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Development and Evaluation of an Instrument for Exploring Achievement Emotions of General Chemistry Students: General Chemistry Achievement Emotions Questionnaire

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DEVELOPMENT AND EVALUATION OF AN INSTRUMENT FOR EXPLORING ACHIEVEMENT EMOTIONS OF GENERAL CHEMISTRY STUDENTS: GENERAL CHEMISTRY ACHIEVEMENT EMOTIONS QUESTIONNAIRE

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Has been approved as meeting the requirement for the Degree of Doctor of Philosophy in the College of Natural and Health Sciences in the Department of Chemistry and Biochemistry, Program of Chemical Education

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ABSTRACT

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General Chemistry, a course that is required for many STEM degree programs, is often perceived as a difficult and stress-inducing course by students. One aspect of a student's course experiences that can be measured are achievement emotions. Emotions that students can experience that can affect and are affected by academic performance are called achievement emotions. Achievement emotions, such as anxiety, have been extensively studied in recent years in relation to student performance and retention in different courses. Instruments that have been developed to measure achievement emotions in broad academic settings. However, achievement emotions have been determined to be domain-specific, meaning achievement emotions experienced in one setting can be different to those in a different setting. Therefore, to measure achievement emotions that students experience in a General Chemistry course, an instrument designed to measure these emotions in this setting would need to be developed. The purpose of this study was to design an instrument to explore the connections between achievement emotions and academic achievement of students enrolled in a first-semester General Chemistry course, as well as evaluate how both achievement emotions and academic achievement affect student retention in chemistry.

To create the General Chemistry Achievement Emotions Questionnaire (AEQ-GCHEM), a previously developed achievement emotions instrument (the Shortened Achievement Emotions

Questionnaire) was modified to contain more chemistry-centric language, as well as adding laboratory-specific questions to assess student achievement emotions in general chemistry lab courses, which are often taken in tandem with General Chemistry courses. This instrument was developed through several iterations and given to student populations (N = 1091) across four postsecondary institutions and six semesters. Evidence of reliability and validity was found through the use of qualitative interviews (N = 48), factor analysis, and analyzing the relationships between the achievement emotions and settings. These results suggest that the modifications made to develop the AEQ-GCHEM produced an instrument that can collect reliable and valid data on the achievement emotions experienced by students enrolled in a General Chemistry course.

The achievement emotions of hopelessness in the classroom setting and pride in the testing setting of a General Chemistry course were found to have predictive qualities in regards to a student's academic performance in the course. Hopelessness in the classroom setting was found to have a negative relationship with academic performance, meaning more hopelessness predicted worse academic performance, while pride in the testing setting showed a positive relationship. Through interviews with students, potential sources of these achievement emotions were explored. Further development of these types of instruments and exploration of achievement emotions is necessary for instructors to fully understand student experiences in a General Chemistry course in the development of novel and equitable teaching practices.

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CHAPTER I

INTRODUCTION

Learning is an emotional experience in which emotions influence academic performance and overall academic development (Pekrun, 1992a). The emotions that students experience in a classroom can be tied to a multitude of constructs, such as self-efficacy, learning attitudes, expectations, values, interests, motivation, and achievement, all of which have been studied in an attempt to understand factors influencing how students learn (Flaherty, 2020).

Achievement emotions, proposed by Pekrun (2006) through the control-value theory (CVT) of achievement emotions, are emotions that influence a wide array of constructs, including attitudes and motivations. These emotions consist of affective, cognitive, motivational, and physiological aspects. For example, anxiety can be experienced as tense or uneasy feelings (affective), worrisome thoughts (cognitive), impulses to escape one's situation (motivational), and biological responses such as sweating or dizziness (physiological) (Pekrun et al., 2011). Pekrun et al. have identified nine achievement emotions that predominantly affect students: enjoyment, hope, pride, anger, anxiety, shame, hopelessness, boredom, and relief (2011). Most of these emotions have not been extensively studied; an exception to this is anxiety, which has been studied broadly in recent years as an emotion that has a mostly negative effect on both academic performance and retention in many academic disciplines, such as chemistry and other sciences (Andrew, 1998; Bowen, 1999; Dougherty et al., 1995; Eddy, 2000; Jegede, 2007; Keeves & Morgenstern, 1992; Kurbanoglu et al., 2009; Udo et al., 2004; Uzuntiryaki & Azizoğlu, 2004; Wamser, 2006; Wynstra & Cummings, 1993), early childhood and high school

education (Dweck & Leggett, 1988; Zimmerman et al., 1992), and statistics (Keeley et al., 2008; Papanastasiou & Zembylas, 2008).

Statement of the Problem

Student retention rate is usually defined as the percentage of first-time, full-time college students returning to an institution for a second year of education. For science, technology, engineering, and mathematics (STEM) disciplines, retention has been a concern for more than a decade (Leary et al., 2020; National Research Council, 2012). General Chemistry, a course required for a degree in many science-based fields, is often perceived as a difficult and stress-inducing subject by students (Eddy, 2000; Tai et al., 2005). While the difficulty of the material taught in a chemistry course is an inherent factor in the DFW rates, or the percentage of students that receive a failing grade (D or F) in a course or withdraw from the course, many students have expressed that the way the chemistry course is taught can also have as large of a factor in student retention as the difficulty (Cooper, 2010). For this reason, evidence-based teaching practices have been researched in recent years in the field of chemical education to diminish these effects that reduce student retention (Arnaud, 2014; Frey et al., 2017; Perla et al., 2023; Watson et al., 2020).

Research has also been conducted in the chemical education field to specifically study and attempt to reduce the amount of inequity found to be experienced by marginalized students, such as Black, Indigenous, and Latinx students in STEM degree programs (Carmichael et al., 1986; Ralph & Lewis, 2018; Ralph et al., 2022; Robinson et al., 2019; Witherspoon et al., 2019). Some studies have suggested that minoritized students are more likely to excel at some aspects of a chemistry course while struggling with other aspects when compared to non-minoritized students (Lin et al., 1996), and that the source of these differences could be traced to different

manners of analytical and critical thinking (Clark & Seider, 2020). Based on this evidence, it has been proposed that minoritized students are being excluded from STEM degree programs due to systemic norms entrenched in how students in General Chemistry *should* critically think about chemistry concepts instead of assessing an underlying understanding in concepts (Ralph et al., 2022). Since a student's life experiences can affect their emotional state and emotional experiences, which can in turn affect academic performance (Pekrun et al., 2002), research into how minoritized students *emotionally* experience a General Chemistry course, alongside previous literature of how minoritized students analyze and understand chemistry topics, could be used to shape educational norms, policies, and practices to establish a more equitable chemistry classroom.

Emotional experiences, also known as affect, are linked to achievement and retention in many academic disciplines (Lewis, 2014; Pekrun et al., 2002). Therefore, affect can be seen as especially important in gateway courses, or courses that precede other courses required for a degree program (e.g., the first semester of a two-semester General Chemistry course). These gateway courses, and especially first-semester General Chemistry courses, often have low retention rates, leading to all courses requiring the gateway courses to have low student populations (Chambers & Blake, 2008; Cracolice & Busby, 2015; Freeman et al., 2014).

