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Digital Badges and Student Motivation in the Undergraduate Chemistry Laboratory

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DIGITAL BADGES AND STUDENT MOTIVATION IN THE UNDERGRADUATE GENERAL CHEMISTRY LABORATORY

by

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For my family-

Especially Gaga – I know where I got my brains

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ABSTRACT

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Laboratory courses have been the focus of much research and debate in the field of chemistry. One goal for the laboratory that is consistently cited by faculty is student learning of hands-on skills. Despite this, hands-on skills are rarely assessed in practice because to do so is resource intensive. Digital badges allow each individual student to demonstrate their proficiency in a hands-on lab skill while relieving the constraints associated with assessing individual students during a laboratory period. Previously at Purdue, digital badges were developed for the pipet, buret, and volumetric flask. These badges were shown to support student learning of these techniques. This study builds on that work by investigating student perceptions of digital badges in the chemistry laboratory. As the badges are posited to influence student motivation, we aim to look at student motivation in the laboratory and how this interacts with their perception of the badges and what potential impact the badges have on the students' laboratory experience. To answer these questions, the theoretical framework of expectancy value theory was used. A survey was developed to measure student value beliefs regarding laboratory techniques. The validation and implementation of the survey is discussed as well as its use to identify interview participants for a qualitative study of student motivation. Students with varying levels of motivation who have completed the badges were interviewed to gain an understanding of the relationship between motivation and digital badges in the laboratory. Several themes in student motivation and perception of badges were identified and compared with prior work to make recommendations for the future implementation of badging activities in the curriculum.

CHAPTER 1. INTRODUCTION

Laboratory courses have been a staple of college chemistry curricula for many years (Hofstein & Lunetta, 1982; Hofstein & Mamlok-Naaman, 2007; Reid & Shah, 2007). Though these courses are widely taught and assumed to be necessary, debate still exists regarding the function and necessity of laboratory courses (Hofstein & Mamlok-Naaman, 2007; Kirschner & Meester, 1988). Because these courses are very time and resource intensive, it is important that institutions conduct these courses with specific goals and objectives in mind to minimize the possibility of wasted resources(Hofstein & Lunetta, 2004; Hofstein & Mamlok-Naaman, 2007). To this end, research has been conducted about both student and faculty goals for laboratory instruction (Bretz, Fay, Bruck, & Towns, 2013; L. B. Bruck, Towns, & Bretz, 2010; DeKorver & Towns, 2015, 2016; Galloway & Bretz, 2015a). While faculty have more varied goals, the students have more specific goals, mainly in the affective domain (L. B. Bruck et al., 2010; DeKorver & Towns, 2015; Galloway & Bretz, 2015b). It has been proposed that in order for the faculty's goals for laboratory to be achieved, they need to align with student goals. Because students are motivated by their grades and completing course objectives, goals that are important to faculty must be tied to course assessments.

One of the goals that faculty hold for their laboratory courses is to teach students how to use laboratory equipment and develop hands on skills that cannot be taught in a classroom (Bretz et al., 2013; A. D. Bruck & Towns, 2013; L. B. Bruck et al., 2010). These skills, while valued, are rarely directly assessed (Chen, She, Chou, Tsai, & Chiu, 2013; Hofstein & Lunetta, 1982). Students are traditionally assessed on their laboratory reports, worksheets, or data that they produce. These assessments do not provide direct information about students' laboratory skills. They may be able to indicate that there is a deficiency, but will not tell the instructor what exactly the student is doing incorrectly. Another possibility is that the student would use an incorrect or unsafe laboratory technique but still produce usable data. For these reasons, if one of the goals of laboratory is to teach hands on skills, those skills must be directly assessed.

Digital badges provide a method by which to assess a student's hands-on laboratory skills. A digital badge is a credential that is awarded based on evidence that a person has demonstrated some skill or knowledge. This is similar to the idea of badges in other organizations such as scouting, and is not unlike credentials required for many jobs. While digital badges have been used in gaming and scouting for many years, they have recently been introduced in education (Abramovich, Schunn, & Higashi, 2013; Davis & Singh, 2015; Grant, 2016; Klein & Davis, 2016; A. Reid, D. Paster, & S. Abramovich, 2015; Riconscente, Kamarainen, & Honey, 2013a; Seery et al., 2017). Badges have been used in a variety of educational settings such as English composition courses (A. Reid et al., 2015) and after school programs (Davis & Singh, 2015), and more recently have been used in chemistry courses (Hensiek et al., 2016; Hensiek et al., 2017; Seery et al., 2017; Towns, Harwood, Robertshaw, Fish, & O'Shea, 2015). The badges are hosted online and because of this, they contain metadata about the badge issuer, the requirements for the badge, the date issued, as well as the actual evidence that someone must submit to earn the badge (Riconscente et al., 2013a). When used in education, digital badges provide a new type of assessment that can be recognized by others outside the classroom because the criteria and the evidence can be made publicly available. This lends credibility to the badges and allows for their possible use as a supplement to more traditional resumes and transcripts.

It has been posited that one of the reasons that students do not persist in STEM fields is due to poor affective experiences that can impact student motivation (Chan & Bauer, 2014; Galloway & Bretz, 2015a). Students in large gateway STEM courses do not see value in what they are learning or perceive the material to be too difficult (Ferrell & Barbera, 2015). These factors are related to students' motivation. Students who hold more positive attitudes toward chemistry and students with greater motivation unsurprisingly see greater success in the course (Ferrell & Barbera, 2015). Interventions that increase student confidence and motivation then can be used as potential ways to improve student performance and retention in STEM courses (Chan & Bauer, 2014; Ferrell & Barbera, 2015).

Digital badges have been seen as a potential way to motivate students. They are a type of reward and have the potential to provide a source of extrinsic motivation as well as stimulate a student's sources of intrinsic motivation (Abramovich et al., 2013). They are also a recognition of skills and can draw out a student's intrinsic desire to perform well. Badges have been thought to add a gamification aspect to learning that may help motivate students (Blair, 2016; Grant, 2016).

1.1 Research Questions

This research project examines the interaction between digital badges and student motivation in chemistry laboratory courses using both quantitative and qualitative methods. A quantitative survey instrument based on expectancy value theory was designed to begin to characterize different types of student motivation. Using the results of the survey, students were purposefully sampled for qualitative interviews to determine the relationship between their motivation to learn lab techniques and the digital badge activities they completed. The study is guided by the following research questions:

- To what extent can differences in student motivation to learn laboratory techniques be detected by using participant perception indicator (PPI) and value survey instruments?
- How do students with varying types of motivation to learn laboratory techniques perceive digital badges?
- What role do badges play in student learning of laboratory techniques?

1.2 Overview of Chapters

Chapter two will include a review of the literature related to student learning in the laboratory, digital badges, and student motivation. Chapter three will discuss prior badge work that has been completed at Purdue. Chapter four will discuss the development of the value instruments for both the pipet and buret and an analysis of their implementation in a general chemistry course. Chapter five will discuss the methodology used to conduct the qualitative portion of the survey. Chapter six details the results from the qualitative interviews regarding students' motivation and thoughts about badging. Chapter seven provides a conclusion and implications of this work for future research and practice.

CHAPTER 2. LITERATURE REVIEW

2.1 Learning in the Laboratory

The laboratory has long been a standard feature of chemistry courses. For at least the last thirty years, the role of the laboratory however, has been called into question (Hawkes, 2004; Hofstein & Lunetta, 1982; Kirschner & Meester, 1988; Reid & Shah, 2007). Hofstein and Lunetta (1982) called for research into a variety of areas pertaining to laboratory education. After decades of research, we now know more about what happens in the laboratories as well as some strategies for effective laboratory teaching. However, these strategies are not always implemented and there are calls to develop more effective ways to teach and assess students in the laboratory (Hofstein & Lunetta, 2004). Because laboratory courses are so costly and resource-intensive to implement, it is important that there is proof that students are actually benefitting from such courses (Hawkes, 2004; Reid & Shah, 2007).

Recently, researchers have studied students' and instructors' goals for the laboratory. Students' goals provide a driving force for how they behave and what they prioritize when making decisions in the laboratory (DeKorver & Towns, 2015, 2016). DeKorver and Towns (2015,2016) found that students in both upper-level and lower-level courses justified their actions in the laboratory based on their goals for the course. Many of these were affective goals such as getting a good grade, and finishing the lab quickly. This caused the students to perform parts of the experiments incorrectly or to ignore the goals that the faculty members had for the laboratory, such as learning concepts or how to use equipment. Interviews and surveys of faculty members have shown that faculty hold varied goals for the laboratory courses for their students (Bretz et al., 2013; L. B. Bruck et al., 2010). Faculty value cognitive goals such as gaining knowledge of chemistry and learning when to apply the knowledge. They also value psychomotor goals of learning how to use laboratory equipment. Faculty had fewer common affective goals, though some may include working as a team and gaining scientific independence (Bretz et al., 2013; L. B. Bruck et al., 2010). It is important to consider both faculty and student goals when considering learning in laboratory courses because they are interdependent. As Hoffstein and Lunetta (2004) claim, "…students' perceptions and behaviors in the science laboratory are greatly influenced by teachers' expectations and assessment practices and by the orientation of the associated laboratory guide, worksheets, and electronic media..". Students' goals for the laboratory impact their learning and are influenced by the goals that they perceive their instructors to have.

Students base many of their actions in the laboratory on their affective goals (DeKorver & Towns, 2015, 2016). A study of students' cognitive and affective goals in the laboratory revealed that many students had low expectations for their cognitive and affective experiences in the laboratory, and that many of these expectations are met. Even more troubling is that there are many students who start with high expectations for lab but find that their experience is not as positive as they had expected (Galloway & Bretz, 2015a, 2015b). One possible cause of this is a lack of faculty focus on affective goals in the laboratory as well as a general mismatch between faculty goals and student goals. As a result, there have been calls for faculty to consider the affective goals of their students and align their assessment practices with their goals to help make their goals more explicit to students (DeKorver & Towns, 2015; Galloway & Bretz, 2015b).

2.2 Digital Badges

Digital badges are a type of credential. They are a physical representation and a way to display knowledge or skills a person has gained (Gibson, Ostashewski, Flintoff, Grant, & Knight, 2015). The idea of badges and credentials has been around for many years in scouting, the military, and other organizations where people can receive training or must demonstrate their skills (Riconscente, Kamarainen, & Honey, 2013b). Digital badges have been used for years in video gaming and in other computer based areas as a way to motivate users and mark progress or achievements (Jakobsson, 2011). More recently, digital badges have been used in education as a type of evidence based assessment (Gibson et al., 2015; Riconscente et al., 2013b). Digital badges are useful for assessment because of their unique format. Digital badges are hosted online and can contain various types of metadata such as the issuer, date issued, criteria, and the evidence that a student must submit in order to earn the badge (Riconscente et al., 2013b). In this way, badges are able to give a more accurate and detailed picture of a student's knowledge and skills than a typical grade in a course can (Gibson et al., 2015). Sheryl Grant states that the goals of badges in education are "to map progress and foster discovery, signal reputation beyond the community where it was earned, and incentivize learners to engage in pro-social behaviors" (Grant, 2016).

Comparisons between digital badges in education and badges or achievements in video games have been made. Borrowing ideas from video games, one could imagine a "skill tree" of badges that allows learners to choose which badges they find most appealing in a predetermined sequence (Blair, 2016; Jakobsson, 2011). The timing and nature of badges can also be similar to those in video games, with early badges being easier to earn and later badges being more difficult and time consuming. It is also a possibility that the badges can set the tone that it is acceptable to take risks and fail, as some video game achievements have recognized (Blair, 2016).

Digital badges have been used in a variety of educational contexts ranging from K-12 education to postsecondary courses and even professional development and continuing education (Gamrat, Zimmerman Heather, Dudek, & Peck, 2014; Gibson et al., 2015; Klein & Davis, 2016; Moore & Edwards, 2016). Badges have been used in high schools to promote gamification of learning and to help motivate students to prepare for college (Moore & Edwards, 2016). The high school students saw the badges as motivating, with males reporting greater motivation than females (Moore & Edwards, 2016). Students preferred badges that could be earned in elective courses as separate skills that not all of their peers would have (Moore & Edwards, 2016).

Students in informal programs have also reported valuing the recognition of new skills through digital badges (Davis & Singh, 2015; Klein & Davis, 2016). High school participants in a program at a STEM discovery center liked having control over the badges they earned and liked having badges that were unique to their program (Klein & Davis, 2016). The biggest drawback to the badges was that the students wanted them to be recognized outside of their program, especially when applying to colleges (Klein & Davis, 2016). In an after-school program for high school students, students reported similar concerns. They liked being able to distinguish themselves from their peers, and similar to the other students, a major concern was that the badges wouldn't be recognized outside of the program (Davis & Singh, 2015).

In post-secondary contexts, badges have seen increasing use as students become more concerned about the utility of their degrees and are placing more value on learning specific skills that will help them in the workforce. One extreme example of this is at the Purdue Polytechnic where a program in transdisciplinary technology studies was created based solely on credentials and badges rather than overall course grades (Ashby, Exter, Matei, & Evans, 2016). Students had to demonstrate mastery of a variety of tasks and were awarded badges as they learned new skills. This created some challenges logistically for students and faculty with regards to deadlines, feedback, and grading (Ashby et al., 2016). Students found the badge experience both challenging and rewarding. Preliminary feedback from participants indicates that the program gave students more opportunities to explore different topics and learn in new ways. Students and instructors found the benefits to outweigh the negatives (Ashby et al., 2016).

In a study of digital badges among undergraduate nursing majors, the students generally found the badges to be a motivator for learning in their course (Foli, Karagory, & Kirby, 2016). Students mentioned being able to show the badge to future employers and others liked having the recognition and extra push to do the work correctly (Foli et al., 2016). While overall, the attitudes towards the badges were positive, some students noted that they were motivated by a desire to learn the material and that the badge did not matter to them (Foli et al., 2016). In an English composition course, Reid and colleagues found that students' motivation to earn badges change over the course of the semester and this change was different based on their expectation and value of the learning objectives. Students who saw a benefit to what they were learning were more likely to be motivated to earn badges (A. J. Reid, D. Paster, & S. Abramovich, 2015).

In chemistry specifically, digital badges are relatively new. There have been a few reports of digital badges for chemistry in the literature (Hensiek et al., 2016; Hensiek et al., 2017; Seery et al., 2017; Towns et al., 2015). Badges have a great potential for use in chemistry laboratory courses because they are evidence-based assessments that can target skills that are otherwise hard to assess. While instructors say that learning techniques is a goal for their students, in large courses or when students work in groups, techniques are rarely assessed directly for each student and instead the proxy of a lab report is used (Bretz et al., 2013). To mitigate this, the Towns research group investigated the impact of digital badges on student learning in introductory laboratory courses (Hensiek et al., 2016; Hensiek et al., 2017; Towns et al., 2015). It was found that after completing the digital badge activity with a volumetric pipet, the students' knowledge, confidence, and experience about the technique increased significantly with large effect sizes. According to the theory of human constructivism, these pieces are all critical to produce meaningful learning, demonstrating that the badge helped students learn about pipetting (Towns et al., 2015). Similar results were seen when the badge activity was expanded to other techniques in the general chemistry laboratory: using a buret and using a volumetric flask(Hensiek et al., 2016).

Seery and colleagues built on the digital badge approach and created three badges for chemistry students at the University of Edinburgh: titration, distillation, and making a standard solution (Seery et al., 2017). Students showed significant gains in their knowledge, confidence, and experience after completing the badge activities (Seery et al., 2017). The badges also incorporated a peer review component as well as exemplar videos for the students to watch. Students gave feedback and had more dialogue about the techniques, which is thought to help their learning (Seery et al., 2017). This work shows that the badges can be used in various settings and that new badges can be created with similar positive results.

In an overview of digital badges and their role in STEM education, Riconscente and colleagues (Riconscente et al., 2013b) give a few examples of badges being used to scaffold learning for students in informal contexts such as programs at NOAA and other extracurricular programs. They discuss the need for continued development into best practices for implementation and design as well as figuring out how to incorporate more detailed and rigorous STEM content into the badges. They also raised concerns about effective assessment of the badges and learning as well as a need for research into the conditions of badging that support student motivation. It is a concern that adding the badges as extrinsic motivators may decrease student motivation to learn content (Riconscente et al., 2013a).

Although there is a clear need to investigate implementation and evaluation of badges, as well as their impact on learning and motivation, it is likely that a one size fits all solution does not exist. Abramovich (2013) claims that the nature of a badge determines its impact on student learning. Badges that are directly connected to content will not have as many of the issues as other, more disconnected types of extrinsic motivators (Abramovich et al., 2013). Students have been shown to have different thoughts and orientations towards badges based on their ability level and the type of badge being offered (Abramovich et al., 2013). Digital badges had a different impact on high vs low skilled learners in terms of their desire to earn badges and their own performance expectations. Participation versus skill badges also differed in how the students perceived the badge as well as in the impact of the badge on students' learning and motivation(Abramovich et al., 2013) .

2.3 Motivation

Student motivation and its link to student success have been the subject of much research. While researchers have found that student motivation typically decreases over the course of a semester (Zusho, Pintrich, & Coppola, 2003), they have also found that student success in chemistry courses is positively correlated to measures of student motivation (House, 1996; Zusho et al., 2003). House (1996) and Zushto et al. (2003) found that academic self-concept and drive to achieve were significantly correlated with student success in chemistry. They showed that students' motivation generally decreased over the course of the semester, but that higher achieving students had higher motivation at the end of the semester than low achieving students (Zusho et al., 2003).

One theory of motivation that has been popular in education is the theory of self-efficacy which states that people are more likely to engage in a task when they believe that they are capable of doing the task (Albert Bandura, 1977). While Bandura acknowledges that that is not the only source of human motivation, it does play a large role in determining whether or not someone will attempt a task. He also states that attaining self-efficacy in one area can translate to other related areas and make people more willing to accomplish similar tasks. According to the model, self-efficacy is obtained through four sources: performance accomplishments, vicarious experience, verbal persuasion, and emotional arousal. These components all contribute to how much a person believes they are capable of completing a task, and therefore can influence how motivated they are to complete a task (Albert Bandura, 1977).

Motivation can also be viewed as having a component that is external to oneself. Motivation can be divided into intrinsic factors that come from within a person and extrinsic factors that come from outside influences. These types of motivators are described in Self Determination Theory (SDT) (Ryan & Deci, 2000). Deci and Ryan explain that intrinsic motivation is related to a person's enjoyment and satisfaction derived from completing a task. This enjoyment provides a sense of controlled and autonomous motivation that is very powerful for people (Ryan & Deci, 2000). Extrinsic motivation can come from many sources whether it be through bribes or threats or a desire to obtain a specific future result. Bribes and punishments create external motivation which is the weakest form of motivation. A desire to produce an outcome creates introjected motivation, which while still based on an external factor, still has a strong internal component that makes it a stronger type of motivation for people. Deci and Ryan believe that the way to maximize intrinsic and introjected motivation is to give people a sense of competence, relatedness, and autonomy in a task. These are the three basic psychological needs that humans must have met in order to be motivated to complete a task. When people feel they are capable, feel they are connected, and feel that they have control of their lives, they are more likely to engage in an activity and according to SDT, people will seek out tasks that can meet these three needs (Ryan & Deci, 2000).

2.4 Expectancy-Value Theory

Expectancy-value theory is a theory of motivation that is guided both by a person's belief in their own competence or self-efficacy and how much a person values a task. It has been developed by Eccles and Wigfield and applied to various educational settings (Wigfield, 1994; Wigfield & Eccles, 2000). The idea of expectancy is centered around how successful a person believes they will be at a task and is related to self-efficacy as defined by Bandura (A. Bandura, 1977). If a person believes that they will succeed at a task, then they will be more motivated to complete the task and will put forth more effort. The second part of the theory states that motivation to complete a task is also determined by how much a person values the task.

In expectancy value theory, value is defined to be made of four different constructs: utility, cost, attainment, and interest. Utility and cost focus on extrinsic factors that are related to external pressures a person may face such as desire for grades, jobs, or constraints on time or effort. Attainment and interest focus on more intrinsic factors such as a person's identity or internal desire for success and their enjoyment of a task regardless of outcome (Wigfield & Eccles, 2000). The four constructs of value are defined in Table 2.1 along with examples of how each construct can be embodied in a student.

Table 2.1. Definitions of the value constructs in expectancy-value theory (Wigfield & Eccles, 2000)

	Definition	Example
Utility	The extrinsic importance a person places on something based solely on how it will help them accomplish a variety of other short- or long-term goals.	A student takes a course because it is a requirement for other courses or a future career.
Cost	The subjective estimate of loss or use of resources (time, effort, etc.) suffered by a person as a result of trying to perform a task.	A student doesn't complete a task because it makes them nervous or takes too much time.
Attainment	The intrinsic importance that a person places on succeeding at a particular skill or knowing particular information within a subject area, regardless of how that skill or knowledge can be used. A person is compelled internally to succeed.	Student who wants to do well at everything. Being a good student is part of their identity.
Interest	A demonstrated willingness to acquire knowledge and skills, driven by personal emotion or satisfaction.	A student who enjoys an activity and regardless of whether they are good at it or not, they like doing it.

Expectancy-value theory is useful to gauge motivation in an educational setting because students can be motivated by many factors. Students in college have had previous educational experiences and therefore may have a sense of how successful they will be at various tasks. The students also can value the tasks for various external reasons such as grades or prerequisites or future career prospects. Because the students are in college, they also have a sense of what they are interested in, as well as a sense of their own identity as a student. Expectancy-value theory helps capture these different types of motivation.

CHAPTER 3. PRIOR BADGE WORK AT PURDUE

3.1 General Badge Structure and Grading

There are currently three badges that have been implemented in general chemistry courses at Purdue: a buret, a pipet, and a volumetric flask. All three badges follow the same format. The main badge activity consists of the students creating a video showing the proper use of a piece of laboratory equipment. The students are given a detailed list of the steps involved in using the technique correctly. These steps are adapted from the students' lab manuals to represent standard procedure for each technique. The steps are created and reviewed by chemistry professors and laboratory staff to ensure accuracy.

The badges are introduced during the laboratory activity during which the students will use the technique for the first time. This way the students can use the badge to practice and receive feedback early in the semester, before they use the technique for other activities. The students then film their videos during the laboratory period and upload the videos to the badge using the Passport program. Within the Passport program we have also implemented various surveys to assess student learning as a result of completing the badge activity.

The first survey that was developed for use with the digital badges was the participant perception indicator survey (PPI) shown in Table 3.1. This survey was adapted from the literature and is designed to measure students' knowledge, confidence, and experience about various aspects of each laboratory technique using a 5-point Likert scale (Lee, Kerner, & Berger, 1998). The survey is based on the theory of self-efficacy as it focuses on what students believe they can do. A student's belief in their own knowledge, confidence, and experience can influence their motivation to complete the task. It has been shown that students can reliably self report their own knowledge (Ross, 2006) so the PPI survey also functions as a measure of learning occurring as a result of the badge. The pipet instrument is shown and similar instruments were created for the buret and volumetric flask badges (Hensiek et al., 2017) by creating items relevant to the most important parts of each of those techniques.

Table 3.1 Participant Perception Indicator Survey for the Pipet Badge

Statement	Knowledge Low High	Experience Low High	Confidence Low High
1. Identify a pipet from among pieces of glassware.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
2. Identify a pipet bulb from among pieces of equipment.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
3. Use a pipet and pipet bulb to deliver a sample of liquid to a flask.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
4. Connect a pipet and pipet bulb properly.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
5. Draw liquid into a pipet.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
6. Get liquid to the proper level in the pipet.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
7. Dispense liquid from the pipet.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

The surveys are implemented using a retrospective-pre-then post design. In a retrospective-pretest the survey is given after the students have completed the badge activity, but asks students to rate their knowledge, confidence, and experience before the activity. This is a more accurate way to deliver the survey than a true pretest because many of the students in the course have never used the laboratory equipment before (Howard et al., 1979; Rockwell & Kohn, 1989). It is therefore difficult for them to rate their knowledge of something that they have never seen or experienced. The retrospective pre-test therefore is most suitable for our population of students. In the first implementation of the badge, a traditional pre survey was given in addition to the retrospective pre survey. The students rated their knowledge, confidence, and experience higher on the retrospective pre survey than on the traditional pre survey. This indicates that students may have known more about usining a pipet than they had initially thought, but may not have been able to accurately rate their knowledge because they were unsure of the terminology or what the equipment looked like. After the first implementation, the retrospective pre was exclusively used to help mitigate any survey fatigue while providing the most accurate representation of the students' self-efficacy beliefs. In the first implementation, a pre-survey was given, however it was found that valid results could be obtained only using the retrospective pre and post surveys, thus addressing potential survey fatigue (Hensiek et al., 2016; Towns et al., 2015).

