there and look at the screen, and I don't know if the computer program is part of the Pasco System, yeah, so it illustrates the graphs for us so we don't have to come up with them on our own, so if we measured them with thermometers over time we would have to write out every temperature, every second. With the Pasco System, you can just look up and it graphs them for you, so it saves a lot of time. I like that I don't have to graph everything myself.

Sherman: Did you physically use the Pasco System?

Riley: Yes.

Sherman: That is what I did observe when I was in the Lab with you. That, you were actively using it and monitoring it and discussing it.

Sherman: What did you use it (the Pasco System) for?

Riley: Mainly the temperature point, the freezing points, melting points, heat capacity and stuff like that. Like I said, the only thing that we really used was the temperature probe and the computer program.

Sherman: Now I'm gonna talk about individual labs where you used the Pasco System. We're gonna start with the first lab on the statistical properties of pennies

Riley: Uhhh???

Sherman: Really, that is the first one. What was the purpose of, that's why I have my lab manual with me, using the Pasco System in this Lab:

Riley: It was the scales, I'm guessing to weigh the pennies.

Sherman: If you want to open the manual…

Riley: I just don't really know what the Pasco Systems are? The temperature…

Sherman: The temperature probe is one piece, the computer program too, the power link..all..

Riley: What about the scales?

Sherman: No, the balances were…

Riley: We just used the scales to measure the pennies.

Sherman: You didn't use the program, an introduction…

Riley: No, we just used the scales to weigh the pennies. We didn't use anything until we got to the temperature probes, like halfway through the lab.

Sherman: On somewhat of a related note, did you use any spreadsheet programs during that lab?

Riley: No.

Sherman: If these things weren't used in that lab, then let's move on to the next lab. In the gas laws lab, lab or experiment seven, what was the purpose of using the Pasco System in that lab?

Riley: Whenever we did the probes and all the compounds that we used, it would make a graph like the heating curve and the cooling curve, we had to, pretty much, I guess the point of it was to illustrate the graphs for us and draw them for what we were looking at.

Sherman: I think that was experiment eight.

Riley: Yeah, it was eight.

Sherman: This lab was seven.

Riley: Hmmm, this is one where we had to draw a bunch of graphs also, I just don't uuhh.. Oh, okay, okay this is the one with the air pump right?

Sherman: Yes

Riley: Okay, then it measured the pressure of the tube right?

Sherman: Yes

Riley: Then the point of that was, then I guess was, to graph the pressure versus the volume. And the mass, something like that, the volume and pressure?

Sherman: Okay.

Riley: Like it was plugged into a little machine, I guess that was the Pasco machine, and it measured the pressure of the different points of gasses and the inverse of the, I remember.

Sherman: How did this system work for you in this lab?

Riley: It's pretty cool, I've never done anything like this before, our graph looked normal, 'cause we got a good grade in that lab. I know that some other groups didn't get theirs working because there were some issues getting the little thing to attach to the air pump tube, but I think they got it working, I don't know, but ours worked fine, so.

Sherman: Describe how you physically used that pressure sensor? What did you do to make it work?

Riley: We filled up the syringe type thing with natural gas and we had to lock it in, well, first we had to weigh everything, I don't know if that matters? We weighed it with and without the natural gas, and the pressure we measured each time it got to 10 mL until it was gone and then we would graph it out.

Sherman: Did you find the system useful?

Riley: Yes

Sherman: Why?

Riley: Because it graphed everything out for us. Our graph looked normal and like it was supposed to. It was effective.

Sherman: Do you think this would be useful in other laboratories in advanced chemistry courses?

Riley: I really don't know what they do in other advanced chemistry courses, but I think this would work doing stuff with pressures.

Sherman: Do you think this would be useful in laboratories like this one in other science courses?

Riley: Yeah, basically, anything where you need to know what basic pressures are.

Sherman: Let's go on to the calorimetry lab, I did come in and observe that lab, "Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water." What was the purpose of using the Pasco system in that lab?

Riley: To help us measure the temperature changes after we added the different solutions and ice to the water sample that we had. Measuring the water before and after the additions.

Sherman: What did you measure?

Riley: We measured the temperatures of them and then did the specific heat, with the Pasco System, we measured temperatures.

Sherman: How did the probe help you in this lab?

Riley: Like the other one, if we used a regular thermometer measuring every temperature, we would miss a lot of stuff, so have the computer measure it made everything go quicker.

Sherman: How did you physically use it? Talk specifically about the calibration process. What did you do there?

Riley: We filled up the ice water and waited to the temperature got to zero we hit the setup, then the calibrate button. When the temperature hit zero, then you hit set. We took it out for awhile. In the meantime we were boiling water in another beaker and we put a regular thermometer in to make sure it matched the temperature probe, then we hit set for the boiling temperature so it had a basis for measuring other temperatures.

Sherman: After calibration, how did you use the system?

Riley: We measured room temperature of deionized water and after that, we measured the liquid that we used. We used hot and cold water and metal objects. We would measure the water first then the compound and then let it set for awhile. Then we would add the compounds together and then measure the mixture to see how much it increased or decreased.

Sherman: Did you find this system useful for this lab?

Riley: Yeah.

Sherman: Why?

Riley: Same as before, it does it for you. As simple as picking it up and putting it in a cup. It does it for you.

Sherman: How did using the Pasco System in this lab compare to using a thermometer in the calorimetry labs that followed?

Riley: We used the temperature probe for all of them?

Sherman: Weren’t you given an option for using a thermometer?

Riley: Yeah, but I didn’t take that option.

Sherman: Why not?

Riley: Because it is more time consuming. We have a lot of other classes, science classes, and time counts. We get out as soon as we’re done, so why take the option that takes longer?

Sherman: Do you think this system could be used in other laboratories similar in advance chemistry courses?

Riley: Definitely.

Sherman: Do you think this could be used in laboratories in other science courses?

Riley: Yes, a lot of sciences have stuff to do with temperatures.

Sherman: Let’s consider the Pasco system in an overall perspective from your sense. What components of the system were most helpful in conducting the experiments?

Riley: Definitely the temperature probe then the computer software program that did the graphs; and the apparatus that read the pressures. They all helped.

Sherman: What components of the system were least helpful or even a hindrance in conducting the experiments?

Riley: Nothing in my case, but the other group had problems with the pressure thing not staying connected. They could have been doing it wrong. I never had a problem.

Sherman: What components of the system were most helpful in interpreting the data?

Riley: Definitely the graph, the computer program.

Sherman: What about the graphs?

Riley: There was a button that you could click on any point of the graph and it would tell you the readings, so you wouldn't have to look each time or look at the graph and try to line it up yourself. It would tell you down to the right decimal points.

Sherman: What parts of the system were least helpful in interpreting the data?

Riley: There weren't any.

Sherman: Do you think the Pasco System gives you accurate data?

Riley: The times we had to use the thermometer along side if it, it always read exactly what the thermometer said, so yeah, it gave us really good data.

Sherman: With regards to other Chemistry courses beyond General Chemistry, do you see this system as useful?

Riley: Yes, because you're always gonna have things changing temperature and reacting, it has a place to be used.

Sherman: With regards to other science courses do you see this system as being useful?

Riley: Yes, because the same reasons as before.

Sherman: Which science systems to you see this applied in or being used in?

Riley: Any type of labs that involve measuring temperature or reactions. I can't think of anything other than sciences.

Sherman: Any other particular sciences that it could be used in?

Riley: I don't know, I don't know what they do in other science classes. Maybe some kind of ecology class measuring stream temperatures. And, classes taking water samples.

Sherman: Do you think there are any applications of the PASCO device beyond the classroom or the lab?

Riley: Hmmm

Sherman: Think even bigger.

Riley: Maybe like the thermometer used in elementary school, you could take your own temperature. Bigger, you mean like…

Sherman: Outside of science labs.