Pekrun et al. (2011), using the CVT, developed the Achievement Emotion Questionnaire (AEQ) to measure achievement emotions in educational settings. The questionnaire was capable of measuring achievement emotions and correlating them to student motivation, values, and learning strategies (Pekrun et al., 2011). However, the AEQ's length (232 items) could result in a high rate of survey incompletion or inaccurate results due to survey fatigue (Lichtenstein et al., 2008). A shortened version of the AEQ, abbreviated as the AEQ-S, was created to solve the issue

of the original survey's length (Bieleke et al., 2021). Also, studies have shown that achievement emotions are domain-specific, meaning that a student's emotional experiences can vary depending on the setting the student is in (Goetz et al., 2007). For example, the achievement emotions that a student experiences in a physics course will be different constructs entirely from the achievement emotions experienced by that same student in a chemistry course. Likewise, this applies to subdomains as well, where what a student experiences in a biochemistry course would be distinctly different from what that same student would experience in a General Chemistry course. The AEQ-OCHEM, for example, was derived to study achievement emotions in organic chemistry courses (Raker et al., 2018), but no instrument has been developed to measure achievement emotions in a General Chemistry course.

Purpose of the Study

Achievement emotions can be correlated with student motivation, attitudes towards learning, and academic success (Pekrun, 2006). All of these factors have been linked to student retention, which is crucial for instructors to understand in the hopes of employing good education practices (Hall et al., 2013). Due to the difficulty and perception of STEM fields, the retention rate of students in these fields, specifically chemistry, has been a concern of many institutions (Chang et al., 2008; Gasiewski et al., 2012). Since achievement emotions have strong relationships with factors that influence student retention, these emotions have been studied in a variety of academic disciplines. However, achievement emotions have not been studied in a General Chemistry course (typically, the first and second semester of chemistry courses a student would take).

The first objective of this study was to modify an existing instrument to measure achievement emotions in students enrolled in a General Chemistry course. Since achievement

emotions have been shown to be domain-specific, the instrument was crafted with language specific to a student's experience in General Chemistry. This also included adding a component to the instrument to measure achievement emotions in a laboratory setting, since most students enrolled in a General Chemistry lecture course must concurrently enroll in a corresponding General Chemistry laboratory course. The evidence for this objective and other objectives was gathered through a mixed-methods approach, in which both qualitative and quantitative data were analyzed to determine if the objectives were met (Creswell, 2013b).

The second objective of this study was to determine if correlations exist between students' achievement emotions and their academic achievement, or final grade, in their General Chemistry course. By correlating each student's final grade in the course with their score on each emotional scale, the emotions which have the greatest effect on a student's academic performance were explored. The relationship between a student's achievement emotions and intent to continue pursuing a chemistry or STEM degree program was also analyzed to study retention among students enrolled in a General Chemistry course.

The third objective of this study was to explore how demographic factors, such as student race/ethnicity, affect achievement emotions alongside student success and retention.

Research Questions

The purpose of this study was to design an instrument to explore the connections between achievement emotions and academic achievement of students enrolled in a first-semester General Chemistry course, as well as evaluate how both achievement emotions and academic achievement affect student retention in chemistry.

Q1 What modifications of the Shortened Achievement Emotions Questionnaire are needed to produce a brief, general-chemistry-specific Achievement Emotions Questionnaire (AEQ-GCHEM) that measures enjoyment, hope, anger, pride, anxiety, shame, hopelessness, boredom, and relief?

Q2 What validity and reliability evidence supports the use of the AEQ-GCHEM with students in general chemistry?

Q3 To what extent does a student's measured achievement emotions predict academic performance in a first-semester General Chemistry course?

Q4 To what extent do achievement emotions affect retention of students in their degree program that are enrolled in a first-semester General Chemistry course?

Q5 To what extent do students of different demographics, such as race, gender, sexual orientation, employment status, and being a first-generation student, experience achievement emotions differently in a first-semester General Chemistry course?

Significance of the Study

There is a need in the chemical education community to address the affective dispositions and the emotional aspects of learning, known as affective learning, of General Chemistry students. Research in other disciplines has shown the importance of affective learning in education (Dougherty et al., 1995; Lewis, 2014; Marra et al., 2009; National Research Council, 2012; Sawtelle et al., 2012; Wamser, 2006). To further add to this field of research, this study attempts to make the following contributions.

First, this study intends to offer chemistry instructors a new tool for assessing the affective climate of their classrooms, as well as the ability to measure the emotional impact of any new teaching strategies. The modified instrument produced from this study allows instructors to evaluate achievement emotions experienced by students enrolled in a first-semester General Chemistry course in a manner that is neither taxing on the student nor time-consuming for the instructor. The length of this instrument would also allow for instructors to assess their

students' achievement emotions at multiple points throughout the semester, allowing for instructors to further analyze the efficacy of novel instructional methods.

Second, this study could pave the way for testing novel methods in chemistry instruction and curriculum adaptations. Not only does the instrument shed light on how the content delivery of a chemistry course (traditional lecture against a flipped-style course) affects the students' emotional states, but other instructional methods could further be analyzed using this instrument. This would allow instructors to choose the teaching methods that create the emotional environment that they seek to have in the classroom. This instrument could also be used to provide a method of analyzing the efficacy of interventions designed to affect student emotional states, such as anxiety.

Definition of the Terms

Construct – a psychological attribute, which can only be measured by observing the behaviors that represent the construct (Martella et al., 2013)

Control-value theory of achievement emotions – the theory that appraisals of control and values are central to the creation and experience of achievement emotions, which includes activity-related emotions and outcome-related emotions (Pekrun, 2006)

First-semester General Chemistry course – the first course (sometimes referred to as a "gateway" course) of chemistry that most students enrolled in a STEM degree or pre health program are required to complete (Ralph et al., 2022)

Achievement emotions – emotions that are tied directly to achievement activities or achievement outcomes (Pekrun, 2006)

Intrinsic motivation – the degree to which one perceives themself to be participating in a task for reasons such as challenge, curiosity, or mastery (Pintrich et al., 1993)

Extrinsic motivation – the degree to which one perceives themself to be participating in a task for reasons such as grades, rewards, performance, evaluation by others, and competition (Pintrich et al., 1993)

Psychometric analysis – the process to measure the psychological constructs of an individual by analyzing test data.

Expert – An instructor or chemistry education doctoral student that has experience teaching a chemistry lecture or laboratory course.

Assumptions and Delimitations

1. The student population that was sampled for this study is entirely from the United States, specifically from institutions in the Rocky Mountain region, the Midwestern region, and the Southeastern region of the United States. Therefore, the responses to the survey in the study are unlikely to be fully representative of students enrolled in a first-semester General Chemistry course everywhere. Due to this, the study results might have limited generalizability to the entire population of students enrolled in their first semester of General Chemistry.
2. The institutions that students were sampled from for this study have slightly different curricula, policies, teaching philosophies, instructor/student ratios, and demographics. Due to this, some variables of the data collected, such as academic performance, can vary greatly between institutions and may not be indicative of a typical student enrolled in a General Chemistry course. However, for the sake of generalizability, the data from all institutions were combined for much of the analysis of this study.

3. The data gathered in this study were collected from students enrolled in a first-semester General Chemistry course. Therefore, the results may not be generalizable to students enrolled in upper-level chemistry courses or other disciplines.
4. The interview participants were a small sample of volunteers. Therefore, the qualitative data collected might not be representative of the General Chemistry population as a whole.

CHAPTER II

LITERATURE REVIEW

This review is organized into four sections. It begins with a brief history of the control-value theory of achievement emotions. The connection between achievement emotions and education is highlighted. This is followed by an extensive survey of the Achievement Emotions Questionnaire (AEQ) and various iterations of it that were created for different educational fields and demographics. A brief overview of achievement emotions studied in chemistry-related settings is given, followed by a brief discussion on equity in chemical education. Finally, relevant psychometric properties of an assessment instrument are discussed.