The badges are then graded using rubrics, provided in Appendix A, which were developed based on the list of steps that the students were given. For each technique, the directions were analyzed to determine the most important steps that were most crucial for performing the technique safely and accurately. These steps were the focus of the rubric. The rubric was created to have three tiers, 0 points, 0.5 points, and 1 point for each step. To earn the full point for a step, the student needed to complete the step correctly and safely. Errors that did not impact the accuracy of the technique or pose a serious safety hazard were given 0.5 points. If a student made an error that made the technique inaccurate or unsafe, they were given 0 points for that step. Student videos were used to provide examples for each tier of the rubric. An example showing one step for the pipet rubric is shown in table 3.2.

Table 3.2 Sample Section of Pipet Rubric

	1	0.5	0
Draw liquid into the pipet	Smoothly draw liquid in a constant flow past the calibration line but not into the bulb	Draw liquid just to the calibration line without going past it	Draw liquid into the bulb Liquid not at calibration line Air bubbles remain in pipet prior to dispensing

The teaching assistants were trained in how to use the rubrics during staff meeting through use of exemplar videos. This was done to normalize the grading criteria across the entire group of teaching assistants who would be grading the student videos. Having everyone watch the same videos first provides a common reference point for grading and the application of the rubric criteria. The students had access to the rubrics while filming videos and received rubric scores after their video was graded. In addition to the rubric scores, the teaching assistants also were able to write in feedback to the students so that each student received individual feedback on their performance.

If a student made any of the major errors, or made many minor errors, their video was denied. The student would then have the opportunity to refilm and resubmit the videos the following week in lab, so that everyone had the opportunity to earn the badge. The badges were worth 5 points each out of 1000 points in the course.

3.2 Pipet Badge

The first badge that was created and implemented was the pipet badge. It was first implemented in CHM 111 at Purdue in the Fall of 2014. The students filmed videos and answered the PPI survey as a pre, post, and retrospective-pre-assessment. The survey results are shown in Table 3.3 (Towns et al., 2015).

Table 3.3 Pipet badge PPI survey results adapted from Towns et al. 2015

Survey (N=843)	Mean	Standard Deviation
Knowledge Pre	22.92	6.46
Knowledge RetroPre	31.09	5.34
Knowledge Post	34.60*	2.06
Confidence Pre	23.23	6.29
Confidence RetroPre	26.64	4.35
Confidence Post	34.48*	2.22
Experience Pre	22.92	6.46
Experience RetroPre	29.14	6.58
Experience Post	33.42*	4.24

The students showed statistically significant gains with large effect sizes from pre to post in their knowledge, confidence, and experience. This study showed that the pipet badge was a useful and effective way to both assess this technique and help students learn.

3.3 Buret and Volumetric Flask Badges

Badges were created for the techniques of using a buret and using a volumetric flask. These badges were implemented in the same course as the pipet badge as well as in a second semester general chemistry course for engineering students. The results of the PPI survey followed a similar trend to those seen in the original pipet badge implementation. It was found that the students in the second semester course still reported gains from completing the pipetting badge, but started higher on all measures than the students in the first semester course, lending validity to the survey. Students were also asked multiple choice questions and were able to demonstrate their knowledge of the techniques. The results of this work were published in the Journal of Chemical Education and the published article is included in the attached publication.

CHAPTER 4. DEVELOPMENT AND IMPLEMENTATION OF THE VALUE SURVEY

To attempt to determine student motivation in a large course using the framework of expectancy value theory, both expectancies and values must be measured. The PPI survey as described in the previous chapter was designed to capture students' beliefs about their capabilities which can serve as an indicator of their expectancy. An instrument to measure student values in the chemistry laboratory as defined by expectancy value theory has not been published in the literature. This chapter describes the creation of a value instrument based on the value constructs defined previously.

4.1 Survey Development

4.1.1 Initial Development

To begin development of the survey, a small number of similar instruments were found in the literature. These included surveys from Mathematics (Luttrell et al., 2010), Pharmacy (Hagemeier & Murawski, 2014), and English Composition (A. J. Reid et al., 2015). Items were adapted from each of these instruments to reflect the use of laboratory techniques. In addition, some items were generated by the research team to reflect each value construct as defined in Chapter 2. The first set of items focused on using pipets in laboratory was tested with other chemistry education graduate students through a sorting task. Items that did not get sorted as intended were either modified or not considered for further use (Luttrell et al., 2010). This resulted in a set of 28 items as shown in Table 4.1. The items were designed to be administered as Likert-scale questions with a five-point scale: 1 being strongly disagree and 5 being strongly agree.

Table 4.1 List of statements in the first draft of the value instrument with sources

Interest: I enjoyed using a pipet. (C) I would describe using a pipet as interesting. (C) I think using a pipet is not fun. (C) I would like to use a pipet again in the future. (D) I would enjoy learning other ways I can use a pipet. (D) I want to be able to use a pipet. (D)
Attainment: Using a pipet correctly is important to me. (C) I am disappointed if I use a pipet incorrectly. (B) I feel like I must succeed at using a pipet. (A) Even if using a pipet is not useful to me, I want to be good at it. (D) I expect myself to use a pipet correctly. (D) I want to be better than my peers at using a pipet. (D) I do not feel the need to be good at pipetting. (D)
Utility: I see no point in being able to use a pipet. (B) After I graduate, an understanding of using a pipet will be useless to me. (B) Understanding how to use a pipet has many benefits for me. (B) Using a pipet will be an important skill to have for the future. (D) It will be beneficial for me to know how to use a pipet sooner rather than later. (D) I believe pipetting will help me succeed in future courses. (D) Knowing how to pipet will help me get a good grade in this course. (D)
Personal Cost: I felt tense while using a pipet. (C) I was relaxed while using a pipet. (C) Using a pipet causes me a lot of anxiety. (B) I had to try harder at using a pipet than other techniques. (B) It was a waste of [time and] effort learning how to use a pipet. (D) I would describe using a pipet as a low-stress technique. (D) Using a pipet takes too much time. (D) Using a pipet was very easy for me. (D)
Source A = Pharmacy value instrument B = Mathematics value instrument C = Intrinsic motivation inventory (composition) D = Generated by research team

4.1.2 Pilot Survey

The initial version of the survey was piloted in the spring semester of 2017 in the second semester introductory chemistry course for non-majors. Survey results were obtained from 559 participants. The data was cleaned to remove duplicate responses (410), univariate outliers (using Z scores of >3.29), and multivariate outliers (using Mahalanobis distance). There were 382 usable survey responses. The analysis of skewness and kurtosis showed that the data was not significantly non-normal. Exploratory factor analysis, detailed further in section 4.3.1, was conducted with the data. Results of the factor analysis are shown in Appendix B. A four-factor structure was obtained, however it did not fit theoretically with the constructs of value that it was intended to measure. One factor contained primarily negatively worded items and another factor contained a mixture of items representing attainment and utility. There were also many crossloadings that did not improve with selective removal of items. Ultimately this model did not accurately reflect the constructs it was intended to measure.

After some further consultation with other graduate students and Dr. Levesque-Bristol, it was found that many of the items still had confusing wording or were not related to the constructs explicitly enough. Confusing items that did not perform well in the pilot were removed, and other items were re-worded to more carefully target their intended value construct. The revised version of the survey contained 25 items. The revised survey is shown in Table 4.2.

Table 4.2. Revised value survey for Fall 2017 implementation

Utility	Understanding how to pipet has many benefits for me It will be beneficial for me to know how to use a pipet Using a pipet will be an important skill to have for the future Knowing how to pipet will help me reach my goals Knowing how to pipet will be useful to me after graduation Knowing how to pipet will help me succeed in future courses Knowing how to pipet will help me get a good grade in this course
Cost	I felt tense while using a pipet Using a pipet causes me anxiety I was relaxed while using a pipet I would describe using a pipet as low-stress I had to try harder at using a pipet than other techniques Using a pipet takes too much time Learning how to use a pipet was a waste of time and effort
Interest	I would describe using a pipet as interesting I enjoyed using a pipet I would enjoy learning more ways to use a pipet I think using a pipet is not fun. I want to be able to use a pipet I would like to use pipets more often
Attainment	Even if pipetting is not useful to me I want to be good at it I am disappointed if I use a pipet incorrectly I want to be better than my peers at using a pipet I feel like I must succeed at using a pipet Using a pipet correctly is important to me

During the revision of the value instrument for the pipet, a version of the instrument was also developed for the buret. The items for the buret instrument were developed based on the items used in the pipet pilot. As previously stated, there were several items that did not perform as intended in the pilot. While it was hypothesized that many of the items did not perform well due to confusing wording, we were also concerned about possible effects from negatively worded items, which have been shown to produce certain method effects in factor analysis (Molina, Rodrigo, Losilla, & Vives, 2014). Because of this, when developing the final instruments, we made slightly different modifications to each instrument to determine which types of items performed as intended. Since the instruments would be implemented at the same time, it was not possible to modify either of the instruments based on the results of one new iteration. For the pipet value instrument, we focused on revising items to more directly target the intended constructs. For the buret value instrument, we made similar modifications to address confusion; however we also rewrote some of the items to be positively worded to see if the negative wording effects were impacting the factor structure. The buret instrument contained 27 items: six targeting utility, seven targeting cost, six targeting interest, and eight targeting attainment. The buret value survey is shown in Table 4.3.

Table 4.3 Buret Value Survey Items

Utility	Using a buret will be an important skill to have for the future After I graduate, understanding how to use a buret will be useful to me Understanding how to use a buret has many benefits for me I believe being able to use a buret will help me succeed in future courses It will be beneficial for me to know how to use a buret sooner rather than later Knowing how to use a buret will help me get a good grade in this course
Cost	I would describe using a buret as low-stress I was relaxed while using a buret I am not anxious about using a buret Using a buret did not take more effort than other techniques Using a buret takes too much time Learning how to use a buret was a good use of time and effort Using a buret was very easy for me
Interest	I think using a buret is fun I would describe using a buret as interesting I enjoyed using a buret I would enjoy learning more ways to use a buret I want to be able to use a buret I would like to use a buret again in the future
Attainment	Even if using a buret is not useful to me I want to be good at it I feel like I must succeed at using a buret I am disappointed if I use a buret incorrectly I want to be better than my peers at using a buret I expect myself to be able to use a buret correctly I feel the need to be good at using a buret Using a buret correctly is important to me I understand why we learned how to use a buret

4.2 Implementation

The pipet and buret value surveys were administered in a first semester general chemistry course for non-majors in the fall semester of 2017. A majority of students were from the colleges of agriculture and health and human science. The lecture for the course met twice per week and the lab met once per week. Many of the students had not had prior laboratory experience. There were 1068 students enrolled in the course and 936 students completed the pipet value survey. Of these responses, 722 were usable since they contained no duplicate responses, univariate or multivariate outliers. The buret survey had 865 total responses with 592 usable responses after responses with duplicate answers, univariate outliers, and multivariate outliers were removed. The pipet survey was given as a part of the badging activity during weeks 4 and 5 of the semester and the pipet survey was given during the buret badge in weeks 13 and 14 of the semester. The badges were timed to coincide with the first laboratory activity students completed that required use of the glassware for the badge. The surveys were taken after the students had filmed and uploaded their videos to complete the badges, but before they had received feedback on their work. Students completed the survey within the Passport program.

4.3 Data Analysis

4.3.1 An Overview of Factor Analysis

Factor analysis is a statistical technique that seeks to group items based on participant responses in order to account for the variance in responses across a survey. Items with similar response patterns are grouped together into factors and are said to represent the same latent construct. It is a useful technique in instrument development because it allows researchers to ensure their instrument is targeting the intended constructs.

The two most common types of factor analysis are exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). In exploratory factor analysis, there is no model specified prior to the analysis. The analysis seeks to identify patterns in the data with no prior structure. From EFA, the number of factors that best represent the data can be determined. EFA also produces factor loadings for each item which indicate how well an item represents the latent construct for that factor. Factor loadings above .3 are considered to be significant. If an item has a significant loading on more than one factor it is considered a crossloading. During EFA problematic items can be identified and removed to help refine the model and survey to align with theory. CFA is used to test the model generated through EFA. In this case, the factor structure is specified ahead of time to determine how well the data fits the proposed model (Brown, 2006; Child, 2006).

4.3.2 Exploratory Factor Analysis

Because the items from the pilot for the pipet survey had been modified, exploratory factor analysis was conducted again to determine the factor structure of the items and to determine whether they were measuring the intended latent constructs of value. EFA was also conducted using the buret survey data to ensure that the surveys performed similarly. In order to perform a more robust analysis using both EFA and CFA to determine the model, the data for each survey was randomly divided into two roughly equal parts. The sample size was large enough that half the sample met the criteria for analysis of having at least 200 responses or 5-10 responses per item (Child, 2006).

For the pipet survey EFA, a sample of 341 responses were used. After removing univariate and multivariate outliers, a total of 323 responses were used to conduct the exploratory factor analysis. The analysis was conducted in SPSS 23 using principal axis factoring with a varimax rotation as the factors were not shown to be correlated. Because the survey items were written to target the four constructs of value, a four-factor structure was expected. Initial analysis however indicated a five-factor structure. The fifth factor had weak loadings and was not easily interpretable. To clean up the factor structure items were removed that loaded onto the fifth factor, loaded onto the wrong factor, or had significant cross loadings. For the purposes of the analysis, only crossloadings above .3 were examined (Child, 2006) and a crossloading was considered to be significant if it was above .5 or if the factor loadings on the two factors differed by less than .1. Details of the factor analysis are shown in Appendix C.

The final value survey shown in Table 4.3 had 19 items. Six loading with utility, six with cost, four with interest, and three with attainment. The factor loadings were fairly strong with most loadings being close to or above .5. This indicates the items represent their intended constructs well.

Table 4.4. Pipet Value Survey EFA Results

	Utility	Cost	Interest	Attainment
Understanding how to pipet has many benefits for me (U1)	0.778			
It will be beneficial for me to know how to use a pipet (U2)	0.775			
Using a pipet will be an important skill to have for the future (U3)	0.766			
Knowing how to pipet will help me reach my goals (U4)	0.744			
Knowing how to pipet will be useful to me after graduation (U5)	0.636			
Knowing how to pipet will help me succeed in future courses (U6)	0.588			
I felt tense while using a pipet (C1)		0.866		
Using a pipet causes me anxiety (C2)		0.764		
I was relaxed while using a pipet (C3)		0.723		
I would describe using a pipet as low-stress (C4)		0.683		
I had to try harder at using a pipet than other techniques (C5)		0.582		
Using a pipet takes too much time (C6)		0.321		
I would describe using a pipet as interesting (I1)			0.744	
I enjoyed using a pipet (I2)			0.603	
I would enjoy learning more ways to use a pipet (I3)	0.368		0.542	
I think using a pipet is not fun.(I4)			0.461	
Even if pipetting is not useful to me I want to be good at it (A1)				0.655
I am disappointed if I use a pipet incorrectly (A2)				0.578
I want to be better than my peers at using a pipet (A3)				0.49

The variance explained by each factor was 18.6%, 15.4%, 9.5%, and 7.4% respectively with 51.2% of the total variance explained by the factor model.

For the buret badge, 308 responses were used for EFA. The EFA for the buret survey including all 27 items initially produced a factor structure with many crossloadings. Since the factor analysis for the pipet instrument had been carried out previously, we used the results as a guide to refine the buret instrument. There were many similar items between the two instruments. Some items were the same, while others had slight changes to the wording. Items from the buret instrument that did not have a corresponding item in the pipet survey were removed. This was done to keep the items consistent between the two surveys to ensure that we were measuring the same constructs. This resulted in a buret survey with 17 items as, four in utility, five in cost, four in interest, and four in attainment. There were three items in the pipet instrument that did not have a corresponding item in the buret instrument. In addition, there was one item, “I feel that I must succeed at using a buret” that performed well in the buret survey and that we felt represented the attainment construct well but was not used in the pipet survey. The item had strong factor loadings and since attainment was the weakest factor in the pipet survey, we decided to include it in the buret value instrument. The factor structure based on the EFA for the buret survey is shown in Table 4.5 and details of the EFA are shown in Appendix C. The model explained 55.8% of the total variance and the factor loadings for each item were fairly strong with most loadings above .5. This indicates the items represent their intended constructs well.

Table 4.5 Buret Value Survey EFA Results

	Utility	Cost	Interest	Attainment
Using a buret will be an important skill to have for the future	0.773			
After I graduate, understanding how to use a buret will be useful to me	0.660			
Understanding how to use a buret has many benefits for me	0.647			0.317
I believe being able to use a buret will help me succeed in future courses	0.518			0.385
I would describe using a buret as low-stress		0.803		
I was relaxed while using a buret		0.750		
I am not anxious about using a buret		0.658		
Using a buret did not take more effort than other techniques		0.602		
Using a buret takes too much time		0.340		
I think using a buret is fun			0.740	
I would describe using a buret as interesting			0.614	0.331
I enjoyed using a buret		0.358	0.600	
I would enjoy learning more ways to use a buret	0.431		0.600	0.339
Even if using a buret is not useful to me I want to be good at it				0.670
I feel like I must succeed at using a buret				0.645
I am disappointed if I use a buret incorrectly				0.551
I want to be better than my peers at using a buret				0.505

4.3.3 Confirmatory Factor Analysis

In order to test the how well the proposed model from the EFA fit the data, CFA was used. For the CFA procedure, the second half of each dataset was used. After cleaning the data for univariate and multivariate outliers, there were 363 responses used for the pipet survey analysis and 283 responses for the buret survey. The CFA was performed using the LISREL 8.80 statistical program. To determine the adequacy of the model, several goodness of fit indicators are used. In theory, the chi square test should be non-significant to indicate that the model does not differ significantly from a perfect model. In practice, however with large data sets, the chi square statistic is usually significant (Brown, 2006). The root mean square error of approximation ranges is one measure of how well the model fits the data. The larger the RMSEA, the greater the difference between a perfect model and your approximated model. Values below .08 are considered to be acceptable and values below .05 are considered to be a very good fit (Brown, 2006). The comparative fit index (CFI), incremental fit index (IFI), and goodness of fit index (GFI) are all measures of fit based on a scale from 0 to 1 with 1 representing a perfect fit between the data and the model. If these indices are above .90, it is considered acceptable, above .95 is good, and above .98 is excellent (Levesque, Zuehlke, Stanek, & Ryan, 2004).

The CFA for the pipet data showed the initial model was acceptable. The loadings for each individual item were significant. The chi square was significant ($\chi^2 = 461.4$, df = 146, $p < .001$) however the RMSEA was .081, the CFI and IFI were both .95, and the GFI was .88. The RMSEA and GFI were both slightly outside of the acceptable range. To improve the model fit, a correlated error was added between items C3 and C4. These items asked about feeling stress and feeling relaxed while pipetting so it is reasonable that there would be some correlation between these terms. With the correlated error, the model fit improved. The chi square was still significant, (χ^2 = 401.07, df = 145, p <.001) however the RMSEA improved to .07, the CFI and IFI both improved to .96 and the GFI improved to .89 which is closer to the cutoff of .90. All together this model provides an adequate to good fit with the data. Further modifications to the model were not made because they did not significantly improve the fit. The model and LISREL output are provided in Appendix D.

For the buret survey data, the initial CFA showed that the model was acceptable and that there were no modifications that would significantly improve the fit. The RMSEA was .076 (below .08 is accepted), the CFI and IFI were both .97 and the GFI was .89 which is close to the target of .90 or above. The chi square was significant, (X^2 = 313.49 (113), p <.001) which is to be expected with large data sets (Brown, 2006). In the standardized solution, the factor loadings for most items were above .7 indicating that they represented the constructs well. All together this model provides an adequate to good fit with the data. The model and LISREL output are provided in Appendix D.

4.4 Validity and Reliability

The internal consistency of each of the factors was calculated using Cronbach's Alpha. This is used as a measure of reliability of a scale. An alpha value of 0.7 or greater suggests good internal consistency (Tabachnick & Fidell, 2001). For each subscale in the value instrument, the Cronbach's alpha measure of reliability was adequate to high for three of the scales and slightly lower for attainment, which was the smallest subscale: utility α= .85 cost α= .82, interest α= .78, and attainment α= .65. The attainment subscale was the most difficult to define leading to the smallest number of items and therefore a lower Cronbach's alpha. In the buret survey, the Cronbach's alpha was also adequate to high for each subscale: utility α= .85, cost α= .79, interest α= .89, and attainment α= .76. Reliability was also demonstrated by the use of the same or similar items in both instruments. The value instrument was given at two different times with two different laboratory techniques and the same factor structure was obtained for each survey.

To determine whether students were interpreting the items in the pipet value instrument as intended, two student interviews were conducted. Students were asked to read the survey items and provide their response as well as explain what they thought the question meant and the things they thought about when responding. The interviews showed students were interpreting the items as intended. Their responses also provided further evidence for the crossloading seen in “I would enjoy learning more ways to use a pipet” on interest and utility as students discussed possible applications to other courses as well as general enjoyment of using the equipment. The student responses serve as a measure of validity for the instrument, showing that it is measuring the constructs that it was intended to measure in the population in which it was implemented. Since the items for the buret were so closely related to the pipet, and the factor analysis produced a similar model, interviews were not conducted with the buret survey.

CHAPTER 5. QUALITATIVE STUDY

5.1 Theoretical Framework

The theoretical framework guiding this research project is expectancy-value theory. According to expectancy-value theory a student's motivation to complete a task is dependent on their efficacy beliefs regarding how successful they believe they will be as well as how much value they place on the particular task. As described in previous chapters, this expectancy is closely related to self-efficacy and value is comprised of the four constructs, interest, cost, utility, and attainment (Wigfield, 1994; Wigfield & Eccles, 2000). This framework allows for examination of the various experiences, beliefs, interests, and goals that students have when they take an introductory chemistry course and the impact of all of these factors on student motivation in the laboratory.

5.2 Methodological Framework

This research was conducted using a sequential explanatory design. This is a type of mixed methods research that uses quantitative methods first in order to inform the qualitative part of the study (Creswell, 2009). For this study, the PPI and value surveys were implemented first to determine variation in the factors that may influence student motivation. This allowed for purposeful sampling of students for interviews in the qualitative phase of the study. Qualitative interviews were then conducted to determine how students with varying levels or types of motivation think about badges in the laboratory.

5.3 Participants and Setting

Students were recruited for interviews from the pool of students who completed both the PPI and the value survey for the pipet badge with usable data. Cluster analysis was used to determine groups of students with varying motivation to learn laboratory techniques. Cluster analysis is a technique which uses various algorithms to group similar individuals based on their responses to questions. For this analysis, hierarchical cluster analysis was used, which begins with all of the individuals each as their own cluster. It then combines clusters in a nearest neighbor fashion, ending when there is only one large cluster. Clusters are combined to minimize the error sum of squares in each cluster. Specifically for this analysis, Ward’s method with a squared Euclidean distance was used. In cluster analysis, the user can specify the number of clusters that they would like to use (Lewis, 2017) (Ye, Oueini, Dickerson, & Lewis, 2015).

Cluster analysis was conducted on the pipet value survey results and the pipet PPI post survey results separately. For the cluster analysis, means for each factor (knowledge, confidence, experience) in the PPI and value surveys (cost, utility, attainment, interest) were used. For each analysis, a five-cluster solution was examined first. With a reduction to four clusters it was found that the clusters that were combined were not discernably different. The same was true for a reduction to three clusters. Reducing the data to only two clusters mean combining two distinct clusters with a loss of data so a three-cluster solution was determined to be the most meaningful. The cluster analysis results are shown in Table 5.1 and Table 5.2.

Table 5.1 Cluster analysis of the pipet PPI survey results

Cluster	Knowledge	Confidence	Experience
High (378)	4.97	4.97	4.95
Med (207)	4.58	4.53	4.22
Low (300)	3.95	3.92	3.56

Table 5.2 Cluster analysis results from the pipet value instrument

Cluster	Utility	Cost	Attainment	Interest
High (266)	4.09	4.09	4.06	4.01
Med (128)	3.73	2.98	3.91	3.37
Low (292)	3.16	3.68	3.29	3.17

Once the clusters were determined, students were identified who had been included in both the PPI and value survey analyses. For the analysis, we decided to focus on the students who were in the high or low groups of the PPI (expectancy) or value surveys, as they represented more potentially interesting cases. Arranging these students in a matrix, there are four groups of students as shown in Table 5.3.

Table 5.3 Groups of students for interviews based on cluster analysis

	High Value	**Low Value**
High Expectancy	73	44
Low Expectancy	15	56

Students were recruited for interviews one to two months after they had completed the badges. We initially started with a target of four students from each group. Students were contacted by email according to the procedure outlined in the IRB protocol. Unfortunately there were very few students in the high value low expectancy group, and none of them responded to the request for an interview. After exhausting the list of students who fell into one of the defined groups, an email invitation was extended to students who either fell in the high or low value group, which now included students in the middle expectancy group. Through this process we were able to obtain more interview participants. The final breakdown of the interview participants is shown in Table 5.4 and the survey results for the interview participants are shown in Table 5.5. We recruited 18 students to participate in interviews. Two students responded from the middle expectancy group. These students were interviewed to help determine the validity of the value survey.