Riley: No, its pretty much catered to science classes.

Sherman: Are there parts of the Pasco System that you don't understand fully?

Riley: Those that I haven't used yet.

Sherman: Do you have any questions for me?

Riley: No.

Sherman: In your opinion, is there better instrumentation available for the laboratory at UNT?

Riley: Not that I've seen. I haven't seen anything else that could run computer programs.

Sherman: How did you go about learning about the different parts of the Pasco System this semester?

Riley: Trial and error, you read the instructions and sometimes they're not always that clear in the lab manual. Once we did it the first time, we found out what we were doing right and wrong by the TA's. And, then we knew what to do. The only issue was how to navigate different things on the computer.

Sherman: How did ya'll, you and your lab partner or the whole group work through the labs? Who did all the work?

Riley: I did, and sometimes Elana. Some others would help get materials and bring them in. And some did the math part, I'm more into the physical stuff.

Sherman: Describe the discussions that you've had with your TA on how to work the Pasco System.

Riley: The main thing is when she runs over the break-down of the lab and when we're gonna use the temperature probes and the first time when we had to use the computer for the graphs. And learning how to calibrate it and use the pinpoint thing on the graphs.

Sherman: Describe some discussions that you've had with your lab group on how to use the Pasco System.

Riley: How to delete a run, or different trials, to have one deleted but still have it around so the next one will work. So, you don't get thrown off. That's what we talked about the most. Oh, and we talked about the pressure lab and how to lock it in. The syringe and the tube part. That's the only time we used that.

Sherman: This concludes the interview, do you have any questions for me?

Riley: Are you writing a paper on this?

Sherman: Most would call it a "book." This is part of my dissertation.

Ron Interview – April 29, 2010

Sherman: In your opinion, what is/are the purpose(s) of general chemistry laboratories?

Ron: To get a better idea, a hands on point of view of learning the information.

Sherman: What do you think is the purpose of using the PASCO system in the General Chemistry lab? Please elaborate.

Ron: To make it easier and to use technology

Sherman: Did you physically use the PASCO system? If so, what did you use it for?

Ron: Yeah. Used it for titrations, drop counter, and several temperature probes, pressure probes and I think that all we used PASCO for.

Sherman: Now, you're taking not only the first semester of general chemistry, which is the focus of this study, but you're also taking the second semester at the same time?

Ron: Correct.

Sherman: So you are more familiar with items than the students just taking the first semester?

Ron: Probably

Sherman: Now we are going to talk about individual labs, and this is all about first semester labs. We are going to start out with lab one.

Sherman: Describe how you used the PASCO system in the lab "Statistical Analysis on Different Types of Pennies."

Ron: I don't think we used the PASCO system; we used Excel

Sherman: What was the purpose of Excel?

Ron: To find the standard deviation, that's pretty much all we used it for.

Sherman: That means I can skip the rest of these questions because you didn't use it.

Sherman: Now we're going to talk about the lab "Gas Laws – Verification of Boyle's Law, Charles' Law, and Avogadro's Law." What was the purpose of using the PASCO system in this lab?

Ron: We used it to find the pressure in atmospheres and also the temperature. Yeah, temperature and pressure.

Sherman:How did this system work for you in this lab? How did the probe(s) help?

Ron: As far as how well or the materials?

Sherman: Not how well, how did it work for you?

Ron: We used a syringe with a stopper to find the different pressures and for temperature we used probes and put them into whatever liquid we were trying to find. It guessed temperature more, well, more faster than a thermometer would have given us a temperature and the pressure, it would have been kind of hard to figure that out without some kind of probe to figure out what kind of atmospheres or what kind of pressure the gas was under.

Sherman: How did you physically use it? Describe the techniques.

Ron: As far as the pressure, we used air and carbon dioxide and natural gas, so we would suck in air through a syringe and would apply a certain mark on the syringe and then would record how much pressure there was for each air, carbon dioxide and natural gas at different marks at the syringe and the temperature probe was to find the temperature of the liquid so we entered our gas into the water to get the same temperature of the gas.

Sherman: Did you have to do anything special with the probe?

Ron: Yeah, you have to calibrate them in the beginning

Sherman: Describe that.

Ron: For the temperature you put it into an ice bath and set it at zero, calibrate it at zero, and then find a thermometer in the room to calibrate the room temperature at the high end and for the pressure one, I don't remember how you do that one, I don't think there was anything to do to calibrate the pressure

Sherman: Did you find the system useful for this lab? Please elaborate.

Ron: Very.

Sherman: Why?

Ron: to find those pressures, I don't know how you would really do it other than having one kind of probe so that was helpful and the temperature probes got us our temperatures very fast compared to a mercury or regular thermometer would.

Sherman: Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.

Ron: Yes, to save time and to take a lot of guess work out of some calculations.

Sherman: Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.

Ron: Yeah, a temperature probe you can use in any kind of lab when you are trying to figure out the temperature of a gas or liquid.

Sherman: Now we will talk about the lab "Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water." What was the purpose of using the PASCO system in this lab?

Ron: The temperature probe and yep it looks like we just used the temperature probe in this one.

Sherman: So what was the purpose of using this system in this lab?

Ron: We used it to find the temperature change of specific heat of a liquid.

Sherman: How did this system work for you in this lab? How did the probe help?

Ron: It worked really well; it gave us a nice graph and graphed our temperature data so its easy to find our end results. It recorded constant temperature changes.

Sherman: How did you physically use it? Describe the techniques.

Ron: We checked the temperature of the hot water and the cold water or the metal objects that we'd used and we'd mix those two objects to get a final temperature. Using final and initial temperature, we could find specific heat and enthalpies.

Sherman: Did you find the system useful for this lab? Please elaborate.

Ron: Yes, it was easy to get initial and final temperatures

Sherman: How did using the PASCO system for this lab compare to using a thermometer in the calorimetry labs that follow?

Ron: It saved us a lot of time and gave us a nice graph so you could see the change that you wouldn't get with a regular thermometer.

Sherman: Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.

Ron: Yes, anything that makes your job easier is helpful and it saves time.

Sherman: Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.

Ron: Yes, anything you need to graph the temperature of would be helpful.

Sherman: Consider the PASCO system from your perspective/experience in an overall sense: What components of the system were most helpful in conducting experiments?

Ron: The drop counter was really nice for titrations; I think that was my favorite tool. The temperature probe was nice but not I guess necessary because you could use a thermometer for most everything, it just cut down the time it took for a thermometer to get where I needed to and the pressure probe saved us a lot of calculating it would be rather hard to figure out the mathematic flair if you didn't have that probe to use

Sherman: What components of the system were least helpful or even a hindrance in conducting experiments?

Ron: I think we only used one probe at a time its like a junction box kind of deal was kind of in the way sometimes, but I could see how you had more complex mutant cell junction boxes .

Sherman: What components of the system were most helpful for interpreting data?

Ron: It would hook up to the computer and would graph your data for you, definitely helpful.

Sherman: What components of the system were least helpful for interpreting data?

Ron: The junction box, which didn't do any interpreting, but other than that nothing.

Sherman: Do you think the PASCO system gives you accurate data? Why or why not?

Ron: I'd say it pretty close, but if you calibrate it right then yeah, it would be better.

Sherman: With regards to other Chemistry courses beyond General Chemistry, do you see this system as useful? If so, how and for which ones? If not, why not?

Ron: Very, yes. It saves ion mathematical errors and gives the students a visual of when it graphs the data or something for you students don't like to do it by hand and it saves them time, it makes the labs go a little bit quicker and you can focus on the data rather than plotting out the graph or something.

Sherman: With regards to other science courses, do you see this system as useful? If not, why not? If so, which sciences do you see this system as applicable? How can they be applied?