The Control-Value Theory of Achievement Emotions

The framework that was used for this study to define the emotions measured and scales used, as well as for validating the instrument, is the control-value theory (CVT) of achievement emotions (Pekrun, 2006). CVT postulates that emotions are experienced in achievement contexts, which includes not only academic settings but also most other domains in life. This theory builds on ideas from the expectancy-value theory of emotion (Pekrun, 1992a), the attributional theory of achievement motivation and emotion (Weiner, 1985), and the broaden-and-build theory of positive emotions (Fredrickson, 2001). By incorporating aspects of these theories, CVT is able to construct a model of emotions that is based on both outcome-related achievement emotions and activity-related achievement emotions.

In line with contemporary models of emotions (Scherer, 2009), CVT views emotions as groups of interrelated processes that are composed of affective, cognitive, motivational, and

physiological components (Pekrun et al., 2011). Keeping with anxiety as an example, anxiety can be seen to be composed of uneasy feelings (affective), worrisome thoughts (cognitive), "fight or flight" impulses (motivational), and various physiological symptoms. Using a model that contains all four of these aspects is of the utmost importance to obtain a complete picture of an emotion such as anxiety. However, most current test anxiety instruments, one of the most common instruments to measure anxiety, only measure the affective, cognitive, and physiological components of anxiety while neglecting the motivational aspect of anxiety (Pekrun et al., 2011). Emotions in this model are then seen as hierarchical in nature. Anxiety, for example, can be seen as a second-order factor, while each component that makes up the emotion (the affective, cognitive, motivational, and physiological components of anxiety) can be seen as a first-order factor that is nested within the second-order factor. All achievement emotions, then, as second-order factors could be considered a part of a student's emotional state and emotional experiences (Pekrun et al., 2011).

Achievement emotions are defined as emotions that are directly linked to achievement activities or achievement outcomes (Pekrun et al., 2011). While past research into achievement emotions had focused only on emotions linked to achievement outcomes including both prospective and retrospective outcomes (Weiner, 1985; Zeidner, 1998), CVT proposes that *activity* emotions are also achievement emotions. Examples of emotions based on outcomes would include hope and anxiety (prospective), as well as pride and shame (retrospective), while examples of emotions based on activity would include enjoyment and boredom.

Another important distinction to make is that achievement emotions are also linked to the setting in which they are experienced (Pekrun et al., 2011). For example, when considering the achievement emotions experienced in academic settings, the emotions can be divided into

emotions felt during class time, while studying, and during a test. To give an example of why this is, the enjoyment a student might experience learning a concept during a lecture might not be the same enjoyment experienced when being assessed on that topic during a test. Therefore, each achievement emotion should be measured separately in various academic settings to obtain a more-complete picture of the achievement emotion as a whole.

On a related note, achievement emotions, as well as emotions generally, can be thought of as either state-like or trait-like emotions (Pekrun et al., 2011). The difference between these types of emotions can be thought of as the time period that the emotions are experienced. State-like emotions are emotions that are experienced due to the specific environment or situation that the individual is in, while trait-like emotions are emotions that are felt generally or habitually by the individual. Test anxiety, for example, can be thought of as trait-like if it is felt before every assessment taken (Zeidner, 1998), but it can also be thought of as state-like if it is felt only before a specific assessment and not others (Spielberger et al., 1976). One can also imagine that many emotions a student might experience over a semester-long course could fluctuate between trait- and state-like, meaning many achievement emotions might not exist as entirely trait- or state-like emotions but as something in between.

It is worth discussing why achievement emotions are experienced. Achievement emotions are experienced when an individual experiences an emotion while either being in control or out of control of an outcome (Pekrun et al., 2011). To understand this principle, one must understand how an individual can evaluate the control they have over an outcome. When evaluating one's control over a situation, one uses either action-control expectancy or outcome-control expectancy as their control appraisal method (Skinner, 1996). Action-control expectancy is the expectation that one can perform the action that they intend to perform; this is more

commonly referred to as self-efficacy in modern education literature (Bandura, 1977). Outcome-control expectancy is the expectation that one's actions will produce a desired result (e.g., studying for an exam will produce a good grade). Hence, achievement emotions are experienced when different conditions of these control appraisal methods are met in academic settings. For instance, enjoyment might be felt when the student appraises themself to have a high amount of action-control expectancy for understanding the material. Conversely, a low amount of action-control expectancy in the classroom could lead to the student experiencing boredom. A high amount of outcome-control expectancy for taking an assessment would induce the feeling of hope, while a low amount would be experienced as hopelessness. It is worth noting that the student must also appraise a level of importance for the action they will perform; if the student values an assessment as having a low level of importance, they could experience little to no anxiety for that assessment, even with a low amount of outcome-control expectancy. Furthermore, the level of control a student feels would also affect the specific achievement emotion experienced. If a student feels some control over an assessment that they have a low amount of outcome-control expectancy for, they might feel anxiety; however, if the same student felt they had *no* control over the same assessment, they might feel hopelessness (Pekrun, 2006).

According to CVT, achievement emotions can affect student learning and academic performance (Pekrun, 2006). Emotions are thought to affect a student's motivation to learn, types of learning strategies used, and a student's regulation of their learning. Pekrun et al. (2011) postulates that positive activating emotions (enjoyment, hope, and pride) promote a student's motivation to learn, flexible learning strategies, and supportive self-regulation, which would all lead to greater academic success. Conversely, negative deactivating emotions (boredom and hopelessness) have the opposite effect on motivation, learning strategies, self-regulation, and

academic success. Positive deactivating (relief) and negative activating (anger, anxiety, and shame) are seen, however, to have more complicated relationships with the above components of student learning. Anxiety, as an example, can reduce one's intrinsic motivation to attain academic success, but anxiety can also raise one's extrinsic motivation at the same time. Anxiety could also promote more rigid learning strategies and self-regulation in students, leading to academic success. Following this reasoning, negative activating emotions could have a positive effect on academic performance (Lane et al., 2005; Turner & Schallert, 2001). However, some research has found that the negative effects from these emotions outweigh the positive effects (Boekaerts, 1993; Hembree, 1988).

The Achievement Emotions Questionnaire

The emotional scales chosen for the AEQ (enjoyment, hope, pride, anxiety, anger, shame, hopelessness, boredom, and relief) were based on two criteria: emotions that have been previously shown to be experienced by students (Pekrun, 1992c; Pekrun et al., 2002) and emotions in the categories discussed before. As previously discussed, emotions can be grouped into activity emotions (enjoyment, boredom, and anger), prospective outcome emotions (hope, hopelessness, and anxiety), and retrospective outcome emotions (relief, pride, and shame). The emotions chosen for the AEQ also represent positive and negative emotions, as well as activating and deactivating emotions. Thus, the AEQ can be said to measure positive activating emotions (enjoyment, hope, and pride), positive deactivating emotions (relief), negative activating emotions (anger, anxiety, and shame), and negative deactivating emotions (boredom and hopelessness). Also, as discussed earlier, separate scales were created for each achievement emotion in the three settings assessed: class-related emotions, learning-related emotions, and testing-related emotions.

The AEQ was created by assembling a list of items to measure the previously noted achievement emotions in each academic setting. The large initial list of items was paired down into a condensed selection of items for each emotion and setting (Pekrun et al., 2002; Titz, 2001). The items chosen from the initial selection were chosen due to the items having strong convergent validity, meaning the item possessed high factor loading for the desired emotion, and divergent validity, meaning the item possessed low factor loading for other emotions. The final iteration of the AEQ possessed 24 scales (eight scales for each of the three settings) each composed of several items scored on a 5-point Likert scale (Pekrun et al., 2011). Each emotion is present in each setting, with the exceptions being relief, which is absent from the class-related and learning-related emotion scales, and boredom, which is replaced with relief for the testing-related emotion scales.