Table 5.4 List of interview participants based on grouping from cluster analysis

Group	Number of Students
High Expectancy High Value	6
Low Expectancy Low Value	5
High Expectancy Low Value	6
Middle Expectancy Low Value	2

Table 5.5 PPI Post Survey and Value Survey Results for Interview Participants

	PPI Post Data			Value Instrument Data			
	Knowledge	**Confidence**	**Experience**	**Utility**	**Cost**	**Attainment**	**Interest**
LELV							
Janet	4	4	4	3.33	3	3	3
Olivia	4	4	4	2.67	3.83	4	2.5
Jack	4	4	4	1.67	3.83	4.33	4
Madison	3.71	3.43	3.57	3.67	2.67	3.33	2.5
Susan	4	4	4	3	4.5	2.67	2.75
HELV							
Kate	5	5	5	3	3.33	3	3.25
Annie	5	5	5	1.17	3.83	3.67	3.5
Sophie	5	5	5	3	4.33	4	3
Kevin	5	5	5	2.17	4.17	3	1.75
Caroline	5	5	5	2.5	3.83	4	2.5
Faith	4.86	5	4.86	2	4	4	3.75
HEHV							
Kyle	5	4.71	4.71	4.83	3.17	4	3.75
Randall	5	5	5	4.17	4.5	4.67	4.25
Tess	5	5	5	5	4.83	4.67	4.75
Chrissy	5	5	5	4.67	4	5	5
Charlotte	4.86	4.86	4.71	4.67	4.5	4.67	4.75
Beth	5	5	5	4.67	4.83	5	4.5
Shelly	5	5	5	4.83	4.83	4.33	4.75

5.4 Interviews

The participants were interviewed using a semi-structured interview protocol (Appendix E) to help answer the following research questions presented previously.

- To what extent can differences in student motivation to learn laboratory techniques be detected by using participant perception indicator (PPI) and value survey instruments?
- How do students with varying types of motivation to learn laboratory techniques perceive digital badges?

The protocol was based on expectancy value theory and self-efficacy themes and was designed to elaborate on the survey responses from the PPI and value surveys for the pipet badge. This was done because the interview participants were classified into groups based on their survey responses. In order to characterize the differences seen in the quantitative data in a qualitative way, the interview protocol was designed to get students to elaborate on the same themes that were present in the surveys. The interview protocol also asks about the students' opinions about digital badges and their role in learning lab techniques. The interviews lasted between sixteen and forty minutes. The audio recordings were transcribed by a professional transcription service and the transcripts were checked for accuracy by members of the research team.

5.5 Data Analysis

The data was coded using a deductive coding scheme with the initial codes comprised of the categories of expectancy and value used in the survey instruments and a more general code for any statements related to students' thoughts about badges. Examples of how the coding scheme was applied are shown in Table 5.6.

Table 5.6 Examples of the application of the coding scheme

Code	Generic Example Statement
Knowledge	I know how to use a pipet Lists steps in proper pipet technique
Confidence	My confidence increased over the semester I was already confident before the badge
Experience	My high school had no laboratory courses I took 4 semesters of high school chemistry with lab
Interest	Learning how to use new lab equipment is really cool
Utility	I plan to work in research in the future I am never going to use this in my business major
Attainment	I am a perfectionist I like doing things correctly
Cost	Redoing techniques over takes too much time. It was scary having to pipet in front of the group for the first time
Badges	I thought of badges as just another assignment for points It was fun to get a badge. I told my mom about it

Once the interviews were coded, the students' utterances were summarized by code to generate an overview of how each student thought about the different components of both expectancy and value. Once the students' thoughts had been summarized individually, each code was examined by group to determine the ways that each group talked about the expectancy and value themes. The themes that were found for each group are presented in the next chapter. Once this was done, the groups were compared with each other for each expectancy and value theme to see how the differences shown in the quantitative cluster analysis were reflected in the qualitative data.

To analyze students' utterances about badges, the statements that were coded for badging were gathered, summarized, and interpreted to reflect themes in the students' quotes. Students' comments about badges in general were analyzed by group to see if students' expectancy or value beliefs were related to their thoughts about badging. The students were also characterized as having a positive or negative attitude towards badging and those students' responses to the expectancy and value themes were compared to determine which features of a student's attitude or motivation contribute to their thoughts about the badge assignment.

5.6 Validity and Reliability

The study design contributes to the validity and reliability of this study allowing for triangulation between the quantitative and qualitative data. Results of the interviews and the surveys can be compared to ensure that the responses are similar between the two measures across the same student. The interview prompts were developed based on the survey items and similar questions that had been used in the literature (Abramovich et al., 2013; Luttrell et al., 2010). This lends content validity to the interview protocol and ensures that the intended constructs are being targeted according to our theoretical frameworks. During the analysis, other chemistry education graduate students were consulted to ensure interrater reliability. Two other graduate students were given a list of 20 representative quotes chosen from across all codes from multiple students along with the coding guide in Appendix F. This was done because many of the students had similar responses to the interview prompts so a few representative quotes could encompass a large portion of the data for each code. Quotes were chosen that represented multiple codes or that were potentially difficult to code. This allowed for refinement of the codebook and ensured that coding and interpretation of the data was done in a way that made sense and was consistent with the published definitions of the codes. After a first pass of the coding across three coders, there was 80% agreement with a Krippendorff's alpha value of 0.80. This constitutes fairly good agreement as a minimum value of 0.80 for Krippendorff's alpha is accepted. After discussion and revision of the coding scheme, we were able to achieve 95% agreement and a Krippendorff's alpha value of 0.96. This indicated that the coding scheme was applied consistently throughout the data and helped minimize and correct for any researcher bias that occurred during initial coding.

CHAPTER 6. ANALYSIS OF STUDENT INTERVIEWS

6.1 Introduction

At the end of the fall 2017 semester, student interviews were conducted with 18 students over the course of two weeks. The students were selected according to the procedures detailed in Chapter 5 and were all students in CHM 111 during the Fall 2017 semester. The purpose of the interviews was to provide depth and meaning to the quantitative survey results as well as to see if the quantitative differences between the groups generated by the cluster analysis were also reflected meaningfully in a qualitative way. The interview protocol was based on the themes of both expectancy and value as defined in the PPI and value survey instruments. The interview data was analyzed according to the procedure outlined in Chapter 5. The interviews were coded according to the coding scheme in Appendix F. The codes used were based on the themes from the two survey instruments. No new codes were added during analysis. Data was compared across participants within groups and across groups to determine similarities and differences between groups. Students' ideas about badges were also compared across groups. This chapter will examine the similarities and differences between the three groups that were examined: high expectancy high value (HEHV), high expectancy low value (HELV), and low expectancy low value (LELV).

6.2 Student Expectancies

Student expectancies were compared across the three groups of interview participants. As shown in the cluster analysis results in Tables 5.2 and 5.5 there was a ceiling effect in the post surveys for students' expectancies. A summary of the findings is shown in Table 6.1 with a comparison between groups of students' responses to the knowledge, confidence, and experience interview prompts. Since all of the groups had an average of over 3 out of 5 on the Likert-scale survey, results across groups tended to be fairly similar. The largest difference between high expectancy and low expectancy groups was seen in the students' knowledge, while the student responses were more similar for confidence and experience. With regards to students' expectancies, we did not see an interaction with their value beliefs. This could be partly due to the fact that there was limited variation in student responses across groups. It is also more likely that students' ability beliefs influence their value beliefs and not the other way around so any interactions between the two will most likely manifest in the value portion of the interviews (Eccles & Wigfield, 1995).

Table 6.1 Summary of the similarities and differences in expectancy beliefs between student groups across for knowledge, confidence, and experience. Similarities are shown on the left, differences on the right.

Knowledge

Similarities	Differences
• Many students did not mention having liquid left after dispensing liquid • Students said to put the bulb on the pipet and then squeeze the air out • At least one student in each group did not mention meniscus	LELV • Used vague terminology. • Confused words like calibration line, meniscus • Said practicing helped them learn techniques
	HELV • TA demonstrations helped them learn how to use techniques
	HEHV • TA demonstrations and lab manual helped them learn techniques

Table 6.1, continued

Confidence

Similarities	Differences
• All were not confident before the badge • All were now very confident – 8 or 9 out of 10 • Badge helped them learn how to do it • Feedback and practicing for badge increased confidence the most	LELV None
	HELV None
	HEHV None

Experience

Similarities	Differences
• Took some high school chemistry • No experience with pipets before CHM 111 • Now has a good amount of experience with pipets • Experience came mostly from using the pipet in multiple labs	LELV None
	HELV • One person had used pipets before in CHM 115
	HEHV • One person had used pipets before in AP chem

6.2.1 Knowledge

In terms of knowledge about pipetting, we focused on students' ability to accurately remember the steps involved in properly using a pipet as well as the features of the course that students believed helped them learn how to pipet most effectively. Three out of eighteen students correctly explained how to use a pipet including all of the steps that they were required to show in their video. Two of these students were in the HELV group and one was in the LELV group. The most common mistake was to not mention that there would be liquid left in the tip of the pipet, even with extra prompting to think about what happens when the liquid is dispensed. Another common error was to say that the bulb should be attached to the pipet before it is collapsed. This error was made by students in all three groups. Students in the LELV group were the most likely to forget to mention the meniscus and calibration line, though they could usually do so after prompting. They were also most likely to use vague terms when talking about the level of the liquid such as "when the line passes 10mL" or "squeeze until the meniscus line". Students in the high expectancy groups were able to use more specific terminology like "make sure the bottom of the meniscus touches the line". In general, similar mistakes were made across all three groups of students however group of students in the LELV group were less accurate and confident with their use of terminology than the students in the higher expectancy groups.

The features of the course that students cited as helping them learn the most were TA demonstrations, reading the instructions and lab manual, and practicing and filming the videos. There was a difference across groups in which of these strategies were mentioned. The HEHV students were least likely to mention specific things that helped them learn, though they talked mostly about looking in the lab manual and seeing TA demonstrations. The HELV group most frequently cited TA demonstrations as being the most helpful and some talked about making the videos and practicing. When asked about what helped her learn the most Sophie said, "Having someone show me and explain it as I'm doing it even was very helpful." In the LELV group, nearly all students mentioned that doing the badge and getting to practice the techniques in lab experiments is what helped them learn the best and only a couple of students cited TA demonstrations as being helpful. Olivia said, "I'm more hands on with everything so I liked practicing and watching all the liquid go up and go down and try to adjust it." Students with high expectancy were more likely to talk about how the TA helped them learn than students with low expectancy. It is unclear if the students in the low expectancy group did not ask for help from or pay attention to their TA or if their TA did a less thorough demonstration than other TAs. Students with lower expectancy may not have an appreciation for how helpful watching a TA can be for their learning. It is also possible that since these data were collected from post-surveys, the students who had lower expectancies could have been less knowledgeable or confident in their abilities because of their lack of engagement with their TA.

6.2.2 Confidence

The confidence portion of the interview focused on students' confidence both before and after the badges. There was no difference between the groups in how they talked about confidence. All students said they were not very confident before doing the badges and then after doing the badges and multiple laboratories with pipets they are now very confident. Most students rated their confidence as an eight or nine out of ten after having done the badges and labs regardless of whether they were in the high or low expectancy group. As Susan from the low expectancy group said, "Before I wasn't really confident, I guess I didn't really know how to use it. I was just kind of figuring it out, but after a while I was pretty confident. I did pretty good after the fact. Like I remembered everything after that first lab." From the high expectancy group Caroline said about her confidence before the badges, "Not very confident. I wasn't confident at all. I knew what it was but I wouldn't have done it by myself." Then about her confidence after the badge, "I'm pretty confident I think. Yeah I can do it now for sure by myself so I'm very confident." Since their answers were so similar, the discrepancy in their survey scores could be due to some students' interpretations of the Likert scale or due to the fact that the interviews were conducted weeks after the surveys were taken, during which time the students had more opportunities to use the glassware and increase their confidence in the lab.

6.2.3 Experience

Similarly to confidence, the experience interview prompts focused on students' experience in lab and using pipets both before and after the badge exercise. Since CHM 111 is a course designed for non-science majors, the majority of the students came into the course with minimal experience in chemistry. Most had only taken one year of chemistry with a few labs. One student in the HELV group had taken CHM 115 previously and was the only student with significant experience using volumetric pipets. Most students did not have any experience using pipets even if they had previous lab experience. Since the interviews were done at the end of the semester, all students reported having more experience with pipets and they all felt very comfortable with pipetting. There was no difference in reported experience across the three groups of students.

6.3 Student Values

Students' value beliefs about pipetting were initially measured using the value instrument detailed in Chapter 4. During the student interviews, questions about the four themes of value (utility, cost, interest, and attainment) were designed to probe deeper into how students were thinking about each of these constructs and what impact each construct had on total motivation. We also wanted to get a sense of any additional factors students were considering in relation to the different value constructs. The purpose of the interviews was to determine the factors that influence student motivation and how those may interact with student thoughts about badges as well as to see if the differences shown in the quantitative data could be reflected qualitatively. A summary of the similarities and differences for each group is shown in Table 6.2.

Table 6.2 Summary of the similarities and differences between student groups across the value constructs: cost, interest, attainment, and utility

Cost

Similarities	Differences
• Everyone mentioned time • Didn't want to redo things	LELV • Mentioned being nervous about chemistry – or nervous about using equipment and not breaking it
	HELV • Useful to have specific guidelines • Talked about specific parts of technique – bulb meniscus
	HEHV • Useful to have specific guidelines • Talk about specific parts of technique – bulb meniscus

Interest

Similarities	Differences
• All mentioned connecting lecture to lab – most prevalent in LELV • All mentioned lab being applicable to other contexts in daily life – most prevalent in HEHV • Like learning lab techniques • Like "hands on" activities • Liked learning new things • Liked visual aspect and seeing things happen/mixing things	LELV • Connect lecture to lab most frequently • Mentioned liking things that were easy
	HELV • Liked things at were easy or that they understood
	HEHV • Connect lab to applications most frequently • Had the most variety of examples for connecting lab to the real world e.g. research, articles, major

Table 6.2, continued

Attainment

Similarities	Differences
• 2 people in each group mentioned being a perfectionist	LELV • Wanted to do things correctly for grade
	HELV • Wanted to do things correctly for grade
	HEHV • Didn't mention grade in the lab • Wanted to get good data or results • More people mentioned wanting to know things for personal knowledge • Said knowing how to do things is important other than for a grade

Utility

Similarities	Differences
• Almost everyone will not use chem again. • At least one person in each group said they will use chem again • All mentioned knowing thigs for exams and HW • One person in each group mentioned research	LELV • Focus on Grades • Exams and HW most prevelant – cared about things that would help them in the course. • Didn't look beyond the course
	HELV • Focus on Grades • Mentioned techniques help them get out of lab quickly
	HEHV • Least mention of grades • Important to know things for exams • Important to know things for soft skills

6.3.1 Cost

Prompts related to cost in the interview focused on the challenges students faced regarding time, effort, or stress while completing laboratory techniques. The biggest factor that students mentioned in relation to cost was time. Across all three groups students consistently mentioned that getting out of lab quickly and avoiding having to redo measurements were their biggest concerns in lab. As Chrissy explained, “We were more focused on just getting out of there in the time that we had instead of doing it right.” Students said that it was important to know how to use lab techniques properly so that they would not have to redo lab procedures and so they could get out of lab faster. As Kate explained, “Being able to do it right the first time to preserve time, If you have to do it twice, then that takes up more lab time and that takes up more of your time.” These results are consistent with previous work done on student goals for laboratory courses (DeKorver & Towns, 2015). For these students the idea that getting a badge will help them make fewer mistakes and save time is a potential way to increase their motivation to earn badges.

The LELV group mentioned being nervous about chemistry and afraid to break things more frequently than the other two groups of students. Olivia, a junior, said that she took chemistry later than most people. “I put it off because I was really nervous. I didn’t do too hot in chemistry in high school.” When asked about learning new lab techniques Madison said, “It’s stressful because I’m always worried that I’m not gonna do it correctly.” Jack mentioned not knowing lab techniques but not wanting to break things, “I knew the glassware was expensive coming in, so I was like, I will be very cautious with the glass.” Since the LELV and the HELV students both had similar value scores, it is possible that this fear comes from an interaction between expectancy and value. The lower knowledge and confidence of the LELV students regarding using the glassware contributes to an added stress and increased cost of working in the lab. The HELV students who reported being more confident and knowledgeable did not talk about fear of breaking things or being nervous about not doing well in chemistry.

Both of the high expectancy groups, HELV and HEHV, discussed that the detailed instructions and extra time spent by the TAs on pipetting during the badge project helped reduce the time and effort it took to learn how to pipet. This relates to the knowledge themes where students in the high expectancy groups reported that they used their TA, rubrics, and the lab manual more than students in the low expectancy group. Students not only used these resources to help them learn, but also felt it made learning how to pipet much easier. Shelly mentioned talking with her lab partner and using the lab manual to learn to pipet. "I feel like you guys made it pretty easy if you need to learn something, to know it." Annie cited her TA's help. "It was pretty easy… I mean my TA did a really good job of explaining it and showing us how to use it, so I mean I didn't think it was too hard."

The final difference between the high expectancy students and the low expectancy students was that the high expectancy students, when asked about challenges related to pipetting, were more likely to cite a specific step in using the glassware. For example, students said that getting the meniscus to the line was the hardest part. Annie said, "I guess the hardest part was like trying to find a bulb that actually suctions the stuff up… also like practicing getting the meniscus at the line. It was hard." Beth had problems with air bubbles. "It's just the bubbles are always a bad thing. So that's what I get frustrated with, when that happens because then you're like 'okay, now you have to redo it… just restart the entire process.'" This is also consistent with the knowledge themes. When asked to describe how to use a pipet, the high expectancy students used more scientific and specific terminology. Because they have that vocabulary and that specific memory of the steps they were more able to recall specific parts of pipetting that were challenging for them.

6.3.2 Interest

Interest was discussed similarly across all three of the groups. Across all groups, participants mentioned liking lab techniques because they were learning something new. They liked doing new things each week and using glassware that they hadn't seen before. All groups also said that they were interested in lab because of the hands-on aspect of the labs. They also liked labs where they could mix things and see what was happening. Students appreciated most the labs that had visual aspects to them – multiple students discussed liking the lab where they tested reactivity by mixing solutions and observing color changes or precipitate formation.

One difference was that in the low value groups, students more frequently said they were most interested in lab when it was easy, a phenomenon seen in other studies as well (Eccles & Wigfield, 1995). Their favorite labs were the ones that were easy to complete and understand. As Madison explained, "I liked the titration ones… it was just easy enough or me to do without being super stressed out about it and it was just easy to do with my partner." Sophie appreciated the chemical interactions lab because, "I love it when you don't have to write a ton of stuff and I can just fill out a chart… puzzles like that I enjoy a lot more than just having a ton of math to do." In contrast, the high value students did not discuss easy labs as being more fun. Also, while both groups of students mentioned enjoying labs that had some connection to what they had learned in lecture, the high value students were able to go beyond that and make more connections. While the students in the LELV group especially only discussed finding interest in connecting lab to lecture, the HEHV students mentioned finding value in connecting lab to daily life, research, or even articles that they had read. As Randall said, "I think it's really cool and I think it's important for my major specifically. I don't think I'll be using some of the techniques… but I think it's important because it allows you to understand the background behind some of the research in some sciences and it's just really cool for me to see." Kyle was able to connect the labs to his major, "They are very fascinating … I really love doing experiments like, especially the extraction of fat and also like just the alcohol percentage of wine because my major is specifically toward food."

6.3.3 Attainment

Attainment themes in the interview data were challenging to identify because in some ways they were conflated with utility themes. Attainment in this context is defined as a student valuing a task or piece of knowledge for its own sake, not because it will have any practical use for the student. High attainment is associated with the idea that having knowledge, or being skilled at something is tied to a student's identity and is important regardless of any other benefits it may provide for a student. The most obvious manifestation of this is when a student self-identifies as a perfectionist. Among the interview participants, two students from each of the groups stated that they were a perfectionist during the interview when asked about the importance of doing things correctly in lab. Jack said, "One I would say a fault about me is I'm a perfectionist so if I have to give a big presentation for class not only do I want us to perform well, I want the presentation to look well. So for chemistry I want to do the technique correctly, I don't want to say to feed my ego, by any means, but just so that I know like hey I'm grasping what they're trying to teach." Beth also said "I'm almost sort of a perfectionist in the sense of if it doesn't go right, then I actually get kind of triggered." In the high value group, students were more likely to discuss wanting to learn things for personal knowledge. Students in the high value group also said that it was important to know how to do things correctly without a reason. Shelly said, “I have the thinking, you are in class anyways so you might as well learn it. You know you could use it sometime somewhere. I guess that would be for me to know what you are doing in general.” Beth also talked about liking learning things for her own sake. “It’s building my knowledge and making me feel smarter. I like doing that. I think that’s kind of cool. That’s the only cool part about lab, no offense.” In contrast students in the low value group related the importance of doing well to external factors. As Janet explained the importance of doing things correctly, “Just kind of important so you know how to do it. It’s important but for what I want to do it’s not that important.”

To elicit beliefs about attainment values, students were asked about the importance of doing things correctly in the lab. Nearly every student answered this question with some external reason for doing things correctly. Even students who said they wanted to do everything correctly because he or she was a perfectionist also mentioned some other practical reason for doing well. In response to the question about the importance of doing things correctly Beth said, “It’s extremely important to me. I’m kind of on that nerdy side. I’m almost sort of a perfectionist in the sense of if it doesn’t go right then I actually get kind of triggered.” She also explains about her goals in lab, “I’m here for the accurate results so if we’re going to fly through this, I got to make sure I’m accurate.” One difference that was seen between the high value and low value groups was how these external factors were framed. In the low value groups the students discussed wanting to do things well because it would get them a good grade in the course. In the high value group, the students talked about doing things well because it would get them good data or good results as Beth did. Kyle also said, “Very sort of like quite important. Because I know if you do something incorrectly for the lab you will actually ruin the whole results." In contrast Annie answered the same question, "Well I just want to like make sure that we're doing the procedure correctly cause we don't want to have to redo it and so that we get accurate information so we can fill out our lab manual correctly 'cause I do want to get a good grade." It is possible that the high value students also thought that getting good data would then lead to good grades on lab reports, but the low value students focused specifically on the tangible end result of grades while the high value students talked in terms of good data without specifically mentioning grades. It is possible they were focused more on the process than the tangible, external reward of a grade.

6.3.4 Utility

Utility refers to the usefulness of a skill or some knowledge in helping a student achieve a short- or long-term goal. Because this study was conducted in a first semester introductory chemistry course for non-science majors, the majority of the students would not have to use any chemistry skills or knowledge for the future. This course simply fulfilled a plan of study requirement. Across all three groups the majority of students said they would not need to use chemistry again for their major or career. At least one student in each group however, did mention the possibility of using chemistry in the future either in future coursework, a potential career, or research with a professor. Students across all groups also mentioned that it was useful to know how to do techniques in lab because lab questions often showed up on homework or exams. This may be related to the fact that students across all groups also enjoyed the labs most that related lecture to lab content.

In the LELV group, students were most focused on the fact that knowing how to use lab techniques would benefit them in the course so that they could get good grades. They did not mention goals or benefits outside of the course. As Jack explained how useful lab skills would be for him, “On a general level for this course, I would say very important because your knowledge will be tested over it. For post-graduation for me it’s not so important.” Olivia stated, “I mean, I want the A, so it’s pretty important but it’s not always at the top of my priority list.” In the HELV group, the students primarily mentioned knowing how to use the techniques so that they could get out of lab more quickly a theme that that has been seen previously in research on student laboratory goals (DeKorver & Towns, 2015). It is possible that since the LELV students were more worried in general about not performing well in chemistry that they were more focused on doing as well as they could in the course. Since the HELV students had more confidence and knowledge and were not as worried about their performance, the goal of getting out of lab quickly took precedence.