Ron: Yeah. Biology has something's that deal with temperature and pressures. Maybe some physics, I haven't taken a lot of physics so I don't really know what the exact use would be in that lab.

Sherman: Do you think there are any applications of the PASCO device beyond the classroom? If not, why not? If so, where can this be used and how?

Ron: Sure, in a real life laboratory situation. Yeah. All kinds of work places where you are titrating or need to find the temperature of something or graph the temperature of some kind of science usually.

Sherman: Are there parts of the PASCO system that you still do not understand fully? Why?

Ron: I'm sure there are extra probes that I haven't seen yet; everything I've seen I understand. It seems like there would be more with the junction box.

Sherman: Do you have any questions for me?

Ron: No.

Sherman: In your opinion, is there better instrumentation available for the general chemistry laboratory at UNT? If so, what are they? Why do you think so?

Ron: It seems like there would be but I haven't been to another college so I don't know what their laboratories would have, I know its a lot better than anything I've had in high schools I assume its pretty good here.

Sherman: How did you go about learning how to use the various parts of the PASCO system during this semester?

Ron: Mainly from the lab book, it showed you how to calibrate it and it gave pretty good step-by-step instructions, how to graph different things, trial and error I guess.

Sherman: Describe how you and your lab partner (or rest of your lab group) worked through labs. Who did the most work? What were the roles of each person?

Ron: We started by calibrating of whatever we had to do and read through the lab book and if you read your lab book, you can get good step-by-step instructions on how to do the lab procedure. We split it up pretty evenly. I don't know if we really had roles, some people who realize hey we're gonna need this chemical coming up so I'll go grab it real quick while you mix it or I'll mix this and you go grab that real quick and I'll clean this and you go grab that.

Sherman: Describe discussions you had with your lab partner (or rest of your lab group) about how to work with the PASCO system.

Ron: I don't really think we discussed how to use the PASCO, I mean it was pretty self-explanatory with the lab book step-by-step instructions and how to calibrate it .

Sherman: Describe discussions you had with your lab TA (teaching assistant) about how to work with the PASCO system.

Ron: Our TA didn't really explain anything about it

Sherman: Did they help you with it at all?

Ron: Not really

Lisa Interview – April 29, 2010

Sherman: In your opinion, was the purpose of the general chemistry laboratories?

Lisa: To get us familiar with the equipment used in the lab situations, and to work on reactions that we see in our actual lectures. Gives us a better understanding of what we've learned.

Sherman: What do you think is the purpose of using the Pasco System in the General Chemistry Lab?

Lisa: It is supposed to make it easier for us to gather information, and it is supposed to be more accurate than the other methods.

Sherman: Did you physically use the Pasco System?

Lisa: Yes.

Sherman: What did you use it for?

Lisa: We used it to measure temperature, pretty much we used it to measure temperatures of the different reactions that we did. Although I know that it can be used for other methods.

Sherman: Now I'm gonna talk about individual labs where you used the Pasco System. We're gonna start with the first lab on the statistical analysis of different types of pennies..

Sherman: What was the purpose of using the Pasco System in this lab?

Lisa: We didn't use it in that lab.

Sherman: You didn't in this lab?

Lisa: No

Sherman: That's fine, I'm gonna move on to the next one which is lab #7, dealing with gas laws. What was the purpose of using the Pasco System in this lab?

Lisa: To measure the pressure. It was a tube that we had to pull on and we stuck a nail in it and measured the pressure.

Sherman: How did this system work for you in this lab?

Lisa: So, basically the Pasco System measured the pressure and it gave us a graph for the different measurements that we were trying to get for the carbon dioxide, we didn't use any other gasses. That's pretty much what we used it for.

Sherman: All right, how did the probes help?

Lisa: In regards to measuring temperature of different substances?

Sherman: In this lab.

Lisa: Oh, uhm, how do, what do you mean?

Sherman: How did the probes…the first part of this had to do with the system overall, and now I want to look at the probes. First of all, let me back up, what probes did you use?

Lisa: I'm not sure of the specific names but I can give you a description. It was like a tube that we.. I don't remember.

Sherman: Okay, paper and pencil…draw it for me.

Lisa: Okay. Looks like this, had different measurements, a thing that you connect to the probe and the nail, had different points where you put it and measure the pressure. It was easy to set up, I didn't have any issues.

Sherman: That was for pressure, okay, and, so you tell me how you…physically used it, now describe your technique….for using this probe.

Lisa: Well, like I said, we were told in the experiment where to put the nail. Okay, so, we were told where to put the nail and measure it and then we would have to give it a minute to measure the readings and it drew the graph for us and we got to see the different pressure points for each gas that we were measuring for that lab.

Sherman: So, did you find the system useful for this lab?

Lisa: Yes.

Sherman: Why?

Lisa: Because it was easy to set up first of all and there wasn't much calculations that you had to do manually so you got the results back faster and it didn't take a lot of time.

Sherman: Do you think this would be useful in other laboratories in advanced chemistry courses?

Lisa: Yeah, I'm sure it can.

Sherman: Why?

Lisa: Like I said, in O chem., there are a lot of reactions that you have to deal with and I'm sure that you could set up the Pasco System that would take measurements, temperature, pressure and whatever else it does. It's not time consuming.

Sherman: Do you think this would be useful in laboratories like this one in other science courses?

Lisa: Hmm, biology, I'm not sure, I've taken genetics ... those experiments, I don't know if it would be useful for that.

Sherman: Let's move on to lab #10 the, "Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water." What was the purpose of using the Pasco system in that lab?

Lisa: For this, we used the Pasco System to measure temperatures where we had to calibrate hot and cold with an ice water bath and then we had to boil water to get the different temperatures. Initially, I was a little confused on how to do that, but once the TA showed us what to press after each time, I didn't have any issues with that.

Sherman: So how did this system work for you in this lab?

Lisa: We got the initial reading of each reaction that we were doing and it gave us, the Pasco System gave us the different temperatures and we could calculate the specific heat of each of the metals that we were using. It made it easier for us to get the data together to do those calculations.

Sherman: So how did the probes help?

Lisa: The probes, they were easy to set up, the only issue was that sometimes is disconnected from the box that it was in so we had to make sure that things were connected properly.

Sherman: So how did you physically use the system with this lab? Describe those techniques.

Lisa: Like I said, we put the probe in the water. We had to calibrate the probe with the ice water bath, we walked thru the steps on the computer to calibrate it, we waited till it hit zero, we waited to return to room temperature and then used the boiling water.

Sherman: Did you find the system useful in this lab?

Lisa: It was easier, there wasn't a lot of manual work that we had to do, it was all computerized and just easier for us to do.

Sherman: How did using the Pasco System in this lab compare with using a thermometer in the calorimetry labs that followed?

Lisa: Well, the Pasco System was a lot more accurate. The thermometer was hard to read 24 could be 25? The Pasco, you could just see it on the computer so that made it a lot more accurate, like it would give like 24.8.

Sherman: Do you think this would be useful in other laboratories in advanced chemistry courses?

Lisa: Yes, for the same reason that we talked about before.

Sherman: Do you think this would be useful in laboratories like this one in other science courses?

Lisa: Well, like for the science courses that I've taken I don't know if it could be used there. I'm sure that we could use it.

Sherman: Let's consider the Pasco system in an overall perspective from your sense. What components of the system were most helpful in conducting the experiments?

Lisa: The probes, the pressure one was kinda hard to set up and read and the nail was hard to keep in there, but the temperature probes I liked those, not much work to be done there.

Sherman: What components of the system were least helpful or even a hindrance in conducting the experiments?

Lisa: The pressure probes, maybe it was due to some errors.

Sherman: What components of the system were most helpful in interpreting the data?

Lisa: The probe. There wasn't much work that you had to do to get the data that you needed. I don't think we used anything else.