Iterations of the Achievement Emotion Questionnaire

The AEQ and select scales of the AEQ have been used in the education research community to establish relationships between achievement emotions and student learning and academic success. Class-related and learning-related emotions have been shown to be linked to students' achievement goals (Daniels et al., 2009; Mouratidis et al., 2009). Mastery goals have been shown to be linked to activity emotions; performance-approach goals and performance-avoidance goals were shown to be linked to positive and negative achievement emotions, respectively (Pekrun et al., 2009).

Achievement Emotions Questionnaire (AEQ)

The first study using the entire AEQ in a general undergraduate student population was conducted by Pekrun et al. (2011). The study was conducted on a population of undergraduate students in psychology courses at a large Midwestern Canadian university, which represented a

wide array of degree programs. The descriptive statistics produced from the study fell in line with prior research, with most emotion scales producing symmetrical data and the differences between female and male emotional data agreeing with previous literature on the topic (Hembree, 1988; Zeidner, 1998). To summarize, the mean value for most scales was close to 0.5 (on a scale of 0 to 1, where 1 represents experiencing the emotion as much as possible). For all three settings, the positive emotions skewed towards zero, and the negative emotions skewed toward one. For gender differences, female students reported more class-related enjoyment and less class-related anger than their male peers. Additionally, female students reported more learning-related anxiety, more test-related anxiety, and less test-related hope than their male peers.

For internal validity, the data were fit against several models designed for the study. The model that produced the best fit ($CFI > 0.95$, $RMSEA < 0.10$) represented each emotion as a separate latent variable, with each emotion-setting pairing (e.g., anxiety-test) being an aspect, or component, of each emotion (anxiety). Internal validity was also shown by comparing how each emotional scale correlated with each other against how previous literature has shown the emotions should correlate (Pekrun et al., 2004). For reliability, Cronbach's alpha was used for each emotion scale; alpha values ranged from 0.75 to 0.85, demonstrating good to excellent reliability for each emotion scale. For external validity, several relationships were examined. Positive emotions were found to correlate positively with academic control, self-efficacy, and task value, while negative emotions correlated negatively with these same appraisals. Positive activating emotions were found to correlate strongly with student learning and academic performance, but it is worth noting that learning- and testing-related emotions correlated stronger with academic performance than classroom-related emotions. Negative deactivating emotions

uniformly showed negative correlations with student learning and academic performance, as expected. Also as expected, positive deactivating (relief) and negative activating (anger, anxiety, and shame) emotions showed a complex relationship with student learning and academic performance by correlating with lower student intrinsic motivation but higher extrinsic motivation. These correlations indicate that whichever motivation, intrinsic or extrinsic, a student is affected by more would determine the main academic outcome. For instance, a student that responds stronger to extrinsic motivation than intrinsic motivation would perform better academically while experiencing high amounts of anxiety and shame, and the opposite would be true of a student that responds stronger to intrinsic motivation than extrinsic motivation. However, the negative activating emotions showed an overall negative correlation with academic performance on average.

Shortened Achievement Emotions Questionnaire (AEQ-S)

The original AEQ, while extensive in scope of emotions and emotional aspects investigated, is a lengthy instrument, making it difficult to administer in many settings, especially repeatedly. Bieleke et al. (2021) altered the original AEQ to contain fewer items per emotion scale, improving the ability to administer the instrument (AEQ-S). For each emotion-setting combination (e.g., enjoyment-classroom), one item was chosen for each of the four emotional aspects (affective, cognitive, emotional, and physiological). The items chosen were those that demonstrated the highest factor loading in the original AEQ study (Pekrun et al., 2011). Limiting the instrument to just these items shortened it to 96 items from 232 items in the original instrument. The reliability and validity were first analyzed by comparing Pekrun et al.'s 2011 study to the same dataset excluding all data from the items that were removed (referred to as the reanalysis hereafter). A new study was then conducted using the AEQ-S for validation

(Bieleke et al., 2021). The reanalysis showed that the shortened version produces the same emotional data as the original, with the emotional results of the AEQ-S correlating strongly (>0.70) to the results from the original AEQ study. The validation showed that using the AEQ-S in a new population still produced reliable and valid data. The validation of the AEQ-S also shows that emotions could be removed to create a shorter instrument, if desired, and even single-emotion scales from the AEQ-S could be used and still provide meaningful, valid, and reliable data.

Modification of the Mathematics Achievement Emotions Questionnaire (AEQ-M)

Bieleke et al. (2022) also modified an instrument designed to measure achievement emotions in mathematics, AEQ-M (Pekrun et al., 2005), for the purpose of inspecting the validity and reliability of a domain-specific achievement emotion instrument. This study was conducted in two parts: the first part used the original AEQ-M instrument as detailed by Pekrun et al. (2005), while the second part altered the AEQ-M to ensure each emotion scale contained items that measured each component of the emotions: cognitive, motivational, affective, and physiological. The first part of the study confirmed what other studies have found: achievement emotions correlated strongly with academic performance (positively for positive emotions, negatively for negative emotions), achievement emotions correlated strongly with learning strategies and self-efficacy (the correlations behaved similarly as with academic performance), and the reliability and validity of the data were confirmed to be similar to the original study that presented the AEQ (Pekrun et al., 2011) and the AEQ-M (Pekrun et al., 2005). One noteworthy aspect of the study is that the scale and items focused entirely on achievement emotions in mathematics, by measuring seven achievement emotions (enjoyment, pride, anger, anxiety, shame, hopelessness, and boredom) in the domain of mathematics. The results demonstrate that

achievement emotions that are felt in a specific domain can affect the student's performance in that same domain. The second part of the study altered the original AEQ-M to have distinct items to measure each emotion in an affective, cognitive, motivational, or physiological sense. This allowed the researchers to segregate the data for each emotion, measuring, for example, how just the *cognitive* aspect of anxiety affects student learning habits and academic performance. The results of the second part of the study showed that each aspect of an emotion correlated with the emotion as a whole; for example, if a student felt more anxiety than the average student, they would feel more affective anxiety (anxious feelings), cognitive anxiety (worrisome thoughts), motivational anxiety (desire to leave), and physiological anxiety (queasiness) than the average student. Some limitations of this study are that the study was conducted on students in a secondary school in Germany, and that the study did not analyze for differences in gender among the student populations. Due to this, the AEQ-M and altered AEQ-M could yield different results depending on the population analyzed. It should be noted, however, that studies have found mathematical emotions to consistently affect students equally regardless of culture and gender (Frenzel et al., 2007a, 2007b).

The Achievement Emotions Questionnaire for Pre-Adolescents (AEQ-PA)

Peixoto et al. (2015) developed the AEQ-PA to measure achievement emotions in Portuguese students aged 10-13 years. This study was conducted in two parts. The first part of the study translated and shortened the original AEQ to measure achievement emotions in the population mentioned. Interviews were conducted with students to ensure the translation was interpreted as the original prompt. The number of items in each emotion-setting scale was reduced to six, retaining the items with the highest factor loadings in the original AEQ study. Also removed were the learning-related achievement emotions, as the researchers felt that the

learning-related emotions were not as impactful as class- and test-related emotions as the education level of the subjects. Confirmatory factor analysis was conducted on this part of the study, resulting in poor fit and difficulty identifying clear factors, indicating that the data did not conform to the CVT the instrument was designed around.