The biggest distinction in utility values was between the high value group and the other groups. In the high value group students mentioned the utility of learning laboratory skills and completing the badge exercise in terms of soft skills not directly related to chemistry. Students talked about learning how to follow instructions and going through the process of learning new skills that will benefit them in the future. They also talked about the skill of being able to explain and demonstrate techniques as being useful in their future courses or careers. As Randall explained, “The specific equipment skills? I don’t think so. But I think I can use some of the presentation skills or stuff. Explaining like, ‘this is how you do this’. Sure, I can see myself doing that, but because of my major, I don’t think I’ll have to worry about pipetting anytime soon.” Shelly also said, “I might not be pipetting myself, but … learning those techniques, the whole process of learning a technique and being able to be proficient at it is something that I will need definitely." None of the students in the low value groups mentioned these soft skills. This distinction is important in helping to motivate students. Since students who have higher value beliefs tend to be more motivated to accomplish tasks, it is important for students to be able to find utility in the tasks they are learning. The HEHV students said they would not use chemistry again, just like students in the other groups, but they were still able to find some usefulness for what they were learning outside of its obvious academic context.

6.4 Student Beliefs about Badges

As part of the interview procedure, students were asked about their thoughts on the badge assignment and how they felt about the idea of digital badges in both chemistry and other contexts. This section will detail students' general impressions about the badging assignment as well as how their responses to other interview prompts relate to their impressions of digital badges. One thing to note is that while the expectancy and value surveys and interview prompts were all centered around the pipet badge, the questions about badges often led the students to bring up their experience with all three badges (pipet, buret, and volumetric flask) that had been done during the semester since these interviews were completed towards the end of the semester.

6.4.1 Student Reflections on Digital Badges

In general, strong trends did not emerge regarding students' impressions of badges based on their expectancy and value groups. The HEHV group did have a slightly higher number of students respond positively to the badges than in the other two groups however. Since there was not strong enough evidence to find themes within each group, this section will focus on general trends and impressions that emerged across all students with regards to the badge assignment.

The first theme that was discussed in the interviews centered around practical concerns of the badge assignment such as the timing of the badge and using the Passport program. Multiple students were concerned about the time it took to complete a badge and the badges fitting into the lab curriculum. For some of the badges students felt rushed as they tried to finish the lab procedure and the badge. As Chrissy noted, "I think the badges were kind of a nuisance. … Basically you write a script down on our paper and you rehearse it in your mind so you're not as focused on the lab that day when you have a badge to do. Because you're more focused on making this video and not messing up and making sure you seem intelligent and stuff like that." A few students also mentioned having issues using the Passport app, especially from their phone, but none of the students said that it was a major concern or made them not want to complete the badges.

Another major practical concern that students mentioned was the timing of the badge assignment. Many students said that they would have appreciated having the badges before the lab where they needed to use the technique. As Olivia said about the buret badge, "Just knowing that is going to help me for next week's lab makes me more interested in it than if I have to do the lab and then do the buret [badge]… I feel like the buret should be learned before the lab so we know what we're doing while we do the lab." She and other students discussed that doing the badges before the lab that they would need the technique for would be beneficial in terms of having the knowledge and feedback ahead of time, as well as saving time by putting the badges at the end of the shorter lab experiments. This is a consideration for future implementations of the badge assignment. Giving students time to complete the badges before they need the technique on days where the lab does not take the full lab period can relieve time constraints on some of the longer labs and give students more practice with the equipment before they need to use it in a lab procedure.

In terms of how students thought about techniques with badges in comparison to lab techniques that did not have a badge, many students said that having to practice the techniques in order to earn the badge was valuable in helping them learn the technique. Many students also discussed that having the badges made them care about the technique more. As Madison says, “I thought about it a little bit differently because I had to directly outline, step-by-step what I was doing rather than just doing it.” Similar to this, many students also cited the benefit of having more instruction for badge techniques than for other techniques. Several students noted that having detailed guidelines and a rubric was helpful to know what to do and what not to do. Other students talked about the fact that their TA spent more time going over the techniques for the badges. Kate explains, “So I feel like the pipet, I felt more confident… Our TA really took the time to walk us through it and he said, ‘You guys are gonna be fine. I just have to grade these videos so I want to make sure that you’re doing it right. I want to teach you the right way.’”

Students were also asked about the meaning of a badge. Many students’ initial response was that the badge did not mean anything to them beyond a grade, which is consistent with students’ focus on getting good grades in laboratory courses (DeKorver & Towns, 2015). When asked about what a badge meant to her, Faith said, “Just that I know how to use it I guess. I don’t really think about it as a badge. I don’t know. I just think about it as a grade.” This sentiment was common among students who just saw the badge as another assignment. Even students who appreciated the practice and the knowledge they got from completing the activity didn't think that framing it as a badge gave it any extra meaning. Two students said that they didn't really care about the badges because they didn't think they had a lot of meaning behind them. Madison explains, "No, it doesn't mean a whole lot to me… because while I might know how to do this with this badge, I know for a fact that other people kind of half assed it and still got the badge, so it means less to me I would say." Despite this, when students were asked how they would explain having a badge to someone else, the most common answer was that the badge meant that they had learned how to use the glassware correctly. For example, Olivia initially said the badge didn't mean anything to her and it was something she did for the class, but when asked how she would explain a badge she said, "The pipet badge shows that I know how to pipet liquid and do a good job in chemistry."

There were some students who did not simply see badges as just another grade or assignment. Beth explains, "I'm kind of a competitive person so when you win awards, you know it's kind of cool. I mean it's not like I'm competing against anyone but I've been in sports my entire life. Every time you get a star or a badge or an award or whatnot it's just like 'hey yeah I did this.' That's almost kind of like you get a cookie for something." Jack mentioned that badges are an affirmation that you are doing a good job. Sophie appreciated the idea of badges and the points associated with them and said that the idea of having badges is "… kind of fun. Makes you feel like you've earned a little prize… extra points in class." One student said the idea of badges was fun and her TA played up the badge concept by talking about who had earned a badge in their lab section and it became a community building thing in their lab section. She also said it would have been fun to have physical badges to hand out. This shows that while some of the reasons for viewing a badge as more than a simple assignment came from students' experiences and personalities, it is possible for the instructors to also present the badges in a way that makes them stand out.

In terms of the utility of a digital badge, students held varying conceptions. Students were unsure of how people outside of the course would perceive the digital badges. The students stated they had told their parents or their roommates about the badges, mostly as a way to update them on what they had been doing in school. Students said they would share it for future Purdue courses or if they needed it in CHM 112 the following semester because they didn't think it would be useful outside of Purdue. As Sophie explains, "As far as I'm aware, this is the only program I've ever heard of that does badges for certain lab techniques. … Until it becomes a more widespread idea, it's not really something I'd share with an employer. I'd probably just say I'm comfortable doing x, y, and z lab techniques." For students like Sophie who may have reason to share the badges, the students were unsure about what it would mean. Since badges are so new, there is no precedent for putting them on a resume or CV, and therefore students are unsure of their value.

Students did seem more open to the representational value of badges when they believed that people outside of Purdue would understand what achieving the badge meant. Susan, a nursing major, stated she would show people badges if it was for an achievement in a medical field that people would recognize. Caroline also said badges would be useful in nursing. "But it would be really cool if we did that, like digital badges for nursing when we learn different skills. How to use the blood pressure cuff, and do that… I guess it really does depend on your major and how important that class is to you." Kevin had a similar reaction. "If I learn how to do CAD really well, I mean, I can tell employers and stuff like that. That's one of the big topics and stuff they look for so if you get a badge in CAD, you'd be set." Thus, students can envision the utility of a badge professionally in a case where the badge relates to professional skills that are valued in their field. Presenting the badges in a way that helps students to see their value may help students to be more motivated to complete the badges. It is possible that chemistry or other science majors who would use these skills more in the future would find these badges more useful and motivating.

6.4.2 Interactions Between Badges and Motivation

In relation to the expectancy and value groups, there were no strong trends in how students thought about badges. Because students were grouped in the cluster analysis by their expectancy and value beliefs, it was expected that students with similar motivation profiles would have similar reactions to the badges. This was not strongly reflected in the interview data however. By group, the HEHV students had the most positive overall attitude towards badges with four out of seven students stating that the idea of a badge meant something more to them than just an assignment or grade. Two out of six HELV students and only one LELV student out of five shared that attitude toward badges. The other students didn't necessarily think badges were bad, and many other students said they did learn things from the badges, but these seven students made statements like Randall and Jack said, "It feels like a little achievement that you get that you're like, 'Oh, I got that badge'" or "It's an affirmation that I know how to do … the techniques the badges are for. It's you did it Jack. You did a good job."

The students with higher positive value beliefs, did seem to view the badge as a reward or something more than a normal assignment more than students with less positive value beliefs. Looking at the quantitative data, the students who scored most highly on interest and attainment, the more intrinsic motivation factors, were the students who also were most likely to view the badges as a type of reward. This was reflected in the interview data as well in the attainment themes. Students who viewed badges as a reward frequently said that they were perfectionists or thought it was important to learn new lab techniques for general knowledge and not necessarily for a grade or other purpose.

Because expectancy-value theory does not seem to fully explain students' perceptions of digital badges, it may be useful to look at other theories of motivation and learning. One potentially useful theory is that of deep versus surface learning. In deep learning, students make connections between pieces of their knowledge or between new knowledge and everyday experiences. They care about understanding how things work. Students who use surface learning don't connect the tasks to any external knowledge or experience. They are more externally motivated and follow procedures somewhat blindly (Chin & Brown, 2000). The students who valued badges more and had more positive reactions were those who throughout the interview talked about connecting lab to their everyday experiences and could find some future use for either the badge or the knowledge they gained through the badge, using the lab skills or soft skills in future research with faculty and their future careers. It is possible that students who already use deep learning techniques in their courses are more intrinsically motivated and therefore find more value in badges.

Another theoretical framework that could be useful for this research is Self Determination Theory. Self-determination theory classifies motivation into three different parts: amotivation, extrinsic motivation, and intrinsic motivation (Deci & Ryan, 1980). The latter two components are relevant for this research. The idea of extrinsic regulation includes external rewards or punishments, personal importance, and compliance (Deci & Ryan, 1980; Ryan & Deci, 2000). While the idea of a badge can be seen as an external reward or punishment, the idea of personal importance can be related to cost or utility, as can compliance, since this is a required course and assignment for many of the students who completed the digital badges. Intrinsic regulation is more related to the idea of personal satisfaction and interest as represented by the interest and attainment value constructs. An analysis of the data based on the types of motivation elicited within students by the badging assignment and chemistry lab course could prove useful. It has been shown that students who feel very externally regulated are less motivated to complete a task while tasks that support internal regulation are more prone to increase student motivation (Ryan & Deci, 2000). Another component of self-determination theory is that humans have basic psychological needs – autonomy, competence, and relatedness. Tasks that support these three needs tend to lead to greater satisfaction and motivation (Ryan & Deci, 2000). The badges provide an opportunity to feel competent as well as the potential to feel related to others by completion of a shared badging system. An analysis of how the badges support varying types of motivation and students' psychological needs could be useful in determining how the badge assignment influenced student motivation.

It may seem surprising that intrinsically motivated students would value badges more since badges are typically seen as extrinsic motivators. In a study on various types of digital badges, Abramovich et al. classified digital badges into two categories: participation and skill. Participation badges were awarded for spending time and completing a certain number of activities in an online tutor program for math. Skill badges were awarded for demonstrating different types of knowledge and ability so solve new types of problems correctly (Abramovich et al., 2013). The authors found that the skill badges and the participation badges were correlated with different parts of motivation and learning. For high performing students, earning skill badges correlated with an increased expectancy to do well. For low performing students, skill badges didn't impact their motivation, but earning participation badges increased their motivation to do well so they would not look bad in front of fellow students, which is an extrinsic source of motivation that can negatively impact overall academic performance. Abramovich suggests that participation badges are external motivators and may have a negative impact on learning while skill badges are more easily seen as intrinsic motivators by students and can be of more benefit (Abramovich et al., 2013). Since the lab technique badges implemented at Purdue are skill-based badges, they are more directly tied to a student's internal motivation. Since almost all students recognized that the badges meant that they did well at a technique, the badges were most valued by students who already had sources of intrinsic motivation and were able to see the value in the lab techniques.

6.5 Conclusion

Student interviews provided us with insight into how students are motivated to learn laboratory techniques as well as what they think about badges. For some expectancy and value categories, the differences in the quantitative results were reflected in the interviews. The differences were most prevalent for knowledge, utility, interest, and attainment. Students for the most part found the badges to have helped their learning, though some students found more value in the digital badges than others. The students who found the most value in the badges were those who had higher interest and attainment value beliefs, which are intrinsic factors of motivation. Related to this, these students appeared to use deep learning strategies when talking about their laboratory experience. They strived to understand what they were doing in lab and were able to make connections between their lab learning and everyday life. Because the lab technique badges are skill-based badges awarded for performance in the lab, they were most beneficial for students who already were intrinsically motivated and saw value in the skills that they were learning as they reinforced and rewarded this desire to learn and do well. These findings have potential implications for how the badges are implemented in a course that will be discussed further in Chapter 7.

CHAPTER 7. CONCLUSIONS AND IMPLICATIONS

7.1 General Conclusions

This research was designed as a mixed-methods study to investigate student motivation in the laboratory as it related to digital badges using a new quantitative instrument combined with qualitative data. The study was based on the following research questions:

- To what extent can differences in student motivation to learn laboratory techniques be detected by using participant perception indicator (PPI) and value survey instruments?
- How do students with varying types of motivation to learn laboratory techniques perceive digital badges?
- What role do badges play in student learning of laboratory techniques?

These research questions were addressed using a combination of the quantitative and qualitative data. The qualitative data provides evidence to answer the first research question about the quantitative data and the quantitative data was used to help guide qualitative data collection to answer the final two research questions. A summary of findings is shown in Table 7.1 with more detailed conclusions in the following sections.

Table 7.1 Summary of Findings

Research Question	Findings
To what extent can differences in student motivation to learn laboratory techniques be detected by using participant perception indicator (PPI) and value survey instruments?	• Differences were detected in both students' expectancy and value beliefs. • Differences were most prevalent in students' value beliefs. • Students with high value beliefs tend to see utility in lab skills beyond the course. • Students in the low value groups were most likely to focus on the utility of techniques within the course, not beyond it. • Interactions between expectancy and value were seen for some value constructs.
How do students with varying types of motivation to learn laboratory techniques perceive digital badges?	• Few differences across different motivation groups. • Students with high attainment were most likely to see the badges as more than a grade. • Students saw value in badges for things that were useful for their major.
What role do badges play in student learning of laboratory techniques?	• Students saw badges as a course grade. • Students believed badges were a certification that they knew how to use a technique. • Badges draw attention to the importance of techniques and allow students to practice and receive feedback. • Badges assess techniques directly, tying them to students' goals of getting good grades.

7.2 Conclusions about the Instruments

Two quantitative survey instruments were used in the completion of this research. The first was the PPI survey used to measure students' beliefs about self-efficacy and their expectancies for success. The second instrument was the value survey created for both the pipet and the buret to measure students' value beliefs about using the different laboratory techniques as defined by expectancy-value theory. These instruments were used to determine the differences in student motivation in a large lecture course. The survey format allowed for efficient collection of large samples of data which could then be used to inform deeper qualitative studies. While the PPI had been previously validated in the literature and required no additional work, the value instrument was designed specifically for this study. It was hypothesized that the items should load onto four factors, each representing one of the value constructs (utility, cost, interest, and attainment). This was indeed the case, confirming that the survey was targeting the intended constructs and that the survey items aligned well with the theoretical framework. The EFA parameters allowed us to generate a model using a portion of the data. By using CFA with the second half of the data we demonstrated that the model was robust and fit a different set of data well. This suggests that the survey can be used in future courses with a similar student population and will perform well. The survey performed well across two laboratory techniques which also helps to demonstrate its validity.

While we were able to create a valid and reliable survey instrument to examine students' value beliefs, we needed to examine whether the quantitative differences in the survey were meaningful in practice. We used cluster analysis to group the students by their PPI and value survey scores and separated them into high and low groups. Three groups of students resulted: high expectancy-high value, high expectancy-low value, and low expectancy-low value. In terms of expectancies, there was not much difference seen across the groups. This is likely because there was somewhat of a ceiling effect in the PPI survey data to begin with. Students were grouped based on their PPI-post surveys which were completed after the badging exercise where most students rated their knowledge, confidence, and experience to be high. In addition, the interviews were conducted at the end of the semester when students had completed even more laboratory activities than they had done when they completed the survey. Because most students also came from similar backgrounds, they mentioned that their knowledge, confidence, and experience were all fairly low at the beginning of the semester and were now higher. The one difference was seen in the LELV group in terms of confidence. They mentioned being worried about breaking things or being stressed out or nervous to take chemistry more than the other groups. It is unknown if there is any interaction between expectancy and value for this trend because there was no LEHV group for comparison.

For students' attainment values there were still many similarities seen across groups, however more differences were evident as well. This is likely because there was less of a ceiling effect with the value surveys and because these constructs were not necessarily influenced by students' experiences with the techniques so they were less likely to change over the course of the semester. For cost, there was an interaction between the expectancy and value constructs. The HELV students talked about cost more similarly to the HEHV students and mentioned specific parts of the technique that were challenging. The LELV students by contrast mentioned being anxious about chemistry or nervous about breaking the equipment. Because of their lower expectancy values, especially regarding knowledge and confidence, the LELV students focused on different aspects of cost than the students in the high expectancy groups. For interest, students in the low value groups discussed being interested in things that were easy or that they understood. This was independent of their expectancy. The LELV students did focus more on enjoying things that were connected to the lecture than the HELV students, suggesting that the low expectancy students are primarily interested in things that will get them through the course. The HEHV students in contrast enjoyed labs that connected things to contexts outside the course. In attainment, the low value groups focused on getting things correct for their course grade. The HEHV students focused less on grades and discussed being right in terms of getting good results or getting good data. This showed less of an interaction between value and expectancy, but did show that there was a distinct difference between the high and low value students. Lastly, for utility the LELV students again focused on grades and exams and homework. They were very focused on things that could help them in the course. The HELV students were also focused on grades but also discussed getting out of lab quickly. The HEHV students mentioned grades the least and talked about using the skills outside the course as well as the usefulness of soft skills unrelated to lab techniques that they would take away from the course. This showed some interactions between expectancy and value and a clear difference between the high and low value students.

Overall, the interactions between expectancy and value were most prevalent in cost and utility – the more extrinsic motivational factors. For expectancy, the biggest meaningful difference between high and low groups was seen in confidence, however the lack of differences in the other constructs may just be a result of how the interviews and surveys were conducted. For value, differences between high and low groups were seen in all of the constructs. The value survey is therefore useful in detecting meaningful differences between students on its own. There are some features of motivation however that are best explained by using the PPI and value surveys concurrently, especially when looking at extrinsic factors for student motivation which seem to have an interaction with confidence. It is possible that if more of a difference had been seen in the knowledge and experience dimensions, that there would have been more of an interaction between expectancy and value for other constructs.

7.3 Implications for Teaching

This work corroborates the findings of previous research stating that students are motivated in the laboratory by getting good grades and finishing quickly (DeKorver & Towns, 2015, 2016). In previous work these themes were seen in the context of an entire laboratory course while this research shows that these themes are considered by students even at the technique level. To that end, instructors could frame technique instruction to emphasize that learning how using laboratory equipment properly leads to the ability to finish labs more quickly and to get better data, making reports easier to write and leading to better grades. This approach is especially effective with students who have lower motivation, as they most frequently cited time and grades as concerns when learning techniques.

This work also suggests additional factors that can be used to improve student motivation to learn lab techniques. Students who had high expectancy and value beliefs were more likely to make connections between lab and real-world contexts. They were also more likely to see value in soft skills that they were gaining from learning lab techniques and completing the badges. By emphasizing connections to contexts with which students are familiar instructors can model this type of thinking to help increase student motivation.

Similarly, students with high value beliefs, and therefore traits associated with higher motivation, were able to see utility in the badge assignment beyond just the lab skills. These students cited soft skills such as learning how to follow procedures, explain things, and pay attention to detail as being important and useful to them and their future careers. By emphasizing these skills, instructors can help students see value in the badge exercises, even when students don't believe the actual laboratory skills they are learning will be useful in the future.

7.4 Implications for Research

The value instrument is the first instrument to target students' value beliefs regarding chemistry laboratory techniques. Because similar sets of items performed similarly on two different techniques, more value instruments could be developed for other lab techniques or components of chemistry coursework. This provides the basis for researchers to develop similar instruments using expectancy-value theory. These surveys can also be used as the basis for future studies about student motivation in the laboratory. This instrument provides a way to measure students' value beliefs and therefore can be used as a tool for researchers to measure changes in motivation as the result of specific interventions. Likewise it gives researchers the ability to characterize students by their motivation to see how an intervention impacts students who are motivated in different ways.

One of the limiting factors of this study was that it was only performed in one course with one population of students. A future study could be done with varying populations of students. The students in this course were mostly non-science majors who did not have to take future chemistry courses and would not use chemistry in their future career. Conducting this study with a different population of students would provide more variation in the types of motivation and especially values that students place on laboratory techniques. It is possible that a chemistry or other science major would have different value beliefs about pipetting and may also have different expectancy beliefs. The students may value the techniques differently, which may influence how they feel about badges. Students in this study stated that digital badges would be more meaningful to them if they were related to students' majors and careers, indicating that science majors may have a different interaction between motivation and impressions of the badge project than the students in this study did.

Another general finding from this study is that it is important to consider both expectancy and value beliefs when characterizing students' motivation. Differences in student beliefs could not be summarized simply by expectancy or value alone. The combination of the two provided a richer view of the different factors that influence student motivation. Differences were seen between the HEHV and HELV students as well as between the HELV and the LELV students. While these differences were not evident across all factors of expectancy and value, they did emerge from the data especially in the areas of knowledge, cost, and utility. Future research on motivation should consider both of these factors simultaneously in order to obtain a complete picture of student motivation. This work provides an example of one way to combine the expectancy and value beliefs of students in a mixed methods format.