Sherman: What parts of the system were least helpful in interpreting the data?

Lisa: The pressure gauge.

Sherman: Do you think the Pasco System gives you accurate data?

Lisa: Yes.

Sherman: Why?

Lisa: After we had our data, you could go back and check our answers on the literature value.

Sherman: With regards to other Chemistry courses beyond General Chemistry, do you see this system as useful?

Lisa: Yes

Sherman: How could this be useful?

Lisa: I haven't taken any advanced chemistry courses yet, but you could use it for temperature measurements and pressure.

Sherman: With regards to other science courses do you see this system as being useful?

Lisa: No, for the same reasons we mentioned earlier.

Sherman: Do you think there are any applications of the PASCO device beyond the classroom?

Lisa: I'm sure there are, but I haven't thought of any.

Sherman: Are there parts of the Pasco System that you still don't understand fully?

Lisa: The pressure was a little difficult, that's all I can think of.

Sherman: In your opinion, is there better instrumentation available for the laboratory at UNT?

Lisa: Not that I know of.

Sherman: How did you go about learning about the different parts of the Pasco System during this semester?

Lisa: I had to ask my TA, when you don't know something asking someone helps.

Sherman: Describe how you and your lab partner or the whole group work through the labs?

Lisa: Are you talking about each role that we played?

Sherman: Yes, who did the most work in the lab?

Lisa: I think that we all worked pretty well together out of the three of us. There was one guy in another group that had a problem with the TA because they weren't doing very much work and he didn't lead the lab. We had to explain everything, so we lagged behind. But, we took turns doing the work and it went well.

Sherman: Describe some discussions that you've had with your lab group on how to use the Pasco System.

Lisa: We really didn't talk about…what we initially did, the TA went over how to set it up then we took turns calibrating it, the temperature and the ice water bath and hot water bath.

Sherman: Describe the discussions that you've had with your TA on how to work the Pasco System.

Lisa: She showed us how to set up the pressure part, physically showing us how to put the nail where it needed to be, by the manual.

Sherman: This concludes the interview, do you have any questions for me?

Lisa: Yes, what is the reason that you are doing this?

Sherman: Not a lot of people have studied this, not studied instrumentation.

Interview with Mickey April 29, 2010

Sherman: In your opinion, what is/are the purpose(s) of general chemistry laboratories?

Mickey: to go along with the class and to let you see the information that you're given in class and to let you see it in action

Sherman: What do you think is the purpose of using the PASCO system in the General Chemistry lab? Please elaborate.

Mickey: I believe it speeds up the process a lot. You just have to learn how to calculate, what buttons to push, and it can pretty much speed up the process.

Sherman: Did you physically use the PASCO system? If so, what did you use it for?

Mickey: I did. We used it to calculate pressure and temperature changes and graph our results mainly.

Sherman: Describe how you used the PASCO system in Lab 1 "Statistical Analysis on Different Types of Pennies." That was the very first lab you did. What was the purpose of using the PASCO system in this lab?

Mickey: If I'm not mistaken, there are a couple of labs in the beginning that we didn't use the PASCO system…I believe that this one was one we did not use it in.

Sherman: OK, did you use a spreadsheet program to do the analysis?

Mickey: I believe we did mainly calculations because it was asking for just the mass and the standard deviation and we were given the formula. That was a long time ago. I don't remember if we did or not so I don't know.

Sherman: That's fine. So, that cuts out those questions on that lab. We're going to move on.

Sherman: Describe how you used the PASCO system in the "Gas Laws – Verification of Boyle's Law, Charles' Law, and Avogadro's Law." I think that was Lab 7.

Mickey: You know, I think we didn't do this one because it was a snow day. Oh, yeah we did it.

Sherman: What was the purpose of using the PASCO system in this lab?

Mickey: It was to measure atmosphere, atmospheric pressure, and we had the air, yeah. I will be completely honest with you with my labs is I think it was hit or miss with the kinds of groups you had in lab with how much you get out of them. And I think that for some reason, my particular group everybody was always rushing through and a lot of my labs are a blur. I just know that we had to use it for atmosphere and for graph. We had it graph. I think it wasn't until the boiling point lab where we were doing boiling points and freezing points that the system sunk in a little more to me.

Sherman: How did this system work for you in this lab? How did the probe(s) help?

Mickey: Well it made it much easier for us to determine the pressure and to see how it visually changed on the graph.

Sherman: Let me back up. What probes did you use?

Mickey: We just used the…the…I don't remember what it's called but it was for the atmosphere. I know for the temperature we used the temperature probe. I don't remember using a different probe. It must be…I don't remember.

Sherman: How did you physically use it? Describe the techniques.

Mickey: Going to the data studio. I think for the atmosphere at that point following the directions on the computer, just kinda whatever it told us to do. This was earlier on and I remember being so confused with the PASCO system. The lab instructor was kinda walking us through, through the process.

Sherman: Did you find the system useful for this lab? Please elaborate.

Mickey: I don't remember.

Sherman: All right, then I'm going to skip on the rest of those questions and move on to a different lab.

Sherman: Describe how you used the PASCO system in the lab "Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water." It was number 10.

Mickey: That must have been the last one?

Sherman: A later one, yes. What was the purpose of using the PASCO system in this lab?

Mickey: In this lab we measured the…we got the water to room temperature and then we put in the temperature probe. We had to add…The first one was basically the water and then we had to see by adding the metal object how much heat was exited. I'm sorry I didn't have the word. And then we just used it to measure the temperature changes in each of the…with the different metals in the liquid mixture. And then the melting of the ice and it showed, it graphed how, we watched the graph fall until it became constant to see the changes in temperature.

Sherman: How did this system work for you in this lab? How did the probe help?

Mickey: Well you can't really see the changes, so it gave me a visual of what was happening when the probe was inside. For the same or similar reasons, putting the probe in you get a visual versus sticking your finger in the liquid you can't really determine what the changes are.

Sherman: How did you physically use it? Describe the techniques.

Mickey: The PASCO system?

Sherman: Yes

Mickey: And the probe?

Sherman: Yes

Mickey: Well the probe I just put it in the water and you set the system, you calibrate it and you put it in the water and you hit "Start" and you just watch the changes. And when you're done you just take it out and wipe it off.

Sherman: Did you find the system useful for this lab? Please elaborate.

Mickey: I did. Because it give you that visual and it instantly measures the temperature as opposed to a thermometer taking time. It takes time for the line to change and this is like an instant measure.

Sherman: You've taken care of the next question: How did using the PASCO system for this lab compare to using a thermometer in the calorimetry labs that follow like numbers 11 and 12? You had an option in those to use the thermometer or use the system. Just out of curiosity, did you use the system in experiments 11 and 12?

Mickey: I used it for 11. Wait, no I used it for 11.

Sherman: Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.

Mickey: Definitely. I feel like I'm repeating myself but, it's for a lot of the same reasons. It's very efficient and it gives you that visual that you can't get. It instantly graphs it and we know that graphing and working out and all of that takes so much time doing it by hand. It's like instantaneous feedback.

Sherman: Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.

Mickey: I do. I assume this one being the basic introductory to chemistry course we just barely touched on the PASCO system. I mean, I admit myself I don't remember what we did in terms of atmospheric pressure. I don't remember that aspect of it. I assume that the more advanced you get in not only chemistry but in other courses that require chemistry foundation, I believe that there is so much more you can do with it. I can only imagine because it's a whole system. I can't (garbled) a whole system for freezing and boiling points.

Sherman: Consider the PASCO system from your perspective/experience in an overall sense: What components of the system were most helpful in conducting experiments?

Mickey: The probes. You mean like the actual components?

Sherman: Yes. What parts of the system? Any of them?

Mickey: The probe was really useful and having the graph there to give you a visual and these are the parts of the system that I'm most comfortable with. I think that both were very useful and helpful.