The second part of this study involved altering the AEQ-PA used in the first part to produce valid data that supported the CVT. Analysis of the data from the first part of the study indicated that the hope scales showed strong correlations with pride, hope, and enjoyment, and that the anxiety and shame scales showed strong correlation. Based on this, the hope and shame scales were removed from the instrument, retaining the most well-researched emotions. The modified AEQ-PA now contains six items of each emotion (enjoyment, pride, anxiety, anger, hopelessness, boredom, and relief) and two settings (class and test). The data produced by this version of the AEQ-PA were found to be valid, with acceptable values from confirmatory factor analysis. The descriptive statistics from this instrument showed similar results as previous iterations of the AEQ, with most achievement emotion scales producing symmetrical data and the negative achievement emotions skewing higher (being experienced stronger) than the positive achievement emotions (Peixoto et al., 2015).

Survey of Achievement Emotions Previously Studied in Chemistry

While achievement emotions have been explored in an organic chemistry setting (Raker et al., 2018), and the general emotional state of students have been explored in General Chemistry (Bauer, 2008; Jeffery & Bauer, 2020), achievement emotions have not been explored in a General Chemistry setting. Only one achievement emotion, anxiety, has been studied extensively in chemistry (including General Chemistry) settings. This section of the review gives

a brief summary of anxiety studies in General Chemistry. Then, the results of a study where the AEQ was modified for use in an organic chemistry setting are detailed.

Anxiety in Chemistry

Chemistry can be a difficult subject for many students. The cognitive demands asked of a student in a General Chemistry course from solving algebraic expressions to comprehending abstract chemical representations, all while solidifying an understanding of the periodic table and chemical trends. The difficulties that students experience with this cognitive load are, in part, responsible for the high DFW rates and low retention seen in General Chemistry (Lewis, 2014). These factors, both the difficulty of General Chemistry and the *perceived* difficulty of General Chemistry from resulting DFW rates, can lead to an increase in anxiety in General Chemistry students (Widanski & McCarthy, 2009). This feeling of anxiety that is induced by the subject of chemistry has been occasionally colloquially called "chemophobia" (Berdonosov et al., 1999; Eddy, 2000). While this term might not be universally used in the chemical education community, the feeling of *fear* in chemistry that the term evokes is universally understood by much of the chemistry population and especially the General Chemistry student population (Abendroth & Friedman, 1983). Anxiety has been shown to negatively affect academic performance both generally (Spielberger, 1966) and in chemistry-specific environments (Abendroth & Friedman, 1983).

A three-factor, 36-item survey called the Derived Chemistry Anxiety Rating Scale (DCARS) was designed to measure anxiety experienced in chemistry students (Eddy, 2000). The three factors of the survey are separate aspects of the anxiety a chemistry student might experience: learning-related anxiety, evaluation-related anxiety, and anxiety related to handling chemicals. The instrument was derived from a survey used to measure math anxiety in students

(RMARS; Plake & Parker, 1982), since math anxiety and chemistry anxiety were determined to be analogous (Eddy, 2000). The DCARS was adapted by replacing math terminology and concepts with chemistry terminology and concepts. It is worth noting that some of these modified items were ultimately removed from the DCARS due to more than 70% of subjects reporting the lowest levels of anxiety as a response; the researcher posits that this could indicate that some aspects of math anxiety are not analogous to chemistry anxiety. The results of the survey on a population of college students in an introductory chemistry course were analyzed to determine if some demographics of the students experienced higher levels of anxiety. Women were found to experience significantly higher levels of anxiety than men. Chemistry experience was also shown to play a role in the level of anxiety experienced, as students with low chemistry experience (defined in the study as students with two or fewer prior chemistry courses taken in high school or college) experiencing significantly more anxiety than students with high chemistry experience (more than two prior chemistry courses taken). However, the type of major or degree program of the student had no effect on the level of anxiety experienced, and the students with low math experience (defined as less than five prior math courses in high school or college) possessed the same amount of anxiety as students with high math experience.

The DCARS was employed in a more recent study to further examine the demographics present in a university student population for differences in the amount of anxiety experienced (Widanski & McCarthy, 2009). Similar results to the previous study discussed were found in this readministration of the instrument. Women were found to experience higher levels of anxiety than men, but only in evaluation-related chemistry anxiety. Several majors and degree programs were analyzed, and while some majors, such as business major students, seemed to experience anxiety at a much higher level in all aspects of chemistry than other majors and degree programs,

the only significant difference present in the data was that science majors experienced significantly less anxiety than other majors. Also, as found in the previous DCARS study discussed, having previous experience with a chemistry course correlated with experiencing less learning-related chemistry anxiety and evaluation-related chemistry anxiety. Since these DCARS studies produced conflicting results on how a student's major and degree program could impact the anxiety experienced in a chemistry course, further research should be conducted to determine the relationship.

Since high levels of anxiety have been shown to affect academic performance in chemistry courses (Eddy, 2000; Mahajan & Singh, 2005), many studies have been conducted using interventions, both pre- and post-test as well as intratest, to reduce the amount of anxiety experienced in chemistry students (Brodersen, 2017). Pre- and post-test interventions occur outside of an assessment; some examples of this type of intervention are study skills training, anxiety management training, stress inoculation training, counseling, exam analysis, pet therapy, exercise, and many more (Quinn & Peters, 2017; Zeidner, 1995). Intratest interventions, on the other hand, occur during an assessment; some examples of this type of intervention are music therapy, aromatherapy, the allowance of cheat sheets during an assessment, and collaborative testing (Rempel et al., 2021; Soares & Woods, 2020). While no consensus has been reached on which interventions are most effective at reducing anxiety levels in chemistry students, the literature suggests that understanding and attempting to reduce the amount of anxiety experienced by chemistry students is beneficial to both the students' academic performance and student retention in chemistry (Rempel et al., 2021).

Organic Chemistry-Specific Achievement Emotions Questionnaire (AEQ-OCHEM)

An Achievement Emotions Questionnaire was developed to measure achievement emotions in organic chemistry courses (Raker et al., 2018). The goal of the study was to develop an instrument to measure achievement emotions in students enrolled in organic chemistry courses, with the goal of correlating the achievement emotions to success and persistence in the course, as well as retention in chemistry education. The AEQ-OCHEM was created by modifying the AEQ by inserting references to organic chemistry throughout the instructions and items as appropriate, as well as including references to common aspects of an organic chemistry course (e.g., problem sets, homework, etc.). The researchers determined that the modification of the instrument was successful in creating a survey to measure achievement emotions in students in an organic chemistry class through analysis of the validity and reliability of the data.

For internal validity, confirmatory factor analysis (CFA) was employed to determine if the data fit onto the proposed CVT model used in the instrument's design. A model in which each of the nine achievement emotions represented a separate factor and each setting within an emotion was correlated to the other settings (i.e., classroom-enjoyment, learning enjoyment, and testing enjoyment were correlated together in the model) produced an adequate fit. Also, for internal validity, the correlations between emotions were calculated, resulting in positive emotions correlating positively with other positive emotions, negative emotions correlating positively with other negative emotions, and positive emotions correlating negatively with negative emotions. CVT predicts these correlations, supporting the internal validity of the data (Pekrun et al., 2011; Raker et al., 2018). External validity was evaluated by associating the AEQ-OCHEM with academic performance, as well as external study measures, such as subscales of the Motivated Strategies for Learning Questionnaire (Pintrich, 1991), the Academic Motivation

Scale - Chemistry (Liu et al., 2017), and the Regulation of Learning Questionnaire (McCardle & Hadwin, 2015). These subscales measure various attitudes and motivations in chemistry students. Since motivations and attitudes are thought to correlate to achievement emotions (Pekrun, 2006), the correlations were examined to determine if this facet of CVT was shown in the data. The researchers found that the correlations expected through CVT were shown in the data; an example of this would be that the enjoyment-classroom scale (a positive, activating achievement emotion) correlated positively with the student possessing active studying habits. Reliability was evaluated by measuring Cronbach's alpha for each emotion-setting subscale and was found to be at least "good" for all scales and "excellent" for most (Raker et al., 2018).