APPENDIX A. RUBRICS USED FOR BADGE GRADING

Pipet Video Rubric:

	Connect Pipet and Bulb Properly	**Draw liquid into a pipet**	**Get liquid to the proper level**	**Dispense liquid**
1	Hold pipet close to the top Gently twist bulb on 1-2cm	Smoothly draw liquid in a constant flow past the calibration line but not into the bulb	Shows that the meniscus of the liquid is at the calibration line on the pipet.	Uses the valve to release the liquid, being careful not to push all the liquid out Students should show a close up with a few drops left in the pipet tip
0.5	Hold pipet at the wide part of the pipet Collapse bulb after putting it on the pipet	Draw liquid just to the calibration line without going above it	Meniscus slightly above/below calibration line – must mention calibration line in video Makes some obvious attempt to get it to calibration line, but the line is not visible in the video	Doesn't show tip of pipet at end of video but appears to have dispensed liquid properly
0	Hold pipet lower than the wide part of the pipet Push bulb on too far Attach pipet upside down	Draw liquid into the bulb Air bubbles remain in pipet prior to dispensing that impact the volume	No recognition of calibration line	Makes obvious effort to push all liquid out Sucks liquid back into the bulb

Buret Video Rubric:

	Filling the Buret	**Clamping the Buret**	**Initial Reading**	**Final Reading**
1 point	Use a funnel to fill the buret to an initial amount (cannot be 0 mL) Filling takes place at a reasonable height, where the student does not need to stretch to reach the top of the funnel	The buret is clamped, steady and straight prior to the initial reading The buret is clamped prior to dispensing	Reading is done at eye level and initial volume is read correctly to 2 decimal places	The buret is clamped prior to dispensing The stopcock is turned gently to dispense, and the final volume is read correctly to 2 decimal places
0.5 point	The student must reach an unreasonable height (stands on toes, reach high above their head, etc.) to fill the buret *with* a funnel OR Filling takes place at a reasonable height, but a funnel is *not* used	The buret is not clamped until after initial reading The buret is clamped, but not vertical (e.g. crooked, does not fit in the clamp correctly)	Volume is read to less than 2 decimal places (1 or 0 decimal places)	Volume is read to less than 2 decimal places (1 or 0 decimal places)
0 points	The student must reach an unreasonable height to fill the buret *without* the use of a funnel Initial amount starts above 0-mL mark	The buret is not clamped at all prior to dispensing	The buret is read incorrectly, regardless of the number of decimal places	The buret is read incorrectly, regardless of the number of decimal places

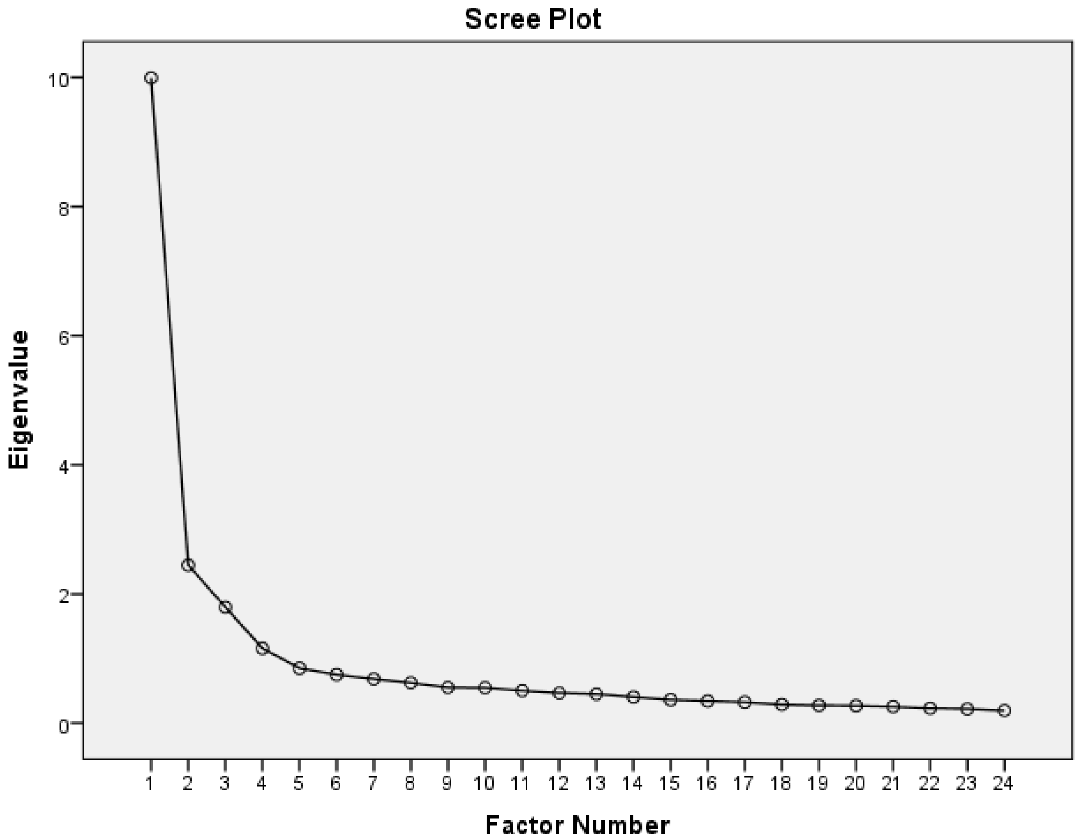
Volumetric Flask Video Rubric:

	Stating Volume of Flask	**Initial Filling of the Flask**	**Final Filling of the Flask**	**Initial and Final Inversions**
1 point	The correct volume of the volumetric flask used is stated correctly to 2 decimal places or the correct number of significant figures	After having some liquid in the flask (either before the video starts or after), the flask is filled partway up the neck (past the curved part and into the straight part of the neck) with de-ionized (DI) water	A medicine dropper is used to fill the flask just to the calibration line. *No solution may be removed in order to reach the calibration line if it was passed*	The flask is covered with parafilm and inverted cleanly to mix the diluted solution, twice overall: first, after the initial filling partway into the neck; second, after a medicine dropper is used to reach the calibration line
0.5 point	The number of significant figures or decimal places is stated incorrectly. **Ex.** *There are two decimal places in 25.00, but there are four significant figures, not just two*	When adding DI water, the diluted solution does not reach up into the straight part of the neck of the flask at all before an inversion is made **Ex.** *The meniscus is below the straight part of the neck, e.g. in the curved part of the flask*	A medicine dropper is not used to fill to the calibration line. **Ex.** *A beaker or graduated cylinder is used*	The flask is not inverted for at least one of the inversions (or both), but the flask is shaken or manipulated in some other way than inversion to mix in both cases Parafilm is not used to mix the diluted solution
0 points	The number of decimal places of the volumetric flask is not stated at all Student does not state the volume of the flask at all	The calibration line is passed with the initial addition of DI water (before the medicine dropper is used and before any inversion is performed)	The meniscus is shown to be above or below the calibration line Some diluted solution is clearly lost from the flask	The flask is not mixed at all, in any way, for at least one of the inversions (or both) Some diluted solution is clearly lost from the flask

APPENDIX B. FACTOR ANALYSIS OF THE PILOT SURVEY

Descriptive Statistics

	N	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Std. Error
After I graduate, an understanding of pipetting will be useless to me	382	-.090	.125	.032	.249
Even if using a pipet is not useful to me I want to be good at it	382	-.230	.125	.169	.249
I am disappointed if I use a pipet incorrectly	382	-.189	.125	-.474	.249
I believe pipetting will help me succeed in future courses	382	-.234	.125	.039	.249
I do not feel the need to be good at pipetting	382	-.439	.125	.549	.249
I enjoyed using a pipet	382	-.082	.125	.037	.249
I expect myself to be able to use a pipet correctly	382	-.581	.125	-.589	.249
I feel like I must succeed at using a pipet	382	-.013	.125	-.799	.249
I felt tense while using a pipet	382	-.406	.125	.182	.249
I had to try harder at using a pipet than other techniques	382	-.332	.125	.041	.249
I see no point in being able to use a pipet	382	-.577	.125	.819	.249
I think using a pipet is not fun.	382	.035	.125	-.080	.249
I want to be able to use a pipet	382	-.124	.125	-.535	.249
I want to be better than my peers at using a pipet	382	.624	.125	-.605	.249
I was relaxed while using a pipet	382	-.378	.125	.028	.249
I would describe using a pipet as interesting	382	-.143	.125	-.237	.249
I would describe using a pipet as low-stress	382	-.604	.125	.707	.249
I would enjoy learning more ways to use a pipet	382	-.143	.125	.271	.249
I would like to use a pipet again in the future	382	.090	.125	-.053	.249
It was a waste of time and effort learning how to use a pipet	382	-.394	.125	.480	.249
It will be beneficial for me to know how to use a pipet sooner rather than later	382	-.165	.125	.043	.249
Knowing how to pipet will help me get a good grade in this course	382	-.205	.125	-.374	.249
Understanding how to pipet has many benefits for me	382	-.253	.125	.011	.249
Using a pipet causes me a lot of anxiety	382	-.514	.125	.682	.249
Using a pipet correctly is important to me	382	-.196	.125	-.204	.249
Using a pipet takes too much time	382	-.284	.125	-.050	.249
Using a pipet was very easy for me	382	-.652	.125	.314	.249
Using a pipet will be an important skill to have for the future	382	-.107	.125	-.340	.249
Valid N (listwise)	382				



Total Variance Explained

Factor	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.585	39.936	39.936	5.179	21.577	21.577
2	2.049	8.539	48.475	3.283	13.679	35.256
3	1.418	5.908	54.383	2.883	12.012	47.268
4	.802	3.342	57.725	2.510	10.457	57.725

Extraction Method: Principal Axis Factoring.

Rotated Factor Matrix[a]

	Factor			
	1	2	3	4
I feel like I must succeed at using a pipet	.726			
It will be beneficial for me to know how to use a pipet sooner rather than later	.707			
Using a pipet correctly is important to me	.640			.303
I want to be able to use a pipet	.639		.393	
Knowing how to pipet will help me get a good grade in this course	.632			
Using a pipet will be an important skill to have for the future	.609			.346
Understanding how to pipet has many benefits for me	.604			.440
I believe pipetting will help me succeed in future courses	.533			.362
I want to be better than my peers at using a pipet	.519			
Even if using a pipet is not useful to me I want to be good at it	.493	.321		.313
I am disappointed if I use a pipet incorrectly	.434			.371
I see no point in being able to use a pipet	.316	.795		
It was a waste of time and effort learning how to use a pipet		.777		
Using a pipet causes me a lot of anxiety		.637	.513	
I do not feel the need to be good at pipetting	.389	.554		
Using a pipet takes too much time		.486		
I was relaxed while using a pipet	.305		.778	
I would describe using a pipet as low-stress	.318		.750	
I felt tense while using a pipet		.507	.634	
Using a pipet was very easy for me	.341		.589	
I would enjoy learning more ways to use a pipet				.755
I would describe using a pipet as interesting				.699
I enjoyed using a pipet	.370		.351	.543

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.

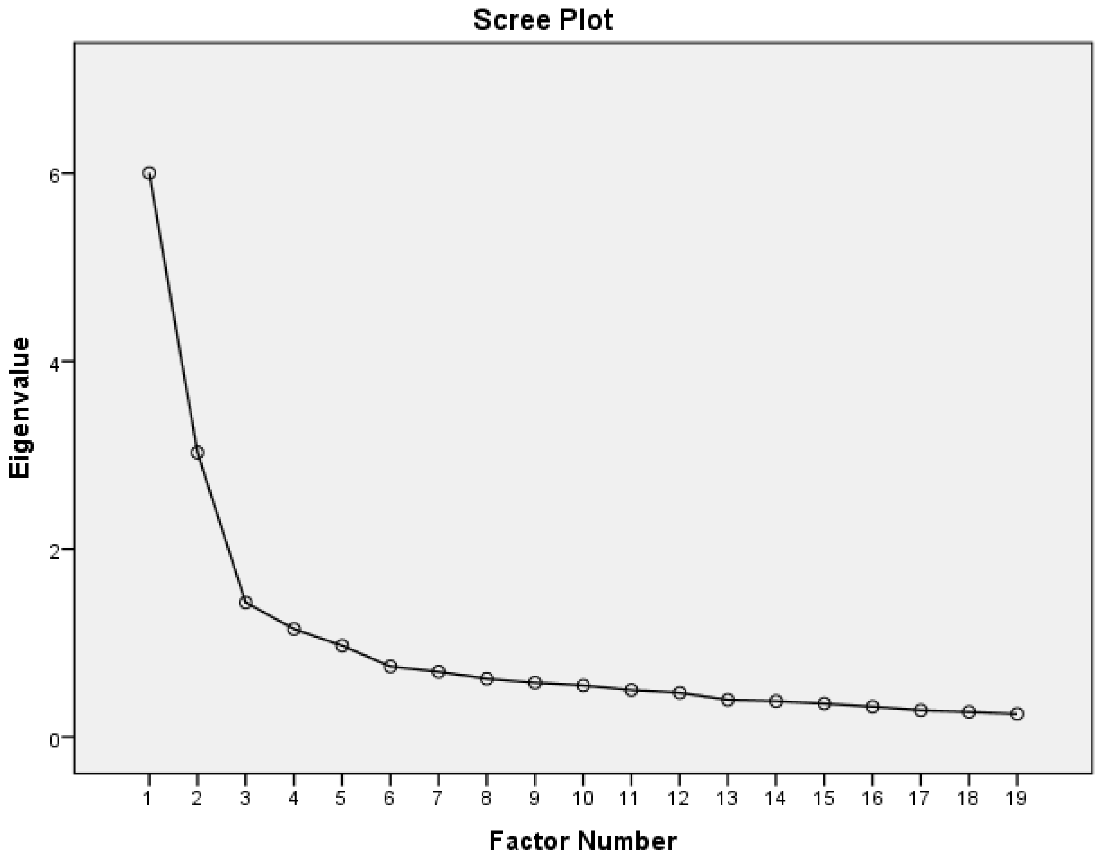
a. Rotation converged in 8 iterations.

APPENDIX C. EFA OF FINAL SURVEY IMPLEMENTATION

Pipet Survey EFA Output from SPSS

Descriptive Statistics

	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Even if pipetting is not useful to me I want to be good at it	323	3.87	.700	-.367	.136	.229	.271
I am disappointed if I use a pipet incorrectly	323	3.64	.757	-.465	.136	-.041	.271
I enjoyed using a pipet	323	3.68	.740	-.052	.136	-.332	.271
I feel like I must succeed at using a pipet	323	4.24	.632	-.240	.136	-.638	.271
I felt tense while using a pipet	323	3.64	.912	-.544	.136	-.089	.271
I had to try harder at using a pipet than other techniques	323	3.36	.950	-.299	.136	-.598	.271
I think using a pipet is not fun.	323	3.42	.762	.014	.136	-.132	.271
I want to be able to use a pipet	323	4.41	.589	-.407	.136	-.692	.271
I want to be better than my peers at using a pipet	323	3.70	.731	.350	.136	-.759	.271
I was relaxed while using a pipet	323	3.81	.805	-.512	.136	-.014	.271
I would describe using a pipet as interesting	323	3.55	.792	-.366	.136	.039	.271
I would describe using a pipet as low-stress	323	3.96	.713	-.516	.136	.476	.271
I would enjoy learning more ways to use a pipet	323	3.41	.776	-.133	.136	-.265	.271
I would like to use pipets more often	323	3.43	.822	.266	.136	-.278	.271
It will be beneficial for me to know how to use a pipet	323	4.05	.697	-.617	.136	.831	.271
Knowing how to pipet will be useful to me after graduation	323	3.04	1.018	.192	.136	-.558	.271
Knowing how to pipet will help me get a good grade in this course	323	4.20	.653	-.226	.136	-.712	.271
Knowing how to pipet will help me reach my goals	323	3.66	.861	-.272	.136	-.252	.271
Knowing how to pipet will help me succeed in future courses	323	3.79	.835	-.710	.136	.755	.271
Learning how to use a pipet was a waste of time and effort	323	3.96	.721	-.585	.136	.601	.271
Understanding how to pipet has many benefits for me	323	3.76	.832	-.335	.136	-.373	.271
Using a piet cause me anxiety	323	3.76	.910	-.605	.136	-.011	.271
Using a pipet correctly is important to me	323	4.04	.725	-.361	.136	-.196	.271
Using a pipet takes too much time	323	3.60	.836	-.460	.136	.096	.271
Using a pipet will be an important skill to have for the future	323	3.77	.934	-.540	.136	-.007	.271
Valid N (listwise)	323						



Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.003	31.595	31.595	5.548	29.202	29.202	3.550	18.685	18.685
2	3.027	15.931	47.525	2.604	13.705	42.908	2.938	15.462	34.146
3	1.432	7.536	55.061	.948	4.989	47.897	1.803	9.489	43.635
4	1.149	6.049	61.110	.620	3.262	51.159	1.430	7.524	51.159
5	.973	5.122	66.232						
6	.752	3.956	70.188						
7	.696	3.661	73.849						
8	.620	3.266	77.114						
9	.579	3.049	80.163						
10	.549	2.888	83.051						
11	.500	2.634	85.685						
12	.471	2.478	88.163						
13	.395	2.079	90.242						
14	.380	2.002	92.244						
15	.356	1.872	94.116						
16	.322	1.695	95.811						
17	.284	1.496	97.307						
18	.266	1.401	98.708						
19	.245	1.292	100.000						

Extraction Method: Principal Axis Factoring.

Rotated Factor Matrix[a]

	Factor			
	1	2	3	4
Understanding how to pipet has many benefits for me	.778			
It will be beneficial for me to know how to use a pipet	.775			
Using a pipet will be an important skill to have for the future	.766			
Knowing how to pipet will help me reach my goals	.744			
Knowing how to pipet will be useful to me after graduation	.636			
Knowing how to pipet will help me succeed in future courses	.588			
I felt tense while using a pipet		.866		
Using a piet cause me anxiety		.764		
I was relaxed while using a pipet		.723		
I would describe using a pipet as low-stress		.683		
I had to try harder at using a pipet than other techniques		.582		
Using a pipet takes too much time		.321		
I would describe using a pipet as interesting			.744	
I enjoyed using a pipet			.603	
I would enjoy learning more ways to use a pipet	.368		.542	
I think using a pipet is not fun.			.461	
Even if pipetting is not useful to me I want to be good at it				.655
I am disappointed if I use a pipet incorrectly				.578
I want to be better than my peers at using a pipet				.490

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 5 iterations.

Buret Survey EFA SPSS Output:

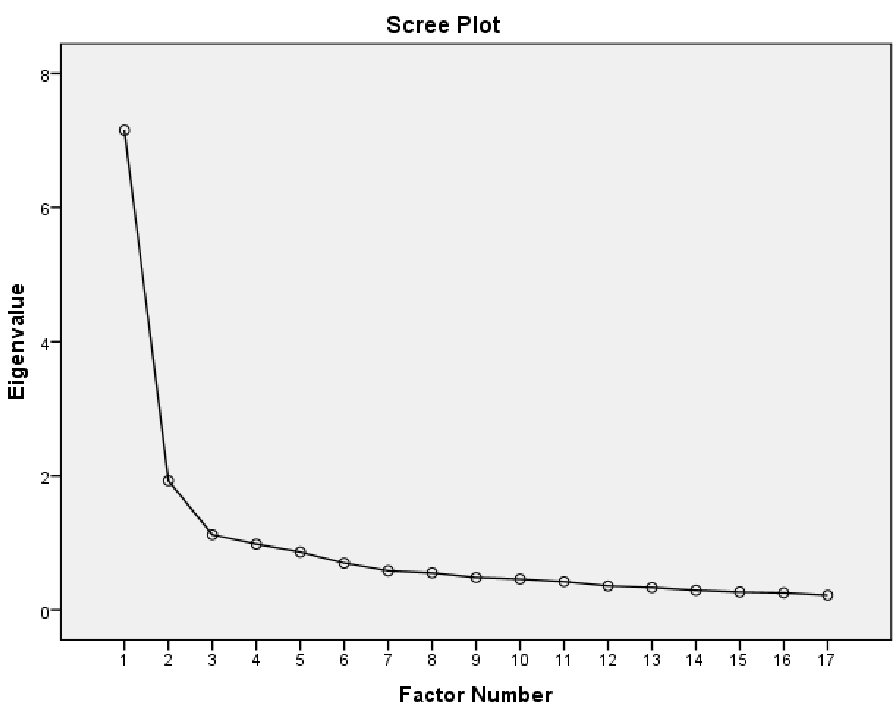
Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
xAfterIgraduateunderstandinghowtouseaburetwillbeusefultome	309	1	5	3.01	.995	-.159	.139	-.576	.276
xEvenifusingaburetisnotusefultomeIwanttobegoodatit	309	2	5	3.72	.705	-.263	.139	-.003	.276
xIamdisappointedifIuseaburetincorrectly	309	1	5	3.51	.836	-.432	.139	-.041	.276
xIamnotanxiousaboutusingaburet	309	2	5	3.66	.762	-.365	.139	-.111	.276
xIbelievebeingabletouseaburetwillhelpmesucceedinfuturecourses	309	1	5	3.66	.779	-.618	.139	.478	.276
xIenjoyedusingaburetampnbsp	309	1	5	3.51	.723	-.310	.139	.346	.276
xxIfeellikeImustsucceedatusingaburet	309	2	5	3.84	.680	-.357	.139	.306	.276
xIthinkusingaburetisampnbspfun	309	1	5	3.35	.834	-.123	.139	-.396	.276
xIwanttobebetterthanmypeersatusingaburet	309	1	5	3.56	.782	.426	.139	-.322	.276
xIwasrelaxedwhileusingaburet	309	2	5	3.75	.733	-.477	.139	.216	.276
xIwoulddescribeusingaburetasinteresting	309	1	5	3.53	.800	-.359	.139	-.209	.276
xIwoulddescribeusingaburetaslowstress	309	2	5	3.84	.693	-.362	.139	.253	.276
xIwouldenjoylearningmorewaystouseaburet	309	1	5	3.37	.797	-.057	.139	-.345	.276
xUnderstandinghowtouseaburethasmanybenefitsforme	309	2	5	3.50	.776	-.152	.139	-.386	.276
xUsingaburetdidnottakemoreeffortthanothertechniques	309	2	5	3.65	.761	-.519	.139	.005	.276
xUsingaburettakestoomuchtime	309	1	5	3.30	.832	-.348	.139	-.191	.276
xUsingaburetwillbeanimportantskilltohaveforthefuture	309	1	5	3.33	.950	-.375	.139	-.226	.276
Valid N (listwise)	309								

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.156	42.096	42.096	6.755	39.737	39.737	2.753	16.195	16.195
2	1.929	11.349	53.445	1.500	8.822	48.559	2.387	14.039	30.234
3	1.123	6.605	60.050	.661	3.889	52.447	2.187	12.865	43.100
4	.983	5.781	65.831	.579	3.404	55.851	2.168	12.751	55.851
5	.866	5.095	70.926						
6	.700	4.119	75.046						
7	.585	3.443	78.489						
8	.554	3.261	81.750						
9	.486	2.857	84.608						
10	.462	2.719	87.326						
11	.423	2.490	89.817						
12	.359	2.110	91.926						
13	.335	1.972	93.898						
14	.294	1.728	95.627						
15	.268	1.574	97.201						
16	.255	1.499	98.700						
17	.221	1.300	100.000						

Extraction Method: Principal Axis Factoring.



Rotated Factor Matrix[a]

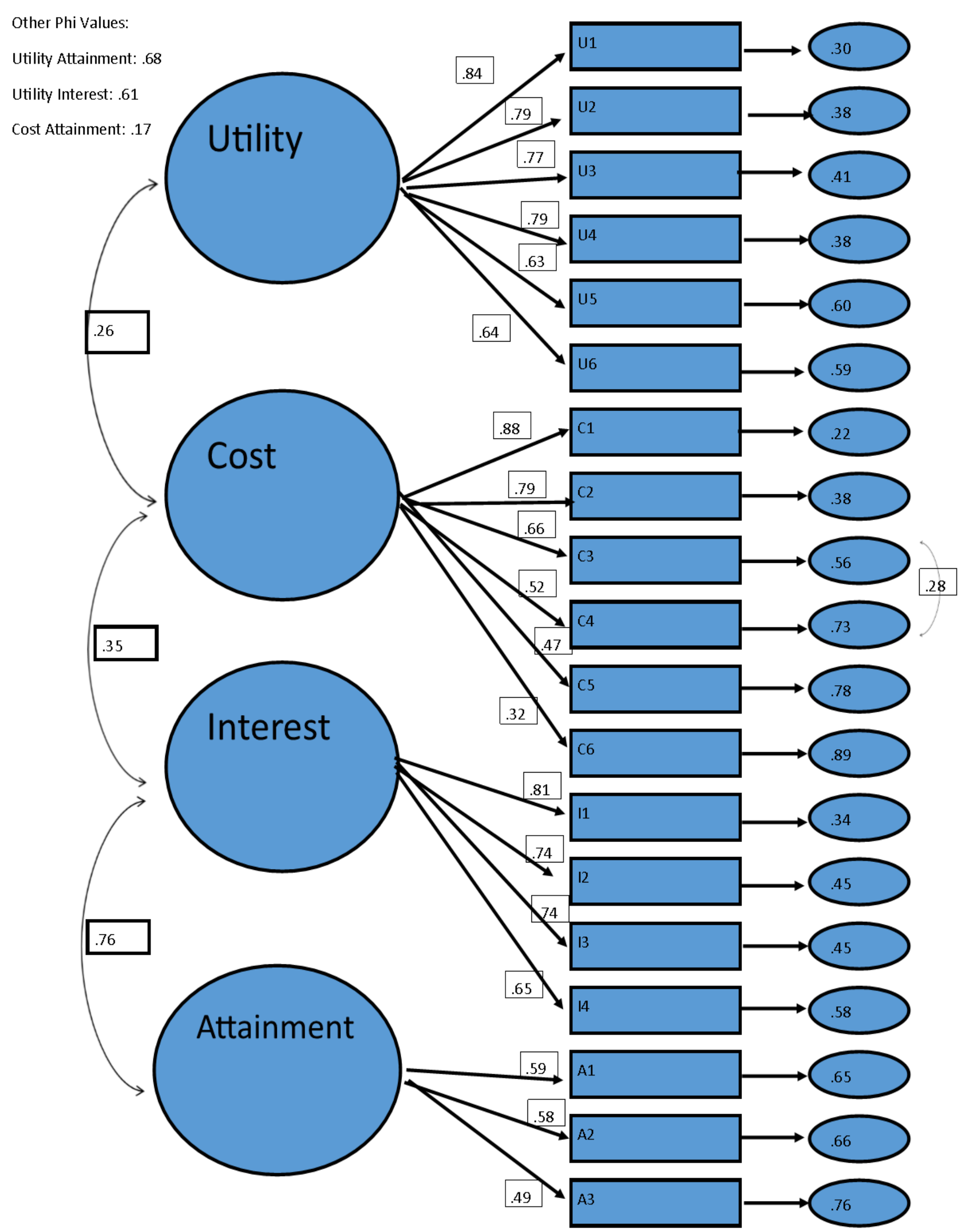
	Factor			
	1	2	3	4
xIwoulddescribeusingaburetaslowstress	.803			
xIwasrelaxedwhileusingaburet	.750			
xIamnotanxiousaboutusingaburet	.658			
xUsingaburetdidnottakemoreeffortthanothertechniques	.602			
xUsingaburettakestoomuchtime	.340			
xUsingaburetwillbeanimportantskilltohaveforthefuture		.773		
xAfterIgraduateunderstandinghowtouseaburetwillbeusefultome		.660		
xUnderstandinghowtouseaburethasmanybenefitsforme		.647	.317	
xIbelievebeingabletouseaburetwillhelpmesucceedinfuturecourses		.518	.385	
xEvenifusingaburetisnotusefultomeIwanttobegoodatit			.670	
xxIfeellikeImustsucceedatusingaburet			.645	
xIamdisappointedifIuseaburetincorrectly			.551	
xIwanttobebetterthanmypeersatusingaburet			.505	
xIthinkusingaburetisampnbspfun				.740
xIwoulddescribeusingaburetasinteresting		.301	.331	.614
xIenjoyedusingaburetampnbsp	.358			.600
xIwouldenjoylearningmorewaystouseaburet		.431	.339	.600