Sherman: What components of the system were least helpful or even a hindrance in conducting experiments?

Mickey: It's hard to say if they were least helpful. It was just my lack of knowledge in how to use them. I just knew my knowledge was very limited on the PASCO system. So it's like people who use a computer that don't know anything about computers. They go 'I just use it for email' and they can usually check their email, but there's so much you can do with them. I feel that's real similar for the PASCO system. There are a lot of areas and parts of the PASCO system that I'd have to stop my lab and go and 'what do I do here?' and 'where do I go? I just messed up. I pushed the wrong button.' That was challenging.

Sherman: What components of the system were most helpful for interpreting data?

Mickey: The graph definitely.

Sherman: What components of the system were least helpful for interpreting data?

Mickey: I can’t think of components not being helpful.

Sherman: Do you think the PASCO system gives you accurate data? Why or why not?

Mickey: I do. Because I believe computers don’t lie. It’s just got the sensor unless the sensor could be off by some…I mean as long as it’s up and working it should be pretty accurate.

Sherman: With regards to other Chemistry courses beyond General Chemistry, do you see this system as useful? If so, how and for which ones? If not, why not?

Mickey: Yes. I think the system works for sure in the next chemistry course. I don’t know but I would hope to get a chance to use it more and get more comfortable with it. I think the more you use it, the more comfortable. The more I use it, the more comfortable I would get.

Sherman: With regards to other science courses, do you see this system as useful? If not, why not? If so, which sciences do you see this system as applicable? How can they be applied?

Mickey: I see it as potentially being able to be useful. I haven’t taken…this is my first real science course. So, but I’m assuming that this is the foundational prerequisite for other courses, I’m assuming it will be useful in several courses

Sherman: Do you think there are any applications of the PASCO device beyond the classroom? If not, why not? If so, where can this be used and how?

Mickey: For similar…I feel like my knowledge is so limited because I’ve only used it for very limited things.

Sherman: But you definitely see a possibility?

Mickey: I definitely see a possibility. I don’t know how, but I definitely can see it.

Sherman: Are there parts of the PASCO system that you still do not understand fully? Why?

Mickey: I think most of the parts of the PASCO system.

Sherman: In your opinion, is there better instrumentation available for the general chemistry laboratory at UNT? If so, what are they? Why do you think so?

Mickey: Is there better?

Sherman: Yes

Mickey: I don’t know because I don’t have anything to compare it with.

Sherman: How did you go about learning how to use the various parts of the PASCO system during this semester?

Mickey: Following the directions in the lab manual, which were sometimes a little confusing. When that happened, I’d ask my lab instructor to assist me with the process. That’s how I learned about it.

Sherman: Describe how you and your lab partner (or rest of your lab group) worked through labs. Who did the most work? What were the roles of each person?

Mickey: Rushing it (laughs). We’d divide up the work pretty evenly. So that if we had 4 people in a group, a couple of people would work on one part of it, and we’d exchange data. I think that it was pretty equal. No one felt like they did it all. They (the roles) varied from lab to lab. We didn’t have someone particularly ‘you do the PASCO system,’ you do…We didn’t have roles like that. It depended on how we could divide each section, made sure it was divided so that everyone had equal amount of work.

Sherman: Describe discussions you had with your lab partner (or rest of your lab group) about how to work with the PASCO system.

Mickey: I think my lab group was a special case. They seemed to like to argue a lot. So I just kinda stayed quiet and didn’t say much during the lab. Yeah, I really tuned it out. There was a lot of frustration between people for some odd, bizarre reason.

Sherman: Probably lots of butting heads?

Mickey: Yes

Sherman: That’s some of what I observed when I was in there.

Mickey: I never experienced that before.

Sherman: Describe discussions you had with your lab TA (teaching assistant) about how to work with the PASCO system.

Mickey: Well, we didn’t really have discussions about it, but when we got ‘stuck’ with it he always was willing to walk through the process. The thing is, I think he would have been so willing throughout the semester to take his time and make sure but the environment with the students was so rushed, that rushed him as well. I feel like I didn’t get as much out of the instructor that I could have. I’m sure he’s got a lot knowledge, but everyone was like ‘just, just get it done.’

Chantal Interview, May 4, 2010

Sherman: In your opinion, what is the purpose of general chemistry laboratories?

Chantal: To help gain a physical understanding of what we're learning in class, doing mathematically in the real world.

Sherman: What do you think is the purpose of using the Pasco System?

Chantal: To simply and make things better.

Sherman: Did you physically use the Pasco System?

Chantal: Yes.

Sherman: What did you use it for?

Chantal: To read temperatures and pressures and to figure out volume.

Sherman: Now I'm gonna ask about different labs. We're gonna start with the first lab on the statistical properties of pennies, if you want to look at the lab manual, I know its been a few weeks. Looking at lab number one, the statistical properties of different pennies, what was the purpose of using the Pasco System in this lab?

Chantal: I did not use the system for this lab, so I'm not sure.

Sherman: Okay, fair enough, so we'll go on to the next lab, which is lab number seven. That's gas laws and verification of Boyle's Law, Charles Law and Avogadro's Law. What was the purpose of using the Pasco System in this lab?

Chantal: We used it to relate temperature, pressure and volume, and how they were related graphically.

Sherman: How did this system work for you in this lab?

Chantal: It worked well, it was simple to set up this device, to measure our readings and it showed the relationship between the volume and pressure.

Sherman: How did the probes help?

Chantal: For the temperature readings and the pressure apparatus, is that considered a probe?

Sherman: Yes it is.

Chantal: It helps measure more accurately, the different readings.

Sherman: How did you physically use it?

Chantal: We trapped the gasses, the CO_2, I guess we used it to trap the gasses and measure the temperature, yeah, for measuring the volume, pressure and temperatures.

Sherman: Did you find this system useful for this lab?

Chantal: Yes.

Sherman: Why?

Chantal: It made understanding the relationships and understanding the gas law more clearer.

Sherman: Do you think this would be useful in other laboratories in advanced chemistry courses?

Chantal: I would believe so.

Sherman: Why?

Chantal: I'm sure the ideal gas laws go way beyond what we learned in Chem I, so I'm sure it would help clarify things.

Sherman: Do you think this would be useful in laboratories like this one in other science courses?

Chantal: Yes, we're doing gas laws in physics right now so I'm sure it would be.

Sherman: Okay, let's move on to the next lab which is number ten, "Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water." What was the purpose of using the Pasco system in this lab?

Chantal: We were using this system to measure the temperatures and calculate specific heats. It collected the temperature data for us and gave us the calculations.

Sherman: How did the probes help?

Chantal: Gave us an accurate reading of the temperature.

Sherman: So how did you physically use it this time?

Chantal: We calibrated the probe using the hot water and cold water bath, and we used it to measure the temperature of either the solid or liquid that was given.

Sherman: Tell me about that calibration.

Chantal: It was pretty easy, we used an ice water bath and we heated some water on a hot plate and that was for the extreme temperatures.

Sherman: How did using the Pasco System in this lab compare to using a thermometer in the calorimetry labs that followed?

Chantal: I would say that it didn't make it any easier or harder than using the thermometers. But, we could get a more accurate reading from the temperature probes on the Pasco System.

Sherman: Do you think this system could be used in other laboratories in advance chemistry courses?

Chantal: Definitely.

Sherman: Why?

Chantal: For more accurate temperature readings.

Sherman: Do you think this could be used in laboratories like this one in other science courses?

Chantal: Yeah, I think so for the same reasons.

Sherman: Now we're going to consider the Pasco System from your perspective and experience in an overall sense. What components of the system were most helpful in conducting the experiments.

Chantal: What do you mean by components?

Sherman: Any specific probes the pressure probe, any software or hardware..