This study showed that the AEQ can be adapted to a specific academic setting and still produce reliable and valid data. However, the researchers note that some limitations currently restrict the usefulness of the instrument and the study. First, the AEQ-OCHEM was adapted from the AEQ, not the AEQ-S, meaning that the AEQ-OCHEM contains 216 items, leading to a high risk of survey fatigue in participants. This also restricts the settings that the instrument can be administered in, as a survey this large will take an amount of time that an instructor might not wish to cede to the researcher. Second, this study lacked qualitative data to support the validation of the AEQ-OCHEM, which could have provided more insights into how participants were interpreting the instructions and items of the survey (Arjoon et al., 2013; Raker et al., 2018). Finally, the researchers note that a section exploring the achievement emotions in a laboratory setting could be necessary for fully understanding how achievement emotions affect chemistry students, due to the laboratory setting developing important cognitive and psychomotor skills in undergraduate chemistry students (Raker et al., 2018).

Equity in Chemistry

Equity, in the context of a chemistry classroom, can be defined as when a chemistry course allocates opportunities and resources according to each student's circumstances to reach equal outcomes (Van Dusen et al., 2022). Van Dusen et al. (2022) went on to describe equality of outcomes as when students of different gender, race, or ethnic groups possess the same average academic achievement at the end of the course and are not owed any "educational debts" (p. 4). These educational debts are ways that society, through marginalization such as racism and sexism, has forgone schooling resources to students; students with educational debt are not equally prepared to succeed in a course, leading to less academic achievement than peers without this debt, which could propagate more educational debt in the process (Ladson-Billings, 2006). Equality of outcome, then, is achieved when a course uses equitable practices to repay students' educational debts (Van Dusen et al., 2022).

Equity has been a concern of the chemical education community for decades. In the 1990s, the National Science Foundation (NSF) funded millions of dollars to a chemistry reform initiative to research proposals focused on creating fundamental change in the undergraduate chemistry curriculum (Lagowski, 1994). Many reform movements took place during this time, seeking goals such as improving student academic outcomes, increasing appreciation for science, and making chemistry education more accessible and interesting to a broader student population. However, Lagowski (1994) critiqued that this reform should have been less focused on curriculum changes as a means to achieve system change. As Lagowski (1994) claims, equity issues should be addressed through changes not only to curriculum but also to assessment, social organization, teacher education programs, general pedagogy, and academic standards.

In a study of courses offered at six institutions, 22% of identified weed-out courses were chemistry courses, with weed-out courses being defined as courses with high enrollment, are required for majors, and have high DFW rates (Arnaud, 2020). Arnaud (2020) found that students with marginalized identities, particularly Black and Latinx students, were more affected by weed-out courses, having DFW rates more than 10% higher than the average student. It is important to note that these higher DFW rates are leading to marginalized students leaving STEM majors at higher rates, even though these students possess the same amount of interest in STEM majors as their nonmarginalized peers (Harris et al., 2020).

Emotions, generally, and achievement emotions, specifically, have been studied in various academic domains with regards to gender. Emotions in post-secondary mathematics courses have been studied (Frenzel et al., 2007a) as well as achievement emotions, specifically, in mathematics (Bieleke et al., 2022). The only conclusions drawn in these studies were that women tend to experience higher levels of anxiety in test settings, which aligns with previous literature on anxiety (Hembree, 1988; Zeidner, 1998). Frenzel et al. (2007a) argue that emotional differences between men and women (and differences between other marginalized groups of students) could be difficult to measure due to women, for example, responding to an item in an instrument in the way they think they are *expected to* rather than how they truly feel. However, there is a lack of analysis of desegregated data based on ethnicity, sexual orientation, and other marginalizations that students could experience and result in educational debt. Since a cause of educational debt is that marginalized students possess unique *experiences* that result in educational debt that nonmarginalized students do not have, *emotional experiences* and how students respond to emotional prompts must be considered when discussing equity (Killermann, 2017).

Psychometrics

Assessments, in a psychological sense, are given to measure some attribute of a subject. Psychometrics is the area of study concerned with these psychological measurements, such as aptitude, intelligence, motivation, depression, anxiety, hope, and many others. Psychometrics is concerned with the attributes of the assessment rather than the attributes of the subject being assessed (Furr & Bacharach, 2013). Since assessments are designed to evaluate the attributes of people, the attributes of the assessment should also be evaluated to ensure the assessment will adequately function as intended by the researcher. Furr and Bacharach (2013) note that "If something… is not measured well, then it cannot be studied with any scientific validity." The two attributes of psychometrics that this section will focus on are validity and reliability. These attributes are important because assessments should produce data that can be interpreted both accurately (validity) and consistently (reliability).

Validity

Validity is, in essence, how the data of an assessment are interpreted in relation to the attribute being measured (Messick, 1995), or, plainly put, what the assessment scores mean. Validity is not a property of the assessment (Furr & Bacharach, 2013), but rather it is "the degree to which evidence and theory support the interpretations of test scores entailed by the proposed uses" (American Education Research Association (AERA) et al., 1999, p. 9). Validity is a measure of how the data can be interpreted to agree with the consensus of how the attributes being measured actually are. To give an example, a balance that can measure mass might give accurate readings for the mass of an orange on Earth, since most balances are calibrated to measure mass using Earth's gravity. However, if the balance and orange were moved to the Moon and the assessment reconducted, the value would be different due to the difference in the

Moon's gravitational force. The mass of the orange did not change, as mass is a constant value, but the assessment returned different data due to how the instrument was used. The balance, in this example, is the instrument; the balance itself is never considered valid or not, since the data are what must be considered valid, based on how the instrument was used. The same applies to instruments (surveys) to measure psychological traits, such as anxiety. Just because a survey has been successfully used by others to draw valid conclusions does not mean that the same instrument will always produce valid data. The instrument must be used in conjunction with how it was originally intended to function, and the data should be interpreted how it was intended to be interpreted.

There are several aspects of validity evidence that should be considered when validating an instrument: evidence based on test content, evidence based on response processes, evidence based on internal structure, evidence based on relations to other variables, and evidence based on the consequences of testing (AERA et al., 2014; Knekta et al., 2019). All of these aspects of validity are concerned with ensuring that the items of an instrument collectively represent all of the important aspects of the construct the instrument is measuring. Not every aspect of validity should be held to the same degree of importance by the researcher using them; the researcher should determine which aspects of validity are most important to the instrument being evaluated (Knekta et al., 2019). This section of the review will briefly define each of these aspects of validity.

Evidence Based on Test Content

Evidence based on test content is found by analyzing the relationship between an instrument's content and the construct that the instrument is intended to measure (Knekta et al., 2019). This can be difficult to achieve, as constructs must be measured by observing the

behaviors that are representative of the construct (Martella et al., 2013). An important facet of test content validity is to ensure that the instrument only assesses behaviors that represent the construct (relevant behaviors) but not behaviors that represent separate, but related, constructs (irrelevant behaviors). The degree to which an instrument measures relevant behaviors and ignores irrelevant behaviors is evidence of its test content validity (Murphy & Davidshofer, 2005).