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

APPENDIX D. CFA OUTPUT AND FINAL MODEL

Pipet Survey CFA Final Model:



Pipet Survey CFA LISREL Output

```
!Add correlated error between (10,9) TD (stress,relaxed)
 DA NG=1 NI=19 NO=363 MA=CM
 LA
 benefits beneficial future goals graduation courses
 tense anxiety relaxed stress try time
 interesting enjoy ways fun
 useful incorrectly peers
 KM FU
 1 0.698 0.651 0.642 0.474 0.508 0.161 0.166 0.323 0.283 0.071 0.287 0.406 0.383 0.411 0.303 0.337 0.392
0.321
 0.698 1 0.609 0.611 0.382 0.497 0.112 0.135 0.2 0.181 0.064 0.335 0.382 0.376 0.377 0.331 0.347 0.32 0.26
 0.651 0.609 1 0.576 0.569 0.481 0.116 0.094 0.295 0.24 0.036 0.25 0.279 0.294 0.334 0.282 0.272 0.265
0.19
 0.642 0.611 0.576 1 0.578 0.5 0.14 0.163 0.271 0.242 -0.016 0.254 0.4 0.38 0.431 0.263 0.31 0.324 0.29
 0.474 0.382 0.569 0.578 1 0.484 0.063 0.06 0.219 0.2 -0.012 0.143 0.315 0.326 0.397 0.198 0.172 0.188
0.18
 0.508 0.497 0.481 0.5 0.484 1 0.163 0.15 0.189 0.144 0.022 0.146 0.262 0.302 0.393 0.268 0.273 0.268
0.189
 0.161 0.112 0.116 0.14 0.063 0.163 1 0.709 0.604 0.427 0.41 0.242 0.144 0.261 0.113 0.368 0.143 -0.069
0.106
 0.166 0.135 0.094 0.163 0.06 0.15 0.709 1 0.47 0.413 0.389 0.246 0.155 0.242 0.138 0.362 0.156 -0.035
0.115
 0.323 0.2 0.295 0.271 0.219 0.189 0.604 0.47 1 0.621 0.274 0.27 0.202 0.326 0.202 0.261 0.189 0.083 0.185
 0.283 0.181 0.24 0.242 0.2 0.144 0.427 0.413 0.621 1 0.332 0.258 0.09 0.249 0.123 0.175 0.11 0.072 0.146
 0.071 0.064 0.036 -0.016 -0.012 0.022 0.41 0.389 0.274 0.332 1 0.2 0.069 0.217 -0.012 0.186 0.032 -0.12
0.066
 0.287 0.335 0.25 0.254 0.143 0.146 0.242 0.246 0.27 0.258 0.2 1 0.249 0.266 0.157 0.264 0.148 0.074 0.104
 0.406 0.382 0.279 0.4 0.315 0.262 0.144 0.155 0.202 0.09 0.069 0.249 1 0.593 0.628 0.542 0.411 0.312
0.341
 0.383 0.376 0.294 0.38 0.326 0.302 0.261 0.242 0.326 0.249 0.217 0.266 0.593 1 0.526 0.521 0.349 0.293
0.284
 0.411 0.377 0.334 0.431 0.397 0.393 0.113 0.138 0.202 0.123 -0.012 0.157 0.628 0.526 1 0.437 0.414 0.345
0.273
 0.303 0.331 0.282 0.263 0.198 0.268 0.368 0.362 0.261 0.175 0.186 0.264 0.542 0.521 0.437 1 0.306 0.129
0.155
 0.337 0.347 0.272 0.31 0.172 0.273 0.143 0.156 0.189 0.11 0.032 0.148 0.411 0.349 0.414 0.306 1 0.328
0.244
 0.392 0.32 0.265 0.324 0.188 0.268 -0.069 -0.035 0.083 0.072 -0.12 0.074 0.312 0.293 0.345 0.129 0.328 1
0.353
 0.321 0.26 0.19 0.29 0.18 0.189 0.106 0.115 0.185 0.146 0.066 0.104 0.341 0.284 0.273 0.155 0.244 0.353
1
 SD
 .844 .734 .951 .881 .977 .792 .819 .820 .793 .751 .930 .798 .773 .723 .806 .736 .668 .762 .731
 SE
 benefits beneficial future goals graduation courses
 tense anxiety relaxed stress try time
 interesting enjoy ways fun
 useful incorrectly peers
 MO NX=19 NK=4 LX=FU,FI PH=SY,FR TD=SY,FI
 LK
 Utility Cost Interest Attainment
 FR LX(2,1) LX(3,1) LX(4,1) LX(5,1) LX(6,1)
 FR LX(8,2) LX(9,2) LX(10,2) LX(11,2) LX(12,2)
 FR LX(14,3) LX(15,3) LX(16,3)
```

```
FR LX(18,4) LX(19,4)
FR TD(1,1) TD(2,2) TD(3,3) TD(4,4) TD(5,5) TD(6,6) TD(7,7) TD(8,8) TD(9,9) TD(10,10) TD(11,11)
TD(12,12) TD(13,13) TD(14,14) TD(15,15) TD(16,16) TD(17,17) TD(18,18) TD(19,19) TD(10,9)
VA 1.00 LX(1,1) LX(7,2) LX(13,3) LX(17,4)
OU NS SC MI
```

Covariance Matrix

	benefits	benefici	future	goals	graduati	courses
benefits	0.71					
benefici	0.43	0.54				
future	0.52	0.43	0.90			
goals	0.48	0.40	0.48	0.78		
graduati	0.39	0.27	0.53	0.50	0.95	
courses	0.34	0.29	0.36	0.35	0.37	0.63
tense	0.11	0.07	0.09	0.10	0.05	0.11
anxiety	0.11	0.08	0.07	0.12	0.05	0.10
relaxed	0.22	0.12	0.22	0.19	0.17	0.12
stress	0.18	0.10	0.17	0.16	0.15	0.09
try	0.06	0.04	0.03	-0.01	-0.01	0.02
time	0.19	0.20	0.19	0.18	0.11	0.09
interest	0.26	0.22	0.21	0.27	0.24	0.16
enjoy	0.23	0.20	0.20	0.24	0.23	0.17
ways	0.28	0.22	0.26	0.31	0.31	0.25
fun	0.19	0.18	0.20	0.17	0.14	0.16
useful	0.19	0.17	0.17	0.18	0.11	0.14
incorrec	0.25	0.18	0.19	0.22	0.14	0.16
peers	0.20	0.14	0.13	0.19	0.13	0.11

Covariance Matrix

	tense	anxiety	relaxed	stress	try	time
tense	0.67					
anxiety	0.48	0.67				
relaxed	0.39	0.31	0.63			
stress	0.26	0.25	0.37	0.56		
try	0.31	0.30	0.20	0.23	0.86	
time	0.16	0.16	0.17	0.15	0.15	0.64
interest	0.09	0.10	0.12	0.05	0.05	0.15
enjoy	0.15	0.14	0.19	0.14	0.15	0.15
ways	0.07	0.09	0.13	0.07	-0.01	0.10
fun	0.22	0.22	0.15	0.10	0.13	0.16
useful	0.08	0.09	0.10	0.06	0.02	0.08
incorrec	-0.04	-0.02	0.05	0.04	-0.09	0.04
peers	0.06	0.07	0.11	0.08	0.04	0.06

Covariance Matrix

	interest	enjoy	ways	fun	useful	incorrec
interest	0.60					
enjoy	0.33	0.52				

ways	0.39	0.31	0.65			
fun	0.31	0.28	0.26	0.54		
useful	0.21	0.17	0.22	0.15	0.45	
incorrec	0.18	0.16	0.21	0.07	0.17	0.58
peers	0.19	0.15	0.16	0.08	0.12	0.20

Covariance Matrix

	peers
peers	0.53

!Add correlated error between (10,9) TD (stress,relaxed)

Parameter Specifications

LAMBDA-X

	Utility	Cost	Interest	Attainme
benefits	0	0	0	0
benefici	1	0	0	0
future	2	0	0	0
goals	3	0	0	0
graduati	4	0	0	0
courses	5	0	0	0
tense	0	0	0	0
anxiety	0	6	0	0
relaxed	0	7	0	0
stress	0	8	0	0
try	0	9	0	0
time	0	10	0	0
interest	0	0	0	0
enjoy	0	0	11	0
ways	0	0	12	0
fun	0	0	13	0
useful	0	0	0	0
incorrec	0	0	0	14
peers	0	0	0	15

PHI

	Utility	Cost	Interest	Attainme
Utility	16			
Cost	17	18		
Interest	19	20	21	
Attainme	22	23	24	25

THETA-DELTA

	benefits	benefici	future	goals	graduati	courses
benefits	26					
benefici	0	27				

future	0	0	28			
goals	0	0	0	29		
graduati	0	0	0	0	30	
courses	0	0	0	0	0	31
tense	0	0	0	0	0	0
anxiety	0	0	0	0	0	0
relaxed	0	0	0	0	0	0
stress	0	0	0	0	0	0
try	0	0	0	0	0	0
time	0	0	0	0	0	0
interest	0	0	0	0	0	0
enjoy	0	0	0	0	0	0
ways	0	0	0	0	0	0
fun	0	0	0	0	0	0
useful	0	0	0	0	0	0
incorrec	0	0	0	0	0	0
peers	0	0	0	0	0	0

THETA-DELTA

	tense	anxiety	relaxed	stress	try	time
tense	32					
anxiety	0	33				
relaxed	0	0	34			
stress	0	0	35	36		
try	0	0	0	0	37	
time	0	0	0	0	0	38
interest	0	0	0	0	0	0
enjoy	0	0	0	0	0	0
ways	0	0	0	0	0	0
fun	0	0	0	0	0	0
useful	0	0	0	0	0	0
incorrec	0	0	0	0	0	0
peers	0	0	0	0	0	0

THETA-DELTA

	interest	enjoy	ways	fun	useful	incorrec
interest	39					
enjoy	0	40				
ways	0	0	41			
fun	0	0	0	42		
useful	0	0	0	0	43	
incorrec	0	0	0	0	0	44
peers	0	0	0	0	0	0

THETA-DELTA

	peers
peers	45

!Add correlated error between (10,9) TD (stress,relaxed)

Number of Iterations = 29

LISREL Estimates (Maximum Likelihood)

LAMBDA-X

	Utility	Cost	Interest	Attainme
benefits	1.00	- -	- -	- -
benefici	0.81	- -	- -	- -
	(0.05)			
	17.06			
future	1.03	- -	- -	- -
	(0.06)			
	16.43			
goals	0.98	- -	- -	- -
	(0.06)			
	17.04			
graduati	0.87	- -	- -	- -
	(0.07)			
	12.74			
courses	0.71	- -	- -	- -
	(0.06)			
	12.94			
tense	- -	1.00	- -	- -
anxiety	- -	0.89	- -	- -
		(0.06)		
		15.45		
relaxed	- -	0.73	- -	- -
		(0.06)		
		12.91		
stress	- -	0.54	- -	- -
		(0.06)		
		9.64		
try	- -	0.61	- -	- -
		(0.07)		
		8.81		
time	- -	0.36	- -	- -
		(0.06)		
		5.89		
interest	- -	- -	1.00	- -
enjoy	- -	- -	0.86	- -
			(0.06)	
			14.30	
ways	- -	- -	0.95	- -
			(0.07)	
			14.27	
fun	- -	- -	0.76	- -
			(0.06)	
			12.30	
useful	- -	- -	- -	1.00
incorrec	- -	- -	- -	1.13
				(0.15)
				7.76

peers	- -	- -	- -	0.92
				(0.13)
				6.94

PHI

	Utility	Cost	Interest	Attainme
Utility	0.50			
	(0.05)			
	9.52			
Cost	0.13	0.52		
	(0.03)	(0.05)		
	4.12	9.65		
Interest	0.27	0.16	0.39	
	(0.03)	(0.03)	(0.05)	
	8.19	5.27	8.75	
Attainme	0.19	0.05	0.19	0.15
	(0.03)	(0.02)	(0.03)	(0.03)
	7.03	2.21	7.27	5.10

THETA-DELTA

	benefits	benefici	future	goals	graduati	courses
benefits	0.21					
	(0.02)					
	9.81					
benefici	- -	0.21				
		(0.02)				
		10.98				
future	- -	- -	0.38			
			(0.03)			
			11.30			
goals	- -	- -	- -	0.30		
				(0.03)		
				10.99		
graduati	- -	- -	- -	- -	0.58	
					(0.05)	
					12.46	
courses	- -	- -	- -	- -	- -	0.37
						(0.03)
						12.42
tense	- -	- -	- -	- -	- -	- -
anxiety	- -	- -	- -	- -	- -	- -
relaxed	- -	- -	- -	- -	- -	- -
stress	- -	- -	- -	- -	- -	- -
try	- -	- -	- -	- -	- -	- -
time	- -	- -	- -	- -	- -	- -
interest	- -	- -	- -	- -	- -	- -
enjoy	- -	- -	- -	- -	- -	- -
ways	- -	- -	- -	- -	- -	- -
fun	- -	- -	- -	- -	- -	- -
useful	- -	- -	- -	- -	- -	- -
incorrec	- -	- -	- -	- -	- -	- -
peers	- -	- -	- -	- -	- -	- -

THETA-DELTA

	tense	anxiety	relaxed	stress	try	time
tense	0.15 (0.03) 5.62					
anxiety	- -	0.25 (0.03) 9.27				
relaxed	- -	- -	0.35 (0.03) 11.67			
stress	- -	- -	0.17 (0.02) 6.70	0.41 (0.03) 12.60		
try	- -	- -	- -	- -	0.67 (0.05) 12.85	
time	- -	- -	- -	- -	- -	0.57 (0.04) 13.21
interest	- -	- -	- -	- -	- -	- -
enjoy	- -	- -	- -	- -	- -	- -
ways	- -	- -	- -	- -	- -	- -
fun	- -	- -	- -	- -	- -	- -
useful	- -	- -	- -	- -	- -	- -
incorrec	- -	- -	- -	- -	- -	- -
peers	- -	- -	- -	- -	- -	- -

THETA-DELTA

	interest	enjoy	ways	fun	useful	incorrec
interest	0.20 (0.02) 9.01					
enjoy	- -	0.23 (0.02) 10.61				
ways	- -	- -	0.29 (0.03) 10.63			
fun	- -	- -	- -	0.31 (0.03) 11.79		
useful	- -	- -	- -	- -	0.29 (0.03) 10.58	
incorrec	- -	- -	- -	- -	- -	0.38 (0.04) 10.71
peers	- -	- -	- -	- -	- -	- -

THETA-DELTA

	peers
peers	0.40
	(0.03)
	11.81

Squared Multiple Correlations for X - Variables

benefits	benefici	future	goals	graduati	courses
0.70	0.62	0.59	0.62	0.40	0.41

Squared Multiple Correlations for X - Variables

tense	anxiety	relaxed	stress	try	time
0.78	0.62	0.44	0.27	0.22	0.11

Squared Multiple Correlations for X - Variables

interest	enjoy	ways	fun	useful	incorrec
0.66	0.55	0.55	0.42	0.35	0.34

Squared Multiple Correlations for X - Variables

peers
0.24

Goodness of Fit Statistics

Degrees of Freedom = 145
Minimum Fit Function Chi-Square = 401.07 (P = 0.0)
Normal Theory Weighted Least Squares Chi-Square = 404.27 (P = 0.0)
Estimated Non-centrality Parameter (NCP) = 259.27
90 Percent Confidence Interval for NCP = (203.13 ; 323.05)

Minimum Fit Function Value = 1.11
Population Discrepancy Function Value (F0) = 0.72
90 Percent Confidence Interval for F0 = (0.56 ; 0.89)
Root Mean Square Error of Approximation (RMSEA) = 0.070
90 Percent Confidence Interval for RMSEA = (0.062 ; 0.078)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.00

Expected Cross-Validation Index (ECVI) = 1.37
90 Percent Confidence Interval for ECVI = (1.21 ; 1.54)
ECVI for Saturated Model = 1.05
ECVI for Independence Model = 17.51

Chi-Square for Independence Model with 171 Degrees of Freedom = 6300.73
Independence AIC = 6338.73
Model AIC = 494.27

Saturated AIC = 380.00
Independence CAIC = 6431.72
Model CAIC = 714.51
Saturated CAIC = 1309.94

Normed Fit Index (NFI) = 0.94
Non-Normed Fit Index (NNFI) = 0.95
Parsimony Normed Fit Index (PNFI) = 0.79
Comparative Fit Index (CFI) = 0.96
Incremental Fit Index (IFI) = 0.96
Relative Fit Index (RFI) = 0.92

Critical N (CN) = 170.26

Root Mean Square Residual (RMR) = 0.050
Standardized RMR = 0.076
Goodness of Fit Index (GFI) = 0.89
Adjusted Goodness of Fit Index (AGFI) = 0.86
Parsimony Goodness of Fit Index (PGFI) = 0.68

Standardized Solution

LAMBDA-X

	Utility	Cost	Interest	Attainme
benefits	0.71	- -	- -	- -
benefici	0.58	- -	- -	- -
future	0.73	- -	- -	- -
goals	0.69	- -	- -	- -
graduati	0.62	- -	- -	- -
courses	0.51	- -	- -	- -
tense	- -	0.72	- -	- -
anxiety	- -	0.65	- -	- -
relaxed	- -	0.53	- -	- -
stress	- -	0.39	- -	- -
try	- -	0.44	- -	- -
time	- -	0.26	- -	- -
interest	- -	- -	0.63	- -
enjoy	- -	- -	0.54	- -
ways	- -	- -	0.60	- -
fun	- -	- -	0.48	- -
useful	- -	- -	- -	0.39
incorrec	- -	- -	- -	0.44
peers	- -	- -	- -	0.36

PHI

	Utility	Cost	Interest	Attainme
Utility	1.00			
Cost	0.26	1.00		
Interest	0.61	0.35	1.00	
Attainme	0.68	0.17	0.76	1.00

!Add correlated error between (10,9) TD (stress,relaxed)

Completely Standardized Solution

LAMBDA-X

	Utility	Cost	Interest	Attainme
benefits	0.84	- -	- -	- -
benefici	0.79	- -	- -	- -
future	0.77	- -	- -	- -
goals	0.79	- -	- -	- -
graduati	0.63	- -	- -	- -
courses	0.64	- -	- -	- -
tense	- -	0.88	- -	- -
anxiety	- -	0.79	- -	- -
relaxed	- -	0.66	- -	- -
stress	- -	0.52	- -	- -
try	- -	0.47	- -	- -
time	- -	0.32	- -	- -
interest	- -	- -	0.81	- -
enjoy	- -	- -	0.74	- -
ways	- -	- -	0.74	- -
fun	- -	- -	0.65	- -
useful	- -	- -	- -	0.59
incorrec	- -	- -	- -	0.58
peers	- -	- -	- -	0.49

PHI

	Utility	Cost	Interest	Attainme
Utility	1.00			
Cost	0.26	1.00		
Interest	0.61	0.35	1.00	
Attainme	0.68	0.17	0.76	1.00

THETA-DELTA

	benefits	benefici	future	goals	graduati	courses
benefits	0.30					
benefici	- -	0.38				
future	- -	- -	0.41			
goals	- -	- -	- -	0.38		
graduati	- -	- -	- -	- -	0.60	
courses	- -	- -	- -	- -	- -	0.59
tense	- -	- -	- -	- -	- -	- -
anxiety	- -	- -	- -	- -	- -	- -
relaxed	- -	- -	- -	- -	- -	- -
stress	- -	- -	- -	- -	- -	- -
try	- -	- -	- -	- -	- -	- -
time	- -	- -	- -	- -	- -	- -
interest	- -	- -	- -	- -	- -	- -
enjoy	- -	- -	- -	- -	- -	- -

ways	- -	- -	- -	- -	- -	- -
fun	- -	- -	- -	- -	- -	- -
useful	- -	- -	- -	- -	- -	- -
incorrec	- -	- -	- -	- -	- -	- -
peers	- -	- -	- -	- -	- -	- -

THETA-DELTA

	tense	anxiety	relaxed	stress	try	time
tense	0.22					
anxiety	- -	0.38				
relaxed	- -	- -	0.56			
stress	- -	- -	0.28	0.73		
try	- -	- -	- -	- -	0.78	
time	- -	- -	- -	- -	- -	0.89
interest	- -	- -	- -	- -	- -	- -
enjoy	- -	- -	- -	- -	- -	- -
ways	- -	- -	- -	- -	- -	- -
fun	- -	- -	- -	- -	- -	- -
useful	- -	- -	- -	- -	- -	- -
incorrec	- -	- -	- -	- -	- -	- -
peers	- -	- -	- -	- -	- -	- -

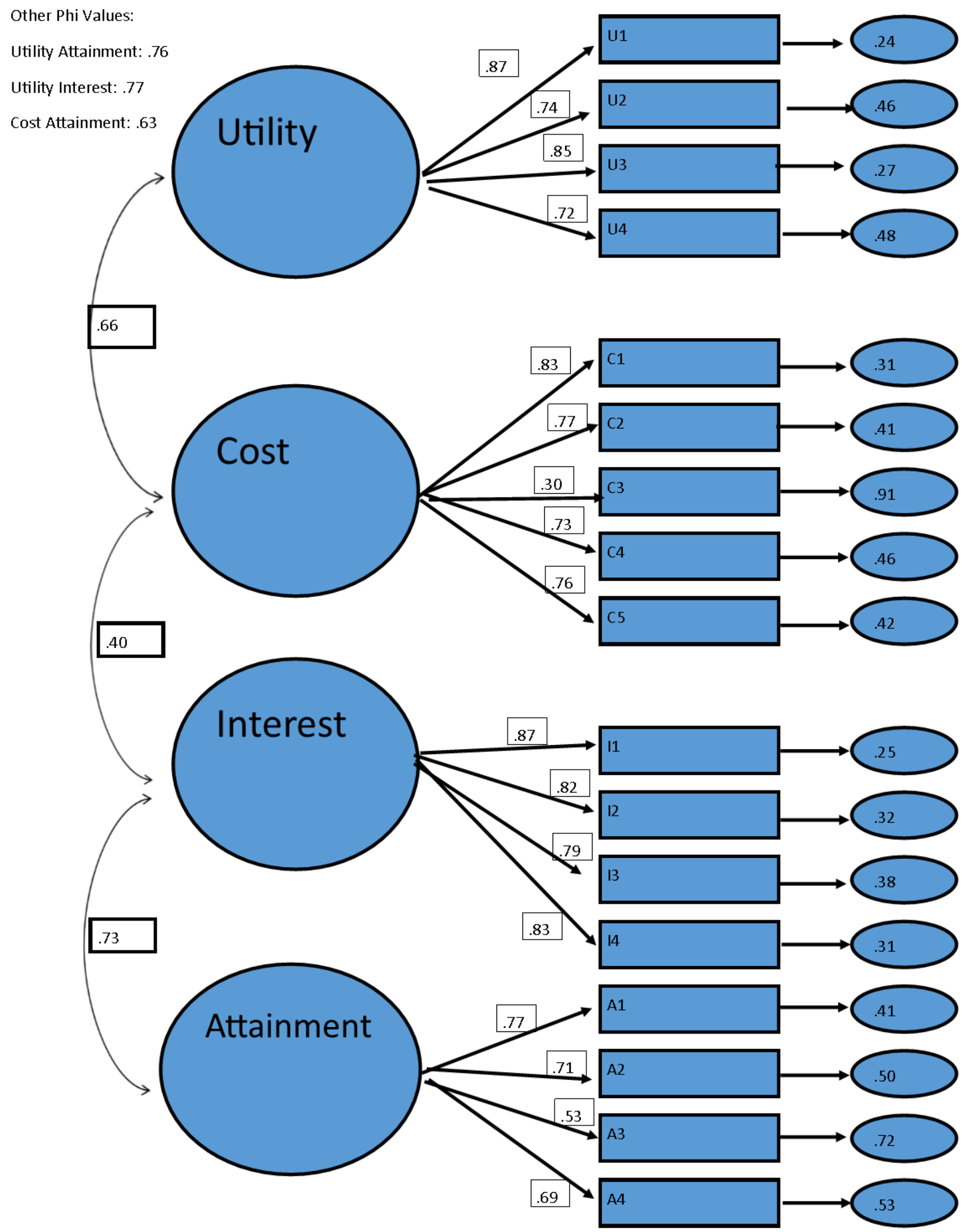
THETA-DELTA

	interest	enjoy	ways	fun	useful	incorrec
interest	0.34					
enjoy	- -	0.45				
ways	- -	- -	0.45			
fun	- -	- -	- -	0.58		
useful	- -	- -	- -	- -	0.65	
incorrec	- -	- -	- -	- -	- -	0.66
peers	- -	- -	- -	- -	- -	- -