Chantal: The temperature and pressure probes were pretty easy to use those definitely helped make it easier.

Sherman: What components of the system were least helpful or even a hindrance in conducting the experiments?

Chantal: I wasn't really taught how to use the software, so jumping into that was a little confusing.

Sherman: What components of the system were most helpful in interpreting the data?

Chantal: The graphical representations were very clear and easy to use, but I didn't always know how to get to the graphs very easily.

Sherman: What components of the system were least helpful in interpreting the data?

Chantal: Again, I would just say my lack of knowledge on using the software.

Sherman: Do you think the Pasco System gives you accurate data?

Chantal: Yes.

Sherman: Why?

Chantal: Everything seemed to be changing and getting readings for my observation.

Sherman: With regards to other Chemistry courses beyond General Chemistry, do you see this system as useful?

Chantal: Yes, I think so.

Sherman: How do you see it being useful?

Chantal: It will continue to expand on all this general knowledge that we've gained. The Pasco System will help us have for accuracy in our experiments.

Sherman: Which courses do you think this could be used in?

Chantal: Chem II and maybe Organic Chemistry.

Sherman: With regards to other science courses do you see this system as being useful?

Chantal: Yes, not some much with my biology lab but from a physics standpoint, it could have been really useful.

Sherman: How can the Pasco System be applied in that physics lab?

Chantal: A lot if it had to do with the similar things, temperature, pressure and volume. And it could have helped with accuracy in those labs.

Sherman: Do you think there are any applications of the PASCO device beyond the classroom?

Chantal: Yes, it could be used in normal laboratory experiments and the workforce.

Sherman: How can you see that being used?

Chantal: I'm sure that it can be used in any pharmacy lab, and other areas in the workplace and labs.

Sherman: Are there parts of the Pasco System that you don't understand fully?

Chantal: I would say there is a lot that I don't understand because we really didn't learn a lot about how to use it especially the software. But, the TA would run over and help us with things.

Sherman: In your opinion, is there better instrumentation available for the general chemistry laboratory at UNT?

Chantal: There is none that I know of that would be better.

Sherman: Now we're gonna take a look at how you're learning the Pasco System. How did you go about learning the different parts of the Pasco System this semester?

Chantal: Pretty much from our TA coming over pretty quickly and helping us out.

Sherman: Describe how you and your lab partner or the whole group work through the labs.

Chantal: We would read the lab before we can to class so we wouldn't have a lot of questions, and we would work setting things up and if we weren't reading something we would always ask a TA come over and help us out and correct the situation if needed.

Sherman: Who did most of the work?

Chantal: We were pretty evenly shared, or shared the work.

Sherman: What were the roles of each person?

Chantal: Someone would always be the material gatherer and someone would be the measurer and someone would be the calculations person and we all had a role.

Sherman: Describe some discussions that you've had with your lab group on how to work with the Pasco System.

Chantal: We all didn't know how it worked so, we talked about how to get it to where it ought to be.

Sherman: Describe the discussions that you've had with your TA on how to work the Pasco System.

Chantal: She would always answer questions when we had them, but I don’t think we were getting to learn the system, just more to get things to work to get through the lab. She would always help us set up and then help us if we had a problem.

Sherman: This concludes the interview.

Pat Interview, May 4, 2010

Sherman: In your opinion, what is the purpose of general chemistry laboratories?

Pat: The purpose is to do, I guess kinda perform, different experiments based off our lecture, like, I guess, applying what we’re learning in our lecture. To see why things happen and how things react – things like that.

Sherman: What do you think is the purpose of using the PASCO system in the General Chemistry lab? Please elaborate.

Pat: To see, I guess, to see different measurements and different scales. You learned the atmosphere scale and getting temperatures and to see how the rate...comparing different variables together and stuff like that.

Sherman: Did you physically use the PASCO system? If so, what did you use it for?

Pat: Yes. To get temperatures of different chemicals, different solutions, and compare/contrast – stuff like that.

Sherman: Describe how you used the PASCO system in the lab “Statistical Analysis on Different Types of Pennies.” What was the purpose of using the PASCO system in this lab?

Pat: I don’t know if we used the PASCO system for this lab. Since this was the first one, I’m not quite sure…Oh, I think we did. I think we entered the data, I guess, to see the range of what I’m not quite sure…We used that to get the…Yeah, we used that to kinda get the data from the different pennies, the pre pennies and the post pennies (pre and post 1982 pennies), and we used that to look at the variation in the two variables.

Sherman: How did this system work for you in this lab?

Pat: I was actually able to visually see what exactly was going on.

Sherman: How did you physically use it? Describe the techniques.

Pat: Plotting...entering data into the program, graph data stuff and then actually seeing the graph.

Sherman: Did you find the system useful for this lab? Please elaborate.

Pat: Yes I did. Because, once again, I was able to visually see the differences in the post pennies and the pre pennies and the change, and things like that.

Sherman: Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.

Pat: Yes I do. Because you're able to actually, I guess, to really just kinda take the information that you have, the data, and actually plug it in and maybe use different units like using the atmospheric and stuff like that, and just kinda actually extend what you learn.

Sherman: Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.

Pat: Yeah, maybe more towards chemistry based. I don't know how much the PASCO system would really be useful to other sciences. I guess it depends on what other science that you're doing.

Sherman: We're going to move on to Lab 7: "Gas Laws – Verification of Boyle's Law, Charles' Law, and Avogadro's Law." What was the purpose of using the PASCO system in this lab?

Pat: I guess I was using it looking at the different temperatures, how the different temperatures related to different volumes, and dealing with different chemicals and stuff like that.

Sherman: How did this system work for you in this lab? How did the probe(s) help?

Pat: In this lab I was able to see the different temperature freeze points and just kinda see when it leveled out to a constant and when it would drop and stuff like that. It was very useful because we used that the entire time. The probes helped good. We had to calibrate them and we had to use them for multiple experiments.

Sherman: Which probe?

Pat: I'm not quite sure what the probe was called. It was…I'm not quite sure where it is (in the lab manual), but it was silver probe that we used, and we really only used one probe I believe. I'm not sure.

Sherman: How did you physically use it? Describe the techniques.

Pat: In this lab, we used an ice bath, cause we would get the temperature of the ice bath and the temperature of a hot bath, a hot water bath. And then, we would use the probe to look at the temperatures of different chemicals that were under different water levels, temperatures, using the ice bath and the hot water bath.

Sherman: Did you find the system useful for this lab? Please elaborate.

Pat: Yes. Because I was able to see what things were held at constant and how the volume and the temperature were related to each other.

Sherman: Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.

Pat: Yes. If we go to Experiment 8, we would go into further depth of that or whatever, or you could use that to actually do more research on it.

Sherman: Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.

Pat: It kinda goes again to my first statement. It depends on what type of science and what type of things it has or learning about

Sherman: Now, Lab 10. That's the one I'm going to ask about now. That's the lab "Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water." What was the purpose of using the PASCO system in this lab?

Pat: We were basically using that to, once again, get the temperature of cold water, the hot water and just using that with just ice and water. Get the temperature and see how they compare using the cold water, deionized water, and then we also used a solution which was the aqueous ethylene glycol. We just used that to get the temperatures – find the initial (temperature)…and yeah that's basically it.

Sherman: How did this system work for you in this lab? How did the probe help?

Pat: It worked pretty well. It took a while to get the temperature, but the temperature would vary. It would go up and it'll go down. The probe was pretty useful. We had to make sure to keep it in the center of the cup so it wasn't able to move around and things like that.

Sherman: How did you physically use it? Describe the techniques.

Pat: We took the probe and we placed it. First we got the mass of the Styrofoam cup, then we put in the water, or the hot water, and we used that, the probe, to get the temperature at that point.