Evidence Based on Response Processes

Evidence based on response processes is found by analyzing how the subjects of an instrument answer the instrument's items (Knekta et al., 2019). When subjects are given an assessment or survey, they engage in certain psychological processes to answer the items in the instrument. It can be assumed by the researcher that each subject utilizes the same processes to answer the items, leading to the assumption that any differences between responses being the result of true differences in the construct being measured. However, this assumption could be false if the subjects are interpreting the items differently and using different psychological processes to arrive at an answer. For example, if a chemistry student was given the prompt, "I feel pride when I succeed in my General Chemistry course.", one student might respond positively to this statement, assessing pride as a positive feeling when they feel their studying habits are rewarded with academic success. However, a different student might interpret pride as a negative feeling, assessing pride as a boastful or arrogant state of mind, leading to a negative response to this prompt. Questions that can be interpreted in several ways should be subjected to thorough investigation to understand the underlying cognitive processes that the subjects would engage in during their responses (AERA, APA, NCME, 1999). Therefore, evidence should be established that respondents to an assessment or survey interpret the items in a consistent

manner, in line with how the researcher intended the items to be interpreted. One method of determining these underlying cognitive processes is to conduct qualitative interviews with participants from the population of interest (AERA et al., 1999; Arjoon et al., 2013).

Evidence Based on Internal Structure

Evidence based on internal structure is found by analyzing the internal relationships between items and scales within the instrument, as well as interpreting how these relationships reflect the model of the measured construct(s) (Knekta et al., 2019). The main method of measuring internal structure validity is factor analysis. Factor analysis is a group of methods that analyze the covariance of sections of the data set to group the data into factors (Brown, 2006). The goal of this analysis is to group the indicators in the data into separate factors, identifying underlying associations between the indicators. The degree to which an indicator correlates to the factor (grouping of indicators) is referred to as factor loading. For example, if a study was conducted to assess anxiety, any items that possessed strong correlations to the subject possessing strong feelings of anxiety, those items would be said to have high factor loading.

Factor analysis can be conducted as either exploratory (referred to as exploratory factor analysis, or EFA) or confirmatory (referred to as confirmatory factor analysis, or CFA). EFA is conducted when the researcher is unsure how the indicators will be grouped into factors. CFA is conducted when either the researcher is aware of how the indicators will fit into factors or if the researcher has a theoretical model to fit the data. For example, the achievement emotions studies previously discussed used CFA as a measure of evidence of internal structure validity since the instrument was designed around the theoretical model of CVT. The researchers are aware of how each item relates to each other and the achievement emotions overall, as well as how each emotion and setting relates to each other. CFA is used to determine the fit of the data to this pre-

existing model of achievement emotions; a strong fit indicates that the data agrees with the theoretical model the researchers assumed is true, which indicates that the data possesses evidence of internal structure validity.

Evidence Based on Relations to Other Variables

Evidence based on relations to other variables can be found by analyzing the relationships of instrument scores to variables external to the instrument and to other instruments that measure the same construct or related constructs (Knekta et al., 2019). Psychological constructs do not exist alone, but rather they operate in concert with other constructs and processes. Due to this, most constructs possess relationships to other constructs, which can be positive or negative in nature. For example, it is assumed that depression is more likely to be correlated with anxiety than happiness will be. Based on this, the scores of an instrument that measures depression should be positively correlated with the scores of an instrument that measures anxiety. When two theoretically related constructs are found to correlate with each other, it is referred to as convergent validity evidence (Furr & Bacharach, 2013). On the other hand, discriminant validity evidence is when two unrelated constructs are found to not correlate with each other (Furr & Bacharach, 2013). These two types of evidence are essential to establishing evidence of validity based on relations to other variables, as it would be expected that the construct an instrument measures should have convergent validity evidence when related to a theoretically similar construct but display discriminant validity evidence when related to a theoretically unrelated construct.

Evidence Based on the Consequences of Testing

Evidence based on the consequences of testing is found by analyzing how the use and interpretation of the data produced by an instrument relates to the proposed purpose of the

instrument (Knekta et al., 2019). Since the validity of data is determined by how accurately the data are interpreted in relation to the construct being measured, one aspect of validity is related to how the interpretation of the data will be used, especially in relation to how the researcher *intended* the data to be used. It is worth noting, however, that this aspect of validity is still highly debated in psychological and educational measurement research (Cizek, 2016; Kane, 2016; Mehrens, 1997).

Reliability

The reliability of an instrument can refer to several aspects of the instrument, such as the consistency of scores over repeat administrations, the correlation between a set of measured data against the true values being measured, the degree to which items in the instrument measure the same construct, and the correlation between instruments that measure the same construct (Martella et al., 2013). All of these aspects are rooted in the principle that a reliable instrument should obtain the same score repeatedly when measuring a single construct. An important distinction between reliability and validity is that reliability does not seek to close the gap between the measured score and the true score for a construct, but rather achieve the same measured score across many items and administrations.

Theory about reliability is based on the notion that the true value of a measurement can never be known, and the error, meaning variation between repeated measures of the same construct, for any given measurement is random (Henson, 2001). Therefore, reliability is not a value as much as it is an estimation, informing the researcher of a range of values that the true value must exist within, assuming the data are valid. Random error is assumed to be present in any given measurement; therefore, any observed score from an assessment is a combination of the true score in addition to some amount of random error.

One of the most common forms of reliability in psychometric literature is the coefficient of internal consistency (Henson, 2001). Two measures of internal consistency that are widely used are Cronbach's alpha (α) and McDonald's omega (ω). Cronbach's alpha uses a formula to sum the covariances between each item-pair that was measured, then placing all of the covariance sums calculated into a formula with the variance scores for the entire instrument (Furr & Bacharach, 2013). The goal of Cronbach's alpha is to ensure that each item possesses an insignificantly different amount of variance (or random error) from each other, ensuring that no one item in the instrument is producing data that possess more random error than another. McDonald's omega uses a similar formulaic method to establish reliability, but McDonald's omega is more appropriate for instruments that use several items to measure the same construct (Hayes & Coutts, 2020). In these cases, Cronbach's alpha assumes that each item possesses the same factor loading for the construct, meaning that each item does an equally acceptable job of measuring the theoretical true value of the construct. However, most instruments possess items with varying factor loadings, meaning some items produce data that fit into the theoretical framework of the researchers to differing degrees. McDonald's omega accounts for this by including the factor loading in the reliability calculations, so that items with low factor loading are not weighed with the same importance as items with higher factor loadings (Hayes & Coutts, 2020).

Summary

Achievement emotions can provide insight into how a student experiences a General Chemistry course, since emotional experiences and learning have been shown to go hand-in-hand. Due to this, an instructor should be aware of how their students are emotionally experiencing the classroom. An instructor approaching from an equity standpoint, particularly,

should be cognizant of how a student's personal experiences through life will affect how they emotionally experience the course and, therefore, affect the ways that the student will learn the material. An instructor's goal should be to ensure that as many students as possible obtain the knowledge they need from a course, which involves ensuring those burdened with educational debt are relieved of it. Being able to measure achievement emotions can provide a lens into how students experience their General Chemistry course, allowing instructors to make curricular and pedagogical changes to the course for the students' benefit.

While many instruments have been designed to measure achievement emotions in various academic settings, no instrument has been designed to measure achievement emotions in General Chemistry courses, a known weed-out course with high DFW rates. The focus of this study was to modify an existing instrument to measure achievement emotions in a General Chemistry-specific context, allowing instructors to gain insight into emotional aspects that could be affecting student performance in ways previously unseen.