THETA-DELTA

	peers
peers	0.76

Buret Survey CFA Final Model:



Buret Survey CFA LISREL Output:

```
DA NG=1 NI=17 NO=283 MA=CM
 LA
 fun ways interesting enjoy
 relaxed anxious time stress effort
 future courses benefits graduate
 succeed useful disappointed peers
 KM FU

 1 0.717 0.715 0.731 0.465 0.388 0.185 0.367 0.49 0.53 0.534 0.553 0.427 0.438 0.514
0.305 0.36
 0.717 1 0.637 0.65 0.426 0.366 0.153 0.366 0.506 0.586 0.524 0.596 0.527 0.467 0.545
0.333 0.44
 0.715 0.637 1 0.64 0.389 0.336 0.204 0.322 0.451 0.468 0.496 0.568 0.398 0.481 0.539
0.263 0.388
 0.731 0.65 0.64 1 0.491 0.443 0.214 0.487 0.503 0.524 0.486 0.563 0.472 0.483 0.529
0.291 0.431
 0.465 0.426 0.389 0.491 1 0.657 0.233 0.648 0.585 0.29 0.364 0.289 0.204 0.44 0.434
0.177 0.341
 0.388 0.366 0.336 0.443 0.657 1 0.198 0.516 0.633 0.234 0.312 0.225 0.134 0.317 0.388
0.231 0.257
 0.185 0.153 0.204 0.214 0.233 0.198 1 0.288 0.212 0.084 0.137 0.092 -0.019 0.137 0.184
0.008 -0.001
 0.367 0.366 0.322 0.487 0.648 0.516 0.288 1 0.538 0.217 0.327 0.226 0.157 0.441 0.327
0.144 0.341
 0.49 0.506 0.451 0.503 0.585 0.633 0.212 0.538 1 0.247 0.402 0.261 0.193 0.34 0.412
0.237 0.289
 0.53 0.586 0.468 0.524 0.29 0.234 0.084 0.217 0.247 1 0.675 0.742 0.673 0.438 0.4 0.237
0.341
 0.534 0.524 0.496 0.486 0.364 0.312 0.137 0.327 0.402 0.675 1 0.582 0.474 0.509 0.547
0.282 0.41
 0.553 0.596 0.568 0.563 0.289 0.225 0.092 0.226 0.261 0.742 0.582 1 0.603 0.545 0.453
0.367 0.481
 0.427 0.527 0.398 0.472 0.204 0.134 -0.019 0.157 0.193 0.673 0.474 0.603 1 0.365 0.293
0.305 0.409
 0.438 0.467 0.481 0.483 0.44 0.317 0.137 0.441 0.34 0.438 0.509 0.545 0.365 1 0.496
0.391 0.596
 0.514 0.545 0.539 0.529 0.434 0.388 0.184 0.327 0.412 0.4 0.547 0.453 0.293 0.496 1
0.455 0.427
 0.305 0.333 0.263 0.291 0.177 0.231 0.008 0.144 0.237 0.237 0.282 0.367 0.305 0.391
0.455 1 0.407
 0.36 0.44 0.388 0.431 0.341 0.257 -0.001 0.341 0.289 0.341 0.41 0.481 0.409 0.596 0.427
0.407 1

 SD
```

```
.866 .842 .782 .77 .722 .761 .934 .753 .802 .98 .812 .848 1.048 .726 .729 .822 .815
SE
fun ways interesting enjoy
relaxed anxious time stress effort
future courses benefits graduate
succeed useful disappointed peers
MO NX=17 NK=4 LX=FU,FI PH=SY,FR TD=SY,FI
LK
Interest Cost Utility Attainment
FR LX(2,1) LX(3,1) LX(4,1)
FR LX(6,2) LX(7,2) LX(8,2) LX(9,2)
FR LX(11,3) LX(12,3) LX(13,3)
FR LX(15,4) LX(16,4) LX(17,4)
FR TD(1,1) TD(2,2) TD(3,3) TD(4,4) TD(5,5) TD(6,6) TD(7,7) TD(8,8) TD(9,9)
TD(10,10) TD(11,11) TD(12,12) TD(13,13) TD(14,14) TD(15,15) TD(16,16) TD(17,17)
VA 1.00 LX(1,1) LX(5,2) LX(10,3) LX(14,4)
OU NS SC MI

DA NG=1 NI=17 NO=283 MA=CM

                Number of Input Variables 17
                Number of Y - Variables    0
                Number of X - Variables   17
                Number of ETA - Variables  0
                Number of KSI - Variables  4
                Number of Observations   283

DA NG=1 NI=17 NO=283 MA=CM
```

Covariance Matrix

	fun	ways	interest	enjoy	relaxed	anxious
fun	0.75					
ways	0.52	0.71				
interest	0.48	0.42	0.61			
enjoy	0.49	0.42	0.39	0.59		
relaxed	0.29	0.26	0.22	0.27	0.52	
anxious	0.26	0.23	0.20	0.26	0.36	0.58
time	0.15	0.12	0.15	0.15	0.16	0.14
stress	0.24	0.23	0.19	0.28	0.35	0.30
effort	0.34	0.34	0.28	0.31	0.34	0.39
future	0.45	0.48	0.36	0.40	0.21	0.17
courses	0.38	0.36	0.31	0.30	0.21	0.19
benefits	0.41	0.43	0.38	0.37	0.18	0.15
graduate	0.39	0.47	0.33	0.38	0.15	0.11

succeed	0.28	0.29	0.27	0.27	0.23	0.18
useful	0.32	0.33	0.31	0.30	0.23	0.22
disappoi	0.22	0.23	0.17	0.18	0.11	0.14
peers	0.25	0.30	0.25	0.27	0.20	0.16

Covariance Matrix

	time	stress	effort	future	courses	benefits
time	0.87					
stress	0.20	0.57				
effort	0.16	0.32	0.64			
future	0.08	0.16	0.19	0.96		
courses	0.10	0.20	0.26	0.54	0.66	
benefits	0.07	0.14	0.18	0.62	0.40	0.72
graduate	-0.02	0.12	0.16	0.69	0.40	0.54
succeed	0.09	0.24	0.20	0.31	0.30	0.34
useful	0.13	0.18	0.24	0.29	0.32	0.28
disappoi	0.01	0.09	0.16	0.19	0.19	0.26
peers	0.00	0.21	0.19	0.27	0.27	0.33

Covariance Matrix

	graduate	succeed	useful	disappoi	peers
graduate	1.10				
succeed	0.28	0.53			
useful	0.22	0.26	0.53		
disappoi	0.26	0.23	0.27	0.68	
peers	0.35	0.35	0.25	0.27	0.66

DA NG=1 NI=17 NO=283 MA=CM

Parameter Specifications

LAMBDA-X

	Interest	Cost	Utility	Attainme
fun	0	0	0	0
ways	1	0	0	0
interest	2	0	0	0
enjoy	3	0	0	0
relaxed	0	0	0	0
anxious	0	4	0	0

time	0	5	0	0
stress	0	6	0	0
effort	0	7	0	0
future	0	0	0	0
courses	0	0	8	0
benefits	0	0	9	0
graduate	0	0	10	0
succeed	0	0	0	0
useful	0	0	0	11
disappoi	0	0	0	12
peers	0	0	0	13

PHI

	Interest	Cost	Utility	Attainme
Interest	14			
Cost	15	16		
Utility	17	18	19	
Attainme	20	21	22	23

THETA-DELTA

fun	ways	interest	enjoy	relaxed	anxious
24	25	26	27	28	29

THETA-DELTA

time	stress	effort	future	courses	benefits
30	31	32	33	34	35

THETA-DELTA

graduate	succeed	useful	disappoi	peers
36	37	38	39	40

DA NG=1 NI=17 NO=283 MA=CM

Number of Iterations = 15

LISREL Estimates (Maximum Likelihood)

LAMBDA-X

	Interest	Cost	Utility	Attainme
	--------	--------	--------	--------
fun	1.00	- -	- -	- -
ways	0.92	- -	- -	- -
	(0.05)			
	17.33			
interest	0.82	- -	- -	- -
	(0.05)			
	16.21			
enjoy	0.85	- -	- -	- -
	(0.05)			
	17.59			
relaxed	- -	1.00	- -	- -
anxious	- -	0.98	- -	- -
		(0.07)		
		13.83		
time	- -	0.46	- -	- -
		(0.10)		
		4.78		
stress	- -	0.92	- -	- -
		(0.07)		
		13.09		
effort	- -	1.02	- -	- -
		(0.07)		
		13.70		
future	- -	- -	1.00	- -
courses	- -	- -	0.70	- -
			(0.05)	
			14.35	
benefits	- -	- -	0.85	- -
			(0.05)	
			17.92	
graduate	- -	- -	0.89	- -
			(0.06)	
			14.03	
succeed	- -	- -	- -	1.00
useful	- -	- -	- -	0.92
				(0.08)
				11.30
disappoi	- -	- -	- -	0.78
				(0.09)
				8.42
peers	- -	- -	- -	1.00

(0.09)
10.96

PHI

	Interest	Cost	Utility	Attainme
Interest	0.56			
	(0.06)			
	8.94			
Cost	0.30	0.36		
	(0.04)	(0.04)		
	7.87	8.10		
Utility	0.50	0.21	0.73	
	(0.06)	(0.04)	(0.08)	
	8.86	5.39	8.93	
Attainme	0.32	0.21	0.35	0.31
	(0.04)	(0.03)	(0.04)	(0.04)
	8.15	7.05	7.93	7.11

THETA-DELTA

fun	ways	interest	enjoy	relaxed	anxious
0.19	0.23	0.23	0.18	0.16	0.24
(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
8.62	9.62	10.10	9.48	8.08	9.41

THETA-DELTA

time	stress	effort	future	courses	benefits
0.79	0.26	0.27	0.23	0.30	0.20
(0.07)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)
11.71	9.87	9.50	7.80	10.38	8.44

THETA-DELTA

graduate	succeed	useful	disappoi	peers
0.52	0.21	0.26	0.48	0.35
(0.05)	(0.02)	(0.03)	(0.04)	(0.04)
10.48	8.57	9.62	11.01	9.88

Squared Multiple Correlations for X - Variables

fun	ways	interest	enjoy	relaxed	anxious
0.75	0.68	0.62	0.69	0.69	0.59

Squared Multiple Correlations for X - Variables

time	stress	effort	future	courses	benefits
0.09	0.54	0.58	0.76	0.54	0.73

Squared Multiple Correlations for X - Variables

graduate	succeed	useful	disappoi	peers
0.52	0.59	0.50	0.28	0.47

Goodness of Fit Statistics

Degrees of Freedom = 113
Minimum Fit Function Chi-Square = 313.49 (P = 0.0)
Normal Theory Weighted Least Squares Chi-Square = 298.80 (P = 0.0)
Estimated Non-centrality Parameter (NCP) = 185.80
90 Percent Confidence Interval for NCP = (138.38 ; 240.89)

Minimum Fit Function Value = 1.11
Population Discrepancy Function Value (F0) = 0.66
90 Percent Confidence Interval for F0 = (0.49 ; 0.85)
Root Mean Square Error of Approximation (RMSEA) = 0.076
90 Percent Confidence Interval for RMSEA = (0.066 ; 0.087)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.00

Expected Cross-Validation Index (ECVI) = 1.34
90 Percent Confidence Interval for ECVI = (1.18 ; 1.54)
ECVI for Saturated Model = 1.09
ECVI for Independence Model = 25.05

Chi-Square for Independence Model with 136 Degrees of Freedom = 7030.02
Independence AIC = 7064.02
Model AIC = 378.80
Saturated AIC = 306.00
Independence CAIC = 7142.99
Model CAIC = 564.62
Saturated CAIC = 1016.75

Normed Fit Index (NFI) = 0.96

Non-Normed Fit Index (NNFI) = 0.96
Parsimony Normed Fit Index (PNFI) = 0.79
Comparative Fit Index (CFI) = 0.97
Incremental Fit Index (IFI) = 0.97
Relative Fit Index (RFI) = 0.95

Critical N (CN) = 136.73

Root Mean Square Residual (RMR) = 0.037
Standardized RMR = 0.054
Goodness of Fit Index (GFI) = 0.89
Adjusted Goodness of Fit Index (AGFI) = 0.85
Parsimony Goodness of Fit Index (PGFI) = 0.66

DA NG=1 NI=17 NO=283 MA=CM

Standardized Solution

LAMBDA-X

	Interest	Cost	Utility	Attainme
fun	0.75	- -	- -	- -
ways	0.69	- -	- -	- -
interest	0.62	- -	- -	- -
enjoy	0.64	- -	- -	- -
relaxed	- -	0.60	- -	- -
anxious	- -	0.58	- -	- -
time	- -	0.28	- -	- -
stress	- -	0.55	- -	- -
effort	- -	0.61	- -	- -
future	- -	- -	0.85	- -
courses	- -	- -	0.60	- -
benefits	- -	- -	0.72	- -
graduate	- -	- -	0.76	- -
succeed	- -	- -	- -	0.56
useful	- -	- -	- -	0.52
disappoi	- -	- -	- -	0.44
peers	- -	- -	- -	0.56

PHI

	Interest	Cost	Utility	Attainme
Interest	1.00			

Cost	0.66	1.00		
Utility	0.77	0.40	1.00	
Attainme	0.76	0.63	0.73	1.00

DA NG=1 NI=17 NO=283 MA=CM

Completely Standardized Solution

LAMBDA-X

	Interest	Cost	Utility	Attainme
fun	0.87	- -	- -	- -
ways	0.82	- -	- -	- -
interest	0.79	- -	- -	- -
enjoy	0.83	- -	- -	- -
relaxed	- -	0.83	- -	- -
anxious	- -	0.77	- -	- -
time	- -	0.30	- -	- -
stress	- -	0.73	- -	- -
effort	- -	0.76	- -	- -
future	- -	- -	0.87	- -
courses	- -	- -	0.74	- -
benefits	- -	- -	0.85	- -
graduate	- -	- -	0.72	- -
succeed	- -	- -	- -	0.77
useful	- -	- -	- -	0.71
disappoi	- -	- -	- -	0.53
peers	- -	- -	- -	0.69

PHI

	Interest	Cost	Utility	Attainme
Interest	1.00			
Cost	0.66	1.00		
Utility	0.77	0.40	1.00	
Attainme	0.76	0.63	0.73	1.00

THETA-DELTA

fun	ways	interest	enjoy	relaxed	anxious
0.25	0.32	0.38	0.31	0.31	0.41

THETA-DELTA

time	stress	effort	future	courses	benefits
0.91	0.46	0.42	0.24	0.46	0.27

THETA-DELTA

graduate	succeed	useful	disappoi	peers
0.48	0.41	0.50	0.72	0.53

APPENDIX E. INTERVIEW PROTOCOL

1. Warm-up questions
    a. What year are you in school?
    b. What major are you in?
    c. What chemistry classes have you taken before this one?
    d. Did they have a lab? How many labs do you think you completed?

Knowledge, confidence, experience

2. Think back to when you completed your digital badges this semester. How much knowledge about laboratory techniques did you have before and after completing the badges?
    a. What helped you learn the most?
        i. Follow-ups about possible learning supports – lab textbook, previous experience, demonstration by graduate teaching assistant, help from lab partner, (get them to be specific)..

3. How confident were you in your ability to perform lab techniques before and after completing the badges?
    a. What about the badges influenced your confidence?
    b. In what ways are you more or less confident?

4. How much experience did you have with these laboratory techniques prior to completing the badges? (number of times)
    a. Characterize your experience with these techniques after completing the badges.
    b. Could you teach this technique to another student who was less experienced? (if yes, see below. If no, ask why.)
    c. Drill down about key aspects of a technique – making a solution in a volumetric flask, using a pipet, using a buret.

Interest/Enjoyment

5. What interests you about chemistry laboratory?
    a. What chemistry laboratory techniques did you know before this class?
    b. What chemistry laboratory techniques have you learned that are new?
6. How do you feel about learning new lab techniques?
7. Did you think about lab techniques with the badges differently than techniques without badges?
    a. In what ways did you consider them differently?

Cost

8. Did you find learning these techniques (the ones badged) to be easy or challenging? (ask specifically about each technique)
    a. What aspects of the technique (identify the technique) were easy or challenging?
9. What were some problems or challenges you had while completing the badges?
    a. How did this influence your desire to complete the badges?

Attainment

10. Compared to other students, where would you rank yourself in terms of your ability in chemistry lab?
11. How important is it to you to learn lab techniques?
    a. Could suggest a 4 point-scale: Not important, slightly important, moderately important, very important
    b. Please explain why you chose that response.
12. How important is it to you to perform lab techniques correctly?
    a. Could suggest a 4 point-scale: Not important, slightly important, moderately important, very important
    b. Please explain why you chose that response
    c. What impact, if any, does performing a laboratory technique correctly have on you?

Utility

13. How might the skills you learned while completing the badges benefit you in the future?
14. What do you intend to do after graduation? (relates back to major question in warm-ups)
15. Will the lab skills you have learned help you in your other courses?
    a. Which ones?
16. What does it mean to you to have a badge?

APPENDIX F. CODEBOOK FOR QUALITATIVE INTERVIEWS

Knowledge	Explaining how to do a technique – demonstrating their knowledge of specific steps Describing things that helped develop knowledge – i.e. features of the course, activities they did
Confidence	Describing confidence before or after learning a technique Specific features of the course that impacted confidence
Experience	Discussing previous experience with pipetting or chemistry Previous courses or lab experiences they have had Discussing how much experience they believe they have with lab techniques
Utility	How useful a technique is in terms of their short-term or long-term goals How the technique will help them externally
Cost	Resources a student has to use to complete a technique. This includes time, effort, stress, anxiety or the lack of these things. i.e. it was really difficult, or it was very easy
Interest	Willingness to acquire knowledge and skills, driven by personal emotion or satisfaction. Students discussing why they like to learn techniques or why they like chemistry.
Attainment	The intrinsic importance that a student places on succeeding at a particular skill or knowing particular information within a subject area, regardless of how that skill or knowledge can be used. A person is compelled internally to succeed. Students talk about being a perfectionist or wanting knowledge outside of any external goal it may help them achieve. Also applies to situations when students answer a question about intrinsic importance with a response about external goals. (demonstrating low attainment or lack of attainment values)
	All above codes should focus specifically on **techniques** not necessarily badges
Badges	Any comments the students have about their thoughts on the badge assignment itself. What it means to have a badge. Comments that are related to the badges more than the techniques.

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VITA

Sarah Ann Hensiek was born and raised in southern New Hampshire. After graduating from Pinkerton Academy she attended Wesleyan University where she completed the BA/MA program working with Professor T. David Westmoreland. At Wesleyan she also discovered her passion for education which led her to Purdue to study chemistry education research. She joined Marcy Towns's research group and completed her PhD. After graduation she accepted a lecturer position to continue her passion for laboratory education in a teaching role at Salisbury University in Maryland.

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Improving and Assessing Student Hands-On Laboratory Skills through Digital Badging

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Supporting Information

ABSTRACT: Building on previous success with a digital pipet badge, an evidence-centered design approach was used to develop new digital badges for measuring the volume of liquids with a buret and making a solution in a volumetric flask. These badges were implemented and assessed in two general chemistry courses. To earn the badges, students created videos of their techniques at the end of lab and uploaded them using the Passport app. Students received individual feedback from their instructors and were able to attempt the technique again if their first performance was unsatisfactory. To evaluate the badge as a laboratory assessment tool, students completed surveys about their knowledge, confidence, and experience using each technique with a retrospective-pre then post survey design. Analysis of these surveys showed statistically significant gains in student knowledge, confidence, and experience across both courses and both badges. Student performance on exams and procedural questions within the badges supports the conclusion that the badges positively impacted student learning of these two techniques. This research establishes that a digital badging approach can be used to improve student hands-on skills across multiple techniques and multiple student populations.

KEYWORDS: *First-Year Undergraduate/General, Chemical Education Research, Curriculum, Laboratory Instruction, Testing/Assessment, Laboratory Equipment/Apparatus*

FEATURE: Chemical Education Research

Research has demonstrated that mastery of hands-on laboratory skills and techniques is an important goal in the undergraduate chemistry laboratory curriculum.[1,2] These skills cannot be learned in lecture and are important for students who wish to pursue careers in chemistry or related STEM fields. Without an understanding of lab techniques, students cannot precisely and accurately collect and analyze data. This compromises their ability to generate plausible explanations based upon experimental evidence and to appreciate the context for chemistry problems they encounter in their coursework.

Laboratory techniques, such as using a buret to make precise volumetric measurements and using a volumetric flask to accurately prepare solutions, are an important component of many experiments in introductory and advanced-level chemistry laboratory coursework. These skills require both physical dexterity and knowledge about the design and function of the equipment. Despite instructions in the laboratory manual or demonstrations by faculty or teaching assistants, many students unknowingly employ improper techniques. Thus, the measurements they obtain become less precise, impacting their calculations and the explanations they construct from their data. When students cannot trust their data, opportunities for learning in the lab are lost as students lose the ability to create meaning from the actions they carry out.

Unfortunately, the extent of this issue is concealed by the difficulty in assessing students' hands-on techniques. Many times, constraints on time or personnel resources limit the ability to assess hands-on laboratory skills during a laboratory period. Instead, students are assessed only on written lab reports. While these artifacts allow instructors to gauge errors in data collection, the source of those errors, such as poor technique, go unidentified and uncorrected. This problem is exacerbated in situations where students work in groups or submit group reports, as it provides little individual accountability for the students and limits opportunities for individual assessment and feedback. The lack of assessment of hands-on skills may lead students to believe that these skills are not valued in the laboratory curriculum.

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Digital badging provides an effective way to address some of these problems using an evidence-based approach. Instead of relying on an indirect assessment of students' technique via their reported data, instructors have the ability to monitor students' skills and provide appropriate individual feedback to improve their performance.

LITERATURE REVIEW

Student Learning in the Laboratory

Learning in the undergraduate laboratory has been the subject of much recent research.[1−7] Laboratory courses are generally thought of as an important part of the chemistry curriculum, but researchers have also questioned their value and have raised questions about the learning that occurs in these courses.[8−12] Kirschner and Meester state that students often receive inadequate feedback in the laboratory and that the design of laboratory courses generally does not support student learning of practical skills.[13] Other researchers echo the need for accountability and valid ways to assess lab skills through the development of rubrics.[14,15]

Previous research in the Towns and Bretz research groups has focused on faculty goals for undergraduate laboratory courses,[1−3] and more recently, research has been carried out to elucidate student goals.[5−7] A national survey of chemistry faculty revealed that learning hands-on skills was an important goal across the undergraduate chemistry curriculum.[2] Reid and Shah have also noted the importance of "practical skills" in the undergraduate laboratory.[9]

However, research has demonstrated that this is not an important goal for students, who tend to focus on more affective goals such as achieving satisfaction by finishing the lab quickly and getting better grades, resulting in negative consequences for their learning.[5] By using lab techniques that they believe are the fastest, or having their lab mates carry out the techniques for them, students maximize their own affective goals while avoiding learning the hands-on skills. As it has been posited that students may not learn things that are not aligned with their goals,[8] it is important to incorporate individual accountability for and assessment of hands-on lab skills into the laboratory curriculum.

Digital Badging

Digital badges are an effective way to showcase skills a student has learned while the badging structure itself provides the opportunity for evidence-based assessment of these skills.[16] Using badges as a form of credential is a common practice in many professional organizations. Perhaps the most well-known example is in scouting, where badges are awarded and worn to signify the completion of certain tasks or the mastery of specific skills. In order for a badge to have meaning, it must indicate specific, evidence-based inferences about the earner's knowledge, skills, and/or attitudes. Digital badges serve these same functions, but can extend beyond the boundaries of the awarding organization. Shared online, they can be connected to specific metadata about how the badge was earned (the criteria), who issued the badge, and with video evidence of the specific skills demonstrated in order to earn the badge.[17] Previously, a digital badge has been used as an approach to assess students' hands-on lab skills in pipetting.[18] The students gained experience with and received feedback on their performance of the technique, and as a result, their self-reported knowledge, confidence, and experience significantly improved. Furthermore, the badge design provided direct evidence to the instructors of the individual students' abilities through their videos. In order to explore the use of digital badging beyond the pipetting technique, digital badges need to be investigated and established in a variety of classroom contexts as well as across multiple techniques. This study seeks to evaluate use of digital badges with two other techniques commonly learned in the general chemistry laboratory: filling, reading, and using a buret and making a solution in a volumetric flask. Thus, the research questions are the following: (1) In what ways do digital badges impact student learning of hands-on lab skills related to burets and volumetric flasks? (2) How do digital badges support learning across different populations of students?