Sherman: Did you find the system useful for this lab? Please elaborate.

Pat: Yes. It was a lot easier using the probe instead of having us use a regular thermostat or something like that.

Sherman: Do you think this could be useful for other laboratories like this one in more advanced chemistry courses? Please elaborate.

Pat: Yes…and why?

Sherman: Yes

Pat: It's just way beneficial to be able to actually see what the actual temperature is. You know. 23.8 besides how do we establish that? It was like well, that could be 23.8 and a half. I'm not quite sure.

Sherman: Do you think this could be useful for other laboratories like this one in other science courses? Please elaborate.

Pat: Possibly. It depends on the course.

Sherman: Now we're going to take a look at things from a bigger picture. Consider the PASCO system from your perspective/experience in an overall sense: What components of the system were most helpful in conducting experiments?

Pat: In conducting, let's see…I guess…Does the PASCO system include the computer too?

Sherman: Yes, the whole thing.

Pat: You could change the type of units you wanted the thing to be in, you could add multiple graphs. There are a lot of options and things you could use with the system.

Sherman: Were there any other components that were helpful in conducting?

Pat: The probes were pretty useful, too, because they were able to get the temperatures. It was pretty sturdy at times. It was connected so you wouldn't have to worry about trying to keep both things connected and everything was working properly.

Sherman: What components of the system were least helpful or even a hindrance in conducting experiments?

Pat: It didn't really come with any components that were kinda difficult to deal with besides trying to keep it, if it requested, in the middle, for the probe to stay in the middle and having to hold it there for a long period of time. That was the only issue and hand ache.

Sherman: What components of the system were most helpful for interpreting data?

Pat: Being able to see a visual graph, using the probe with just the temperature, and being able to see when things will stop, and things like that, and getting the initial temperature in general.

Sherman: What components of the system were least helpful for interpreting data?

Pat: I guess with you holding the probe, if you do a slight movement that would cause the temperature to change. Once again, having to physically hold the probe and make sure that it stayed and didn't change data

Sherman: Do you think the PASCO system gives you accurate data? Why or why not?

Pat: To a certain degree, I think it gives you more accurate data compared to other things you can find temperature with like even a thermostat, for example. But, with the different sources of error, you know, with hand holding the probe could cause change in data, or taking it out or putting it back in could cause, you know, change.

Sherman: With regards to other Chemistry courses beyond General Chemistry, do you see this system as useful? If so, how and for which ones? If not, why not?

Pat: Yes I do. I guess I would say General Chemistry II, maybe Organic Chemistry, and Biochemistry, and maybe overall a lot of chemistry.

Sherman: With regards to other science courses, do you see this system as useful? If not, why not? If so, which sciences do you see this system as applicable? How can they be applied?

Pat: Other sciences outside of chemistry?

Sherman: Yes

Pat: I guess, sort of, not necessarily. It depends on what type of experiment. I know this. I guess on the biology side, you know, like that's more dealing with the plants and stuff like that. I guess maybe if you were trying to, you know, look at the pH level or stuff like that, or using a solution, possibly.

Sherman: Do you think there are any applications of the PASCO device beyond the classroom? why not? If so, where can this be used and how?

Pat: No, I don't think so.

Sherman: why not?

Pat: I don't quite understand that question fully.

Sherman: All right, let me rephrase it a little bit. Outside the university setting and high school, any kind of school setting, do you see this as something that can be used?

Pat: Oh, ok. The actual probes and PASCO?

Sherman: Yes

Pat: Yeah, like I guess for like with NASA trying to go outside of the universe possibly. I'm sure it could use some kind of benefit.

Sherman: Are there parts of the PASCO system that you still do not understand fully? Why?

Pat: I know if I do a little bit more work on it and get a little bit more practice. As of now, I've got the general concepts down, but I could always use practice and kinda play around with it and things like that.

Sherman: In your opinion, is there better instrumentation available for the general chemistry laboratory at UNT? If so, what are they? Why do you think so?

Pat: Not that I know of. This is my first chemistry class in college, so it worked pretty well for me.

Sherman: Now we're going to focus in a little bit on the working of it. How did you go about learning how to use the various parts of the PASCO system during this semester?

Pat: Like how, like what I actually did with it?

Sherman: learning how to use it.

Pat: learning how to use it?

Sherman: Yes

Pat: Kinda, I guess, with Experiment 8, I believe, or maybe the one previous, but that's where it (pointing to the lab manual) really went into detail on how to function, how to manipulate and maneuver around the PASCO system, and after that, just kinda practicing and using it for the next experiment. Stuff like that.

Sherman: Describe how you and your lab partner (or rest of your lab group) worked through labs.

Pat: We would usually divide the work up. So, like, either we would do at least two and they would do three, or vice versa, depending on the length of it. But, I guess, we would divide it up. There would be four of us. So two of us would work on two experiments, and we would go through the steps using the PASCO system, and they would do the same thing. We both kinda got use in how to work the PASCO system.

Sherman: Who did the most work?

Pat: It was pretty much 50-50. We both did the same amount of holding probe in one spot or stuff like that and stopping it

Sherman: What were the roles of each person?

Pat: We kinda did different roles of holding the probe, or stopping it when it needed to be stopped at a certain temperature, or getting chemicals, or stuff like that. So it kinda just changed and kinda helped each other out.

Sherman: Describe discussions you had with your lab partner (or rest of your lab group) about how to work with the PASCO system.

Pat: I guess the best way is kinda have a lab partner because you're trying to make sure everything is going right with the probe and stuff like that in the experiment and took the data to see how things are changing.

Sherman: Describe discussions you had with your lab TA (teaching assistant) about how to work with the PASCO system.

Pat: I know sometimes we had, you know, with the probe touching the Styrofoam cup or something other than the chemical it's supposed to touch, would it change it? How to work certain things like on the computer, trying to get multiple graphs up and stuff like that. So, it was questions in general on how to do this and that.

Sherman: This concludes the interview. Do you have any questions for me at this point?

Pat: No, actually not.

OBSERVATION NOTES

April 6, 2010

Tuesday, 3:30 p.m. lab

Lab 9: Determination of Molar Mass by Freezing Point Depression

Five students observed.

<u>Students 1 & 2</u> –

(3:44 – 3:50) Student 1 says "need to get freezing point on this thing" – Data Studio program pulled up on computer and probe assembled correctly – Student 1 watches - Student 2 weighs materials – neither work the program

(3:54-4:01) calibrate cold temperature – Student 1 read directions, Student 2 said "get to zero" – Student 1 impatient – Student 2 works computer to calibrate – does swiftly – 1 and 2 freeze cyclohexane in ice bath – TA helps clarify directions on freezing cyclohexane – Student 2 works computer – Student 1 watches cyclohexane for freezing – as temperature equilibrates – neither watching graph – TA asks them if they want to watch the graph – Student 2 messes with cursor placement

After final temperature drop during Run 1 of the experiment, Students 1 & 2 ask for help. TA comes over to answer questions– they identify the freezing point of cyclohexane from graph – Student 2 moves cursor and TA agrees – Student 2 stops graphing/measuring – puts program display into numerical form – Student 1 & 2 start 2nd run with cyclohexane + unknown solute – running as 2nd graph in different color on screen

Student 3 & 4 –

(3:50-3:54) Both are calibrating temperature probe – other group member explaining to Student 3 & 4 how to do it – discussion on using thermometer to calibrate – Student 4 standing and watching Student 3 weighing – Student 3 trying to make sure computer matches thermometer – they started with hot water bath – After calibration, they determine the freezing point of cyclohexane - Student 4 tells group to put probe in cyclohexane – Student 3 shakes it to cool it down – The graph sampling rate is 10 Hz – The graph window is large so they cannot see the temperature drop. – Student 4 adjusts window to try to find freezing point – examines cyclohexane – not ready – window still too big – Student 4 tries again by moving cursor – I asked Ta if the window can be adjusted by moving axis – She confirmed – Student 3 works on adjusting window with no change – scale of y-axis too big – They get the freezing point for cyclohexane – Student 3 doesn't stop graph running before freezing second solvent. – Students 3 & 4 run the experiment with cyclohexane + unknown solute – running as 2nd graph in different color on screen

Student 5 –

(3:44 – 4:01) Student 5 stands around, watches group do lab, and reads instructions but doesn't share information with the rest of the group – not much participation during lab

April 8, 2010

Thursday 3:30 p.m. lab

Lab 9: Determination of Molar Mass by Freezing Point Depression

One student observed

Before beginning lab, TA instructs group they will use the same technique as last lab with system and cooling curves.