CHAPTER III

METHODOLOGY

Measuring achievement emotions in a chemistry classroom can be insightful to instructors in order to analyze how the emotional experiences felt by students, especially minoritized students, can affect their performance in a general chemistry course. The first objective of this study was to modify an existing instrument to measure achievement emotions in students enrolled in a first-semester General Chemistry course. Since achievement emotions have been shown to be domain-specific, the instrument needed to be crafted with language specific to a student's experience in General Chemistry. This also included adding a component to the instrument to measure achievement emotions in a laboratory setting, since most students enrolled in a General Chemistry lecture course must concurrently enroll in a General Chemistry laboratory course. These laboratory achievement emotions have been previously reported in the literature. The evidence for this first objective and other objectives was gathered through a mixed-methods approach, where both qualitative and quantitative data were analyzed to determine if the objectives were met (Creswell, 2013b). Multiple rounds of response process and factor analysis were used to modify the questionnaire and provide evidence of validity for the data collected. The second goal of this study was to determine if correlations exist between students' achievement emotions and their success in the course and retention in their degree program. By correlating each student's final grades in the course with their score on each emotional scale, the emotions which have the greatest effect on a student's academic performance were further explored. Demographic factors, such as student gender, race, ethnicity,

and others, were analyzed to determine if these factors affect how achievement emotions are experienced.

Research Questions

The purpose of this study was to design an instrument to explore the connections between achievement emotions and academic achievement of students enrolled in a first-semester General Chemistry course, as well as evaluate how both achievement emotions and academic achievement affect student retention in chemistry.

Q1 What modifications of the Shortened Achievement Emotions Questionnaire are needed to produce a brief, general-chemistry-specific Achievement Emotions Questionnaire (AEQ-GCHEM) that measures enjoyment, hope, anger, pride, anxiety, shame, hopelessness, boredom, and relief?

Q2 What validity and reliability evidence supports the use of the AEQ-GCHEM with students in general chemistry?

Q3 To what extent does a student's measured achievement emotions predict academic performance in a first-semester General Chemistry course?

Q4 To what extent do achievement emotions affect retention of students in their degree program that are enrolled in a first-semester General Chemistry course?

Q5 To what extent do students of different demographics, such as race, gender, sexual orientation, employment status, and being a first-generation student, experience achievement emotions differently in a first-semester General Chemistry course?

Theoretical Framework

The framework that was used for this study to define the emotions measured and scales used, as well as for validating the data that the instrument produces, is the control value theory of achievement emotions (CVT), which postulates that emotions are experienced in achievement contexts, including not only academic settings but also most other domains in life (Pekrun, 2006). Achievement emotions are defined as emotions that are directly linked to achievement

activities or achievement outcomes, which includes achievement emotions that one would experience prospectively or retrospectively to achievement activities or during achievement activities (Pekrun et al., 2011). Achievement emotions are linked to the setting in which they are experienced (Pekrun et al., 2011). For this study, achievement emotions that students experience in several academic settings were measured: emotions related to time spent in General Chemistry lecture, emotions related to studying for General Chemistry, emotions related to taking a test in General Chemistry, and emotions related to a General Chemistry laboratory course.

Protection of Human Subjects

In accordance with the Institutional Review Board (IRB) at the University of Northern Colorado, approval was requested for any data collection involving human subjects. The appropriate applications were submitted to the IRB prior to collecting any data (Appendix A), and data collection did not commence until approval was received from the IRB. The voluntary nature of the data collection was explicitly stated and emphasized to all potential participants during invitations by the researcher (Appendix B). Once collected, all sensitive data with personal identifiers were stored on a password-protected computer, whereby only the researcher and research advisor have access. Any non-digital data with personal identifiers were stored in a locked environment, such that only the researcher and research advisor have access. Any interview transcripts were labeled with pseudonyms to protect the identity of the participants.

Phase One: Development of the AEQ-GCHEM

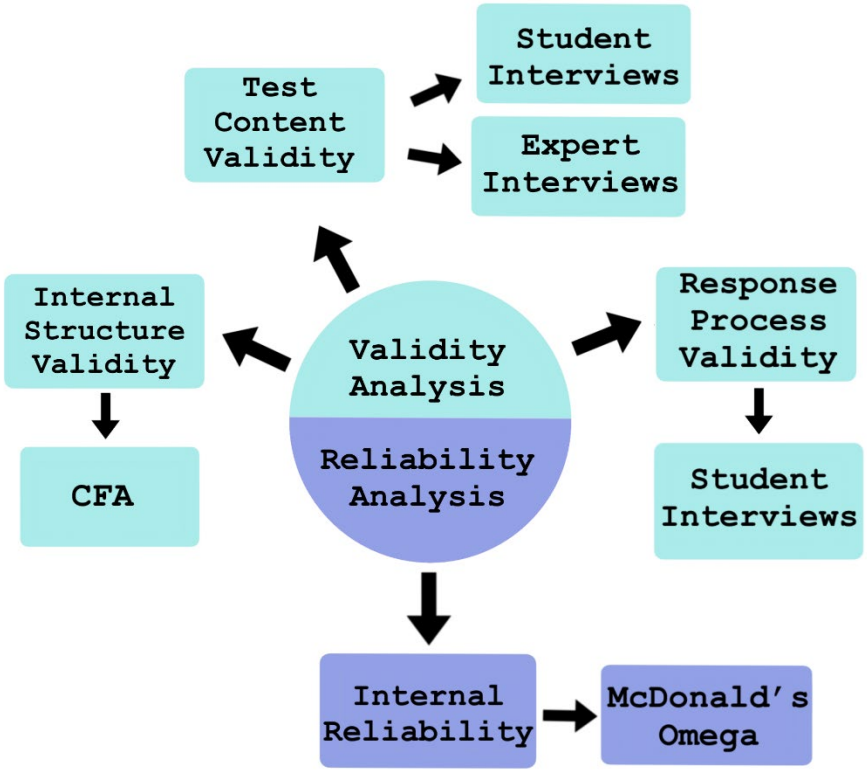
Research Design

The research design employed in this stage of the study was a concurrent nested mixed methods style of research. Mixed methods research blends qualitative and quantitative methods together to enhance the results obtained from both research perspectives. The intent of a mixed

methods design is not only to obtain both quantitative and qualitative data, but to integrate the findings from both methodologies to strengthen the conclusions found (Creswell, 2013b). The qualitative and quantitative data were collected during the same timeframe and from the same population, leading to a concurrent style of mixed methods. In a nested design, one aspect of data collection, either qualitative or quantitative, takes priority while the other aspect is embedded, or nested, in the study (Kroll & Neri, 2009). The goal of this stage was to establish that the instrument modified for this study can produce valid and reliable data (Figure 3.1).

Figure 3.1

Schematic Representation of the Methodology Used to Establish the Validity and Reliability of the Data Collected with the Questionnaire



General Chemistry Achievement Emotions Questionnaire (AEQ-GCHEM)

The shortened version of the Achievement Emotions Questionnaire (AEQ-S; Bieleke et al., 2021) was modified to be used in this study. As Pekrun et al. (2011) note, separate domains of knowledge will evoke separate achievement emotions, meaning that the achievement emotions experienced in a biology classroom will be different from the achievement emotions experienced in a chemistry classroom.

Preliminary Wording Changes

The items from the AEQ-S were modified to contain chemistry-specific language to evoke the subject's achievement emotions, resulting in the General Chemistry Achievement Emotions Questionnaire (AEQ-GCHEM). To give an example, the item from the enjoyment-classroom scale "I enjoy being in class." was modified to be "I enjoy being in chemistry class."

Interviews with experts were conducted to