METHODS

To investigate the research questions, digital badges were created, implemented, and evaluated for properly using a buret and making a solution in a volumetric flask. Human subjects approval was obtained through Purdue University's IRB.

Digital Badge Design

The badges were designed using an approach similar to that used to create the pipetting badge.[18] Because badges must be connected to evidence-based inferences about student knowledge, evidence-centered design is an appropriate framework for developing badge activities. It allows instructors to identify specific constructs of knowledge, skills, and attitudes that students should be able to demonstrate, and then design badging tasks that allow students to demonstrate these constructs.[19,20] Appropriate constructs were identified by generating a list of important steps for each technique. These lists were developed and refined by chemists, course instructors, and teaching assistants according to best practices, with reference to the steps given in the appendix of the students' lab manual. These steps were incorporated into sets of instructions shown in Boxes 1 and 2 to guide students in creating their videos.

Box 1. Fall 2015 Student Instructions for the Buret Badge Video

Buret Video Instructions:

1. State your name and laboratory section number at the beginning of the video.
2. Properly clamp the buret and be sure the stopcock is closed.
3. Place a funnel in the top of the buret.
4. Pour the desired amount of solution into the buret and remove the funnel – do not start at 0 mL.
5. Do an initial straight-on, close-up shot of the meniscus (hold paper behind the buret).
6. Read the starting volume to the appropriate number of significant figures.
7. Use the stopcock to empty some liquid into an appropriate container.
8. Do a final straight-on, close-up shot of the meniscus (hold paper behind the buret).
9. Read the final volume to the appropriate number of decimal places.

Box 2. Fall 2015 Student Instructions for the Volumetric Flask Badge Video

Volumetric Flask Video Instructions:

1. State your name and laboratory section number.
2. Describe the volume of the flask you are using with the appropriate significant figures.
3. Add the appropriate amount of the solution you will be diluting to the volumetric flask.
4. Fill the flask with DI water from a beaker to about halfway up the neck of the flask.
5. Cover the flask with parafilm and invert to mix.
6. Use a medicine dropper to fill the flask so that the bottom of the meniscus is at the calibration mark. Do a close up shot of the calibration line.
7. Cover with parafilm and invert the flask to finish mixing.

Figure 1 is a still shot from a student's buret video showing step number 5 in Box 1, where the student is holding a piece of white paper behind the buret (thus, the buret is white) and is pointing to the meniscus. During the video the student would read the buret, and an instructor or teaching assistant could evaluate if the volume was correct and read to the proper precision. Figure 2 shows a student mixing a solution in a volumetric flask, which is associated with steps 4 and 7 in Box 2. While watching these videos an instructor or teaching assistant can evaluate if the

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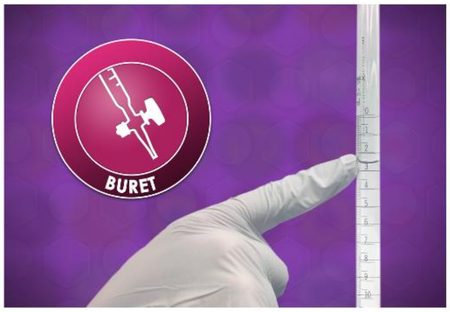

Figure 1. A student demonstrates how to read a buret while creating a video to earn his Buret Badge. He is indicating the location of the meniscus while reading the volume of liquid in the buret.

Figure 2. A student demonstrates how to make a solution in a volumetric flask to earn her Volumetric Flask Badge.

proper procedures are used and if the student fills the volumetric flask to the correct level.

Student assessments of learning were used to evaluate the effectiveness of the badging project. A modified participant perception indicator (PPI) survey was created for each badge.[21] The PPI survey is based on the concept of self-efficacy[22] and focuses on what the students can do and what they believe they can do as a measurement of learning success. The psychometric properties of self-assessment instruments such as the PPI survey have been found to produce consistently reliable results, and there are persuasive results across contexts that self-assessment positively contributes to student learning.[23] Additionally, as Ross[23] noted, "Self-assessment contributes to self-efficacy beliefs, i.e., student perceptions of their ability to perform the actions required by similar tasks likely to be encountered in the future. (p. 6)" Thus, a self-assessment is an appropriate instrument to measure change and build self-efficacy of hands-on laboratory skills that will be used across the semester.

To increase the validity of the measure we used a retrospective-pre then post survey design (also known as retrospective gains[24]), where students evaluated their prior knowledge after completing the task. When compared with a pretask survey, the retrospective-pre survey gives a more accurate reflection of students' prior knowledge and attitudes,[25,26] due to the students' inability to recognize their own lack of knowledge prior to attempting a task.[18,27,28] Thus, the PPI is a valid measure for assessment of learning.

The PPI items were created to assess students' perceptions of their knowledge, confidence, and experience regarding various aspects of using a buret and a volumetric flask. The surveys included both identification and process statements that asked students to rate their knowledge (cognitive dimension), confidence (affective dimension), and experience (psychomotor dimension) on a five point Likert scale where 1 was low and 5 was high. The students were given an example about making a cup of tea to demonstrate how the scales were used. For instance, a student could indicate that she knew how to make a cup of tea (scoring 5 for the cognitive dimension), was confident in her ability to make a cup of tea (reflected by a 5 for the affective dimension), but had little experience in making a cup of tea (denoted by assigning a score of 2 for the psychomotor dimension). In addition to the PPI, a true/false question and a multiple-choice question related to students' knowledge of the technique were implemented on the buret badge to target two misconceptions that were revealed during pilot testing: students incorrectly believed that the buret must be filled to the 0 mL mark for the initial volume reading and were unaware of the precision of the buret. Thus, the two questions on the post survey are designed to test their knowledge. The survey items for each badge are shown in Boxes 3 and 4.

Box 3. Participant Perception Indicator survey questions for the Buret Badge.

Statement	Knowledge Low High	Experience Low High	Confidence Low High
1. Identify a buret from among pieces of glassware.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
2. Properly clamp a buret.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
3. Correctly fill a buret with solution.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
4. Correctly read the volume of liquid in a buret to the correct number of decimal places.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
5. Use a buret to measure and dispense a volume of liquid.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Maximum score for each domain = 25

6. *True/False In order to get accurate measurements when using a buret, the liquid must start at the 0 mL mark (i.e. the buret is full).

7. *To what degree of precision should you read the volume of a buret?

   a. To the nearest 1mL
   b. To the nearest 0.1mL
   c. To the nearest 0.01 mL
   d. To the nearest 0.001 mL

*Only included in post survey

Box 4. Participant Perception Indicator survey questions for the Volumetric Flask Badge.

Statement	Knowledge Low High	Experience Low High	Confidence Low High
1. Identify a volumetric flask from among pieces of glassware.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
2. Identify the calibration line on a volumetric flask.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
3. Properly fill a volumetric flask to prepare a solution.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
4. Know the volume of a volumetric flask to the appropriate decimal place.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Maximum score for each domain = 20

Implementation in Chemistry 11100

Chemistry 11100 is a first semester general chemistry course with a lecture and required laboratory. It primarily serves students in the College of Health and Human Sciences and the College of Agriculture with an enrollment of approximately 1000 students. The results of a 2012 survey implemented in Chemistry 11100 revealed that 30% of the students had completed five or fewer chemistry laboratories in high school. Thus, nearly one-third of the class has had limited experience engaging in hands-on chemistry laboratory activities and deserves particular attention

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to development of hands-on laboratory skills such as the digital badging approach.

The flow of activities to earn a digital badge is shown in Figure 3 where the students complete the tasks in the purple boxes and the instructors complete the tasks in the aqua hexagons. The volumetric flask badge was made available to the students for 2 weeks, beginning during the third lab session of the semester. At the end of the experiment each student created a video in the laboratory using their own device (usually a phone or tablet) for filming following the instructions in Box 2. Each student submitted his or her video through the Passport app.[29] Then, the student completed the retrospective-pre and post PPI surveys within the Passport app as shown in Figure 3.

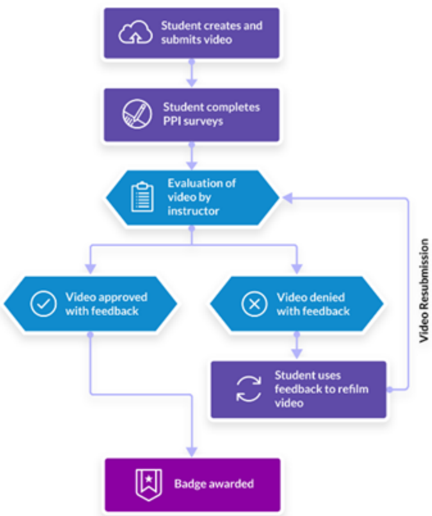

Figure 3. Flow of activities in earning a digital badge where the student completes the purple squares and the instructor completes the aqua hexagons.

An instructor or teaching assistant evaluated each student video using the steps in Box 2 as criteria and gave individual feedback on the student's technique via a textbox within the app and designated the video as approved or denied as shown in Figure 3. If denied, the student could use the feedback to improve his/her technique and subsequently film a new video during the next laboratory period. This video could be submitted for evaluation as shown in the video resubmission loop on the right side of Figure 3.

Evaluation of the videos using the instructions in Box 2 as criteria was discussed with teaching assistants during a staff meeting to normalize the evaluation across all sections in the course. Sample feedback statements to the students were discussed with an emphasis on identifying mistakes and improving the student's technique. For example, if a student filled the flask above the calibration line and then poured out the excess and added solvent back in so that the meniscus was at the calibration line, the video was denied, and the teaching assistant recommended adding the solvent slowly with an eye dropper to reach the calibration mark. For approved videos, the teaching assistants gave positive feedback indicating that the student used the correct technique. Evaluating a lab section of 24 videos required between 45 and 75 min. The teaching assistants noted that they were able to evaluate the videos faster as they became more experienced.

The buret badge was implemented in Chemistry 11100 at the ninth lab session and was also available for 2 weeks. Implementation of the buret badge followed the same steps as shown in Figure 3. A discussion was held in staff meeting with the teaching assistants to normalize the grading across sections. The instructions in Box 1 were used as criteria for evaluating the videos. For example, if a student did not read the initial or final volume correctly, the teaching assistants were told to deny the video and give helpful feedback to the student indicating that the buret should be read from the top down to the correct number of significant figures. Teaching assistants required the same range of time to evaluate 24 videos in a laboratory section and similarly noted that the time to evaluate videos decreased as they gained experience.

A badge was awarded to a student after a video was approved and both PPI surveys were completed. Each badge was worth five points out of 1000 points in the course.

In addition to the student self-assessment of learning, an independent measure was used to evaluate students' understanding of using the glassware through examinations. Multiple-choice questions relating to reading and using a buret and making a solution in a volumetric flask were included on the second and third examination and the final. All examinations include questions about the laboratory since it is a required part of the course.

Implementation in Chemistry 11600

Chemistry 11600 is a second semester general chemistry course with a required lecture, laboratory, and recitation primarily for students in the College of Science and College of Engineering. The enrollment in the fall semester was approximately 420. The students in this course have taken prior college chemistry courses and/or have had one to two high school high school chemistry courses, which provides them with a greater degree of experience with hands-on laboratory techniques and various pieces of glassware than the Chemistry 11100 students.

The buret badge was implemented in Chemistry 11600 at week seven and remained available for 4 weeks due to a holiday break in the academic calendar. As with Chemistry 11100, this allowed students whose initial videos were denied to film another video for submission after reflecting on the feedback they received from their instructors. The implementation followed the same pattern as shown in Figure 3, and the badge was worth 5 points out of 1050 points in the course.

Analysis

For each badge implemented in a course, summing the students' responses for knowledge, confidence, and experience for the retrospective-pre and post-test survey resulted in three pairs of composite scores to be compared. The assumption of normality for each composite score was tested using the Kolmolgorov–Smirnov test. If nonparametric tests were indicated, then they were carried out, and the appropriate effect size measures were calculated. Effect size measures for nonparametric statistics are somewhat less intuitive since they are not as easily interpreted as a Cohen's *d* which is measured in units of standard deviation or the pooled standard deviation. However, given that for large

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Table 1. Results for Chemistry 11100 Buret Badge PPI surveys

Survey	Mean[a] (N = 681)	Standard Deviation	Z Value[b]	Effect Size Measure
Knowledge RetroPre	16.13	6.81	−19.1	0.52
Knowledge Post	22.64	2.98		
Confidence RetroPre	16.39	6.67	−18.9	0.51
Confidence Post	22.64	2.97		
Experience RetroPre	15.28	7.17	−19.1	0.52
Experience Post	22.14	3.53		

[a]Maximum value of 25. [b]Significant at $p < 0.001$.

sample sizes statistical significance is often found, it is important to comment upon the practical importance through effect size measures. A summary of responses to individual questions for all survey items across both badges is presented in the Supporting Information. The percentage correct was calculated for all multiple-choice examination questions.

Validity and Reliability

The method of creation of the PPI instruments and badging instructions supports their validity. Chemistry instructors and chemistry education researchers referenced best practices and the students' laboratory manual instructions to ensure content validity of the PPI items and instructions for badging. Reliability of the PPI was assessed using Cronbach's α. The surveys for both badges showed high reliability (buret $\alpha = 0.944$, volumetric flask $\alpha = 0.947$) likely due to the repetition of survey items across the three domains of knowledge, confidence, and experience as well as the very narrow scope of the items on each survey. Student self-assessment has been shown to be a reliable and valid technique especially when students understand the criteria used and the instrument focuses on performances they perceive to be important.[23]

■ RESULTS

Buret Badge

In Chemistry 11100, 681 out of 1013 students submitted an approved video and completed both the PPI surveys. Of those 681 students, 107 had their first video denied and resubmitted a revised video that was approved. To determine if the assumption of normality held, the Kolmogorov−Smirnov test was used. The results for the knowledge, confidence, and experience composite scores for the retrospective-pre and post survey indicated that the data was not normally distributed, as is often the case with Likert scale data.

A Wilcoxon Signed Ranks Test was used to analyze the scores, and the results are displayed in Table 1. The analysis indicates that the post-test scores are statistically significantly higher than the retrospective-pre scores for the students' self-reported knowledge, confidence, and experience. An effect size measure was calculated by dividing the Z value by the square root of the number of observations.[30] For each comparison, the effect size is large, greater than 0.50, and indicates a practical significance.

Table 2. Results for Chemistry 11100 Buret Badge Knowledge Question: To What Degree of Precision Should You Read the Volume of the Buret?

Response	Distribution of Responses (N = 681)
A. 1 mL	3.4%
B. 0.1 mL	23.1%
C. 0.01 mL[a]	72.2%
D. 0.001 mL	1.3%

[a]Correct response.

Given that some these students have not completed many laboratories it is interesting to identify the statements in the PPI with the largest changes. The item with the largest change was in the Experience domain, "use a buret to measure and dispense a volume of liquid". Looking across all three domains the single item that had the first or second largest change was "identify a buret".

As a part of the post survey two questions were asked related to students' knowledge of using a buret as shown in Box 2. For the true/false question regarding filling a buret, the 74% of students correctly answered that the buret does not need to be filled to the

Box 5: Question on the final exam requiring students (N=968) to calculate a final buret reading by reading the buret shown in the figure and performing a calculation. The distribution of responses is presented in parentheses and (d) is the correct response.

A student is ready to begin a titration using the buret set up shown below. What will be the buret reading after she dispenses 14.50 mL of solution from the buret?

(a) 7.85 mL (11.5%)
(b) 14.50 mL (1.2%)
(c) 21.00 mL (6.8%)
(d) 21.15 mL (73.3%)
(e) 21.85 mL (7.1%)

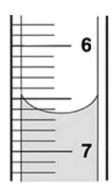

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Table 3. Results for Chemistry 11100 Volumetric Flask Badge PPI surveys

Survey	Mean[a] ($N = 766$)	Standard Deviation	Z Values[b]	Effect Size Measure
Knowledge RetroPre	14.18	4.19	−19.9	0.51
Knowledge Post	18.18	2.13		
Confidence RetroPre	14.27	4.09	−19.9	0.51
Confidence Post	18.17	2.19		
Experience RetroPre	13.47	4.48	−20.3	0.52
Experience Post	17.71	2.54		

[a]Maximum value of 20. [b]Significant at $p < 0.001$.

Table 4. Results for Chemistry 11600 Buret Badge PPI Surveys

Survey	Mean[a] ($N = 270$)	Standard Deviation	Z Values[b]	Effect Size Measures
Knowledge RetroPre	22.51	2.84	−8.0	0.34
Knowledge Post	23.59	2.30		
Confidence RetroPre	22.35	2.97	−7.9	0.34
Confidence Post	23.39	2.48		
Experience RetroPre	22.23	3.05	−8.3	0.36
Experience Post	23.34	2.60		

[a]Maximum value of 25. [b]Significant at $p < 0.001$.

0 mL mark obtain accurate results. The results of the multiple-choice question regarding the precision of a buret are summarized in Table 2, and 72.2% of the students responded correctly.

Questions about properly reading a buret were asked on exam three and on the final exam. On exam three 85% of the students correctly responded to a question that required reading the volume of liquid shown in a figure of a buret to the correct precision. The question appearing on the final is shown in Box 5. This item required the students to read the initial volume correctly, imagine dispensing 14.50 mL of liquid, then calculate the final volume. For this question, 73.3% of students answered correctly.

Volumetric Flask Badge

For this badge 766 students submitted an approved video and completed both PPI surveys. Among those 766 students, 39 had their first video denied and resubmitted a revised video that was approved. The knowledge, confidence, and experience composite scores were tested for normality using the Kolmogorov–Smirnov test. For each score on the retrospective-pre and post-test, $p < 0.001$ indicating that the data was not normally distributed as is often the case with Likert scale data.

Thus, a Wilcoxson Signed-Ranks Test was used to analyze the scores, and the results are shown in Table 3. The analysis indicates that the post-test scores were statistically significantly higher than the retrospective-pre scores for the students' self-reported knowledge, confidence, and experience. An effect size measure was calculated by dividing the Z value by the square root of the number of observations.[30] For each comparison, the effect size is large (greater than 0.50) and indicates a practical significance.

On exam two, a question was asked about the reason for inverting the flask several times when preparing a solution in a volumetric flask when the final small volume of solvent (water) was being added so that the bottom of the meniscus was at the calibration line. On this exam question, 94.7% of students answered correctly that it was to completely mix the solution.

Implementation in Multiple Courses: Chemistry 11600

To assess the badge's performance across courses, the buret badge was implemented in Chemistry 11600, a second semester general chemistry course serving students in the College of Engineering and College of Science. In total, 270 students completed the badge with usable survey and video data. Of that group, 109 students had their first video denied and resubmitted a revised buret video that was approved. As with the Chemistry 11100 data, the Kolmogorov–Smirnov test indicated that the data was not normally distributed; thus, a Wilcoxson Signed-Ranks Test was used. The analysis shown in Table 4 demonstrates that the post-test scores were statistically significantly higher than the pretest scores. The effect size measures were in the medium range.[30]

On the true/false question about buret knowledge (see Box 2), 79% of the 270 students correctly answered false. The results of the multiple-choice question regarding buret precision are shown in Table 5, and 82% responded correctly.

Table 5. Results for Chemistry 116000 Buret Badge Knowledge Question: To What Degree of Precision Should You Read the Volume of the Buret?

Response	Distribution of Responses ($N = 270$)
A. 1 mL	1.24%
B. 0.1 mL	15.22%
C. 0.01 mL[a]	82.61%
D. 0.001 mL	0.93%

[a]Correct response.

■ DISCUSSION

The results of this project demonstrate that digital badges can be used to assess multiple hands-on skills in general chemistry laboratory. The videos provided direct evidence of the students' hands-on skills with each piece of equipment, and served as documentation of their learning. Through this digital badging project, students received individual feedback and were able to improve their technique in a targeted manner.

Chemistry 11100 students reported large, statistically significant increases in knowledge, confidence, and experience for both badges. This finding corresponds well to this group of students' initial lack of experience in chemistry laboratory and their perceived increases after learning more about the

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equipment and how to use it. Chemistry 11100 students perceived substantial gains in their ability to identify and use the equipment.

The buret badge performed well across multiple course settings. The PPI retrospective-pre survey revealed that the Chemistry 11600 students started out with higher self-perceived knowledge, confidence, and experience than the Chemistry 11100 students. They also made statistically significant gains, which were smaller in magnitude than those of the Chemistry 11100 students, and revealed medium effect sizes. These results were expected and support the face validity of the students' self-assessment. Chemistry 11600 students have either taken one or two semesters of college chemistry and/or have taken one or two years of high school chemistry and had more opportunities to use laboratory equipment. Thus, the PPI survey performed as expected, supporting its use as a measure of the students' self-assessment of the constructs of identifying and using a buret, and measurement of the knowledge, confidence, and experience of different student populations. This analysis also demonstrates that badges can benefit students who have already had experience with a lab technique. The students did experience further improvement of their hands-on lab skills and have increased perceptions of success.

We noted in CHM 11600 for the buret badge that a higher percentage of students had their first video denied than in CHM 11000. The evaluation criteria were the same in both classes, and the evaluation criteria was discussed at staff meeting in both courses. Among the denied videos in CHM 11600, the most frequent mistake was reading the buret from the bottom up rather than the top down.

In both courses, a majority of students responded correctly that the initial volume reading of a buret does not need to be 0 mL. The majority of students were also able to identify the correct degree of precision to which a buret should be read. In conjunction with the self-reported data, this provides an objective benchmark with which the students' self-assessment of their knowledge about their hands-on abilities can be compared and provides further support for the efficacy of the PPI survey as an assessment tool. While these questions do not directly assess hands-on lab skills, the questions require procedural knowledge of how a buret is used in order to obtain the correct answer underscoring the utility of the digital badges as a teaching tool. Similarly, the examination results in Chemistry 11100 demonstrate that the majority of students could correctly read the volume of the buret and understood how it was used to measure the volume of liquids. The exam questions also provide evidence that knowledge of the use of a buret was retained throughout the semester.

Implications for Classroom Practice

Faculty can use badging in a variety of ways to support learning in courses. In the case of demonstrating proficiency in laboratory skills, faculty could choose to require that students obtain badges before moving on in the laboratory curriculum. For example, if students are using expensive or hazardous reagents or equipment, the faculty might choose to require that students earn a badge to demonstrate how to appropriately and safely use the equipment. In our case we did not require that students obtain a badge as a prerequisite for continuing to work in the lab. However, faculty could structure a course in that manner.

This project used the Passport app[29] from Purdue University, and we note that other types of digital badging apps and software exist such as Badge List, Badgr, Canvabadges, ForAllRubrics, or Peer 2 Peer University.[31] In this project we were fortunate to have colleagues in Teaching and Learning Technologies at Purdue who assisted us in setting up the badges within Passport and in handling any student use issues which emerged. Implementing a new teaching and learning technology requires time for piloting and troubleshooting. Summer sessions are an ideal time to carry out this activity and refine the implementation for fall semester. We encourage faculty to pilot a digital badge before implementing it in a course in order to test how the technology functions on various platforms and to troubleshoot the activity.

Within some badging platforms (including Passport), students can choose to make the badges they earn public demonstrating their skills and competence analogous to obtaining certification in professional specialties. We reviewed the data in this project and found that 1−2% of the students added their badges to a public profile. In this course there was no incentive to make the badges public. However, faculty could construct and implement a digital badging project wherein students earn badges and make them public for a specific purpose such as demonstrating skills that would be useful in a research laboratory or in the field. Faculty outside the course or employers could review the students' public badges including the videos and any other artifacts that students have included to provide evidence of their skills, knowledge, and abilities. This would give faculty and employers another method of evaluating students and could play a role in determining whether a student is offered an undergraduate research position, a research assistantship or internship, or a job interview.

Limitations

We note that there are limitations inherent to this study. One of the measures used in the study, the PPI, relies on student perceptions rather than observation of the students actually carrying out the technique, although the instructors viewed the videos in order to assess students' ability to carry out the technique. Additionally, the examination questions are used as a proxy to assess student knowledge of procedural skills rather than a laboratory practical.

■ CONCLUSIONS

We have established that digital badging is a valid and effective tool for evaluating hands-on laboratory skills. It is useful across the general chemistry laboratory curriculum over multiple hands-on laboratory techniques. Additionally at Purdue we have lowered our laboratory costs through decreasing the amount of equipment that is broken through improper use. Although we have used the Passport app[29] from Purdue University, other types of digital badging apps and software could be implemented.[31] Thus, this digital badging approach is adaptable and portable to other institutions.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.6b00234.

Summary of survey data for all badges (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

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