Student say "have to set up thermometer thing" – asked for clarification of procedure – calibrate? – TA says yes – Data Studio program pulled up and in standby mode – student starts calibration of temp probe – put probe in ice bath then clicked "set" – student correctly explained how to calibrate probe to another group – student continues to help other group with directions – at 59.2 °C sets calibration at 58 °C according to the thermometer – done for high end of calibration range

Student determines freezing point of deionized water using cooling curve graph – works quickly – had water in ice bath and added NaCl to ice bath

Student tells group next to her "Create Experiment, Select Thermometer , hit calibrate" The group's program hangs up – Student tells them to exit program and unplug probe then plug in again – Student tells them to go to Data Studio, go to Calibrate, put (probe) in ice bath. When it hits zero then say zero then put in water bath (hot)

Student's graph extends as time increases but y-axis is too big – can cut y-axis to make graph taller – TA shortens y-axis scale with a few mouse clicks – Student cheers.

Student restarted water cooling because she really used tap water rather than deionized water – Student got a smoother curve – changed from ice bath to dry ice (carbon dioxide) bath – TA says to zoom in and highlight area – Student does so – Student tries to pull temp probe out of dry ice – TA helps them find the freezing point.

Student running mixture of water and ethylene glycol – done in dry ice bath – goes faster – Student asks TA to help with freezing – supercooling occurs – added more dry ice and restarted graphing/measuring

April 12, 2010

Monday, 12:30 p.m. lab

Lab 10: Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water

Two students observed.

Lab involves using temperature probe and DataStudio™ program for measuring temperature – students looking for temperatures using graphs – leveling off of line over time – TA does redirect to minimize graph screen and use numerical display - Numerical display has both pressure in kPa and temperature in °C – readings displayed to the nearest 0.01 for both pressure and temperature.

Students ask each other what to do – instructions include words "temperature probe" and "thermometer"

Students use graphing mode to find stable temperature readings. One student asked what temperature of water is and grabbed the thermometer, but his partner obtained the measurement faster using the temperature probe.

The higher the temperature reading was, the more accurate it was

After heating metal sample, the students put it into the ethylene glycol with the temperature probe – they both looked for equilibrium temperature on the display. They recorded their results to the nearest 0.1 °C rather than to the nearest 0.01 °C as shown on the display.

April 12, 2010

Monday, 6:00 p.m. lab

Lab 10: Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water

Four students observed.

Student 1, 2 & 3 –

These students work together in a team looks at graph display to get temperature of ethylene glycol in Part 1 – reports temperature as “30.12 – doesn’t make sense” – looking at graph for the reason – temp probe put in hot water – graph jumps – Student noticed graph stopped after 10 minutes then realized graph will show new color when started again – Student 1 asked if they should measure temperature of hot water with probe – Student 2 says to use the thermometer (during calibration) – Student 3 watches the other two in the group work, but questions sources of data and clarifies instructions – Student 1 puts temp probe in calorimeter then hits “Start” for graph – wonders where it is (the line) and realized that it had started – Student 3 points out that the start point for graph #2 lower than T_1 of the water – Student 1 reports to the TA “the thermistor is broke” – Student 3 suggests recalibrating but isn’t done – they read the equilibrium temperature from the graph.

Student 4

Student 4 puts temperature probe in hot water but uses thermometer to calibrate before using temperature probe – uses temperature probe to measure temperature of liquid (T1) in Part 1 of lab – Student 4 completes Part 1 with no issues then works calculations before moving on to Part 2 – the monitor goes to sleep after 15 minutes of inactivity – and Student 2 cannot see what the program is reporting

April 13, 2010

Tuesday 12:30 p.m. lab

Lab 10: Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water

One student observed.

DataStudio™ program open and waiting to be calibrated – Student 1 says, "Has to be calibrated before we can get 30 mL (of water). Can't use temp probe before it's calibrated." Student's partner reminds him not to let the temp probe cord touch the hot plate and instructs Student on how to calibrate the temp probe – Student 1 sets Part 1 at 27 °C and Part 2 at 100 °C. These are the two extremes for calibration of the probe – Temperature read from numerical display. Initial temperature of water recorded to the nearest 0.1 °C but is read to the nearest 0.01 °C. – Student keeps watching temperature values looking for equilibrium temperature.

April 13, 2010

Tuesday 12:30 p.m. lab

Lab 10: Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water

Four students observed that were the same as last week.

TA reminds class about calibrating probes first then tells them to let probe settle down on measuring

Both groups (Student 5 from last week was not present) were smoother and better at using the system.

April 13, 2010

Tuesday 6:00 p.m. lab

Lab 10: Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water

Three student observed all in different groups.

Student 1 –

Uses graph mode to find initial temperature of water after calibrating – graph shows 2 runs – got equilibrium temperature from horizontal portion of graph – small range on y-axis (22-28 °C) – estimates temperature from graph – Student 1 does enthalpy of fusion of ice portion of lab (Part 2) – partner tells her to close graph from Part 1 – starts again when ice added to calorimeter – temperature spike small but visible due to small y-axis scale – Student 1 adjusts axis to try to make spike more visible

Student 2 –

Student 2 uses graph mode to find temperature – has 5 curves showing – large range on y-axis (-40 - +140 °C) – five curves showing – had to restart several times and estimated temperature from graph – Student 2 clears out graph and starts over to get new temperatures

Student 3 –

Student 3 uses numerical mode to get temperatures – gets temperature to the nearest 0.01 °C- then switched to graph mode – Student 3's temperature graph for enthalpy of fusion shows a valley instead of a peak like Student 1's graph – partner switches back to numerical mode

April 16, 2010

Friday 12:30 p.m. lab

Lab 10: Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water

Three students observed.

Student 1 and 2 have calibrated temperature probe and monitor set on numerical display – temperature recorded to 0.1 °C and read to 0.01 °C – Student 1 used temperature probe to stir liquid – they switched display to graphical

Student 3 has both the graphical and numerical display on monitor screen during entire lab

April 16, 2010

Tuesday 3:30 p.m. lab

Lab 10: Introduction to Calorimetry – Determination of Specific Heats of Solids and Liquids, and Enthalpy of Fusion of Water

Four students observed.

Student 1 and her partner calibrating temperature probe – Student 1 sets bottom value at zero with probe in ice bath – They wait for hot water – Student 1 removes thermometer and partner puts temp probe in hot water bath – they can't decide to get it close to 80 °C – Student 1 says that higher is better – calibrated at 86.5 °C. – During Part 2 with ethylene glycol program is put back in calibrate mode just to read the temperature

Student 2 has display in numerical mode and stirs water/hot metal mixture with temp probe – Student 2 also makes sure that temperature probe doesn't touch the bottom of the beaker on the hot plate and waits for equilibrium temperature to be reached

Student 3 has the probe calibrated at beginning of lab but did not tell program "OK" after calibrating before starting making measurements

During measurements, Student 4 asks TA for a numerical display – "I want mine to look like theirs" – pointing to the neighboring group – TA switches display for Student 4.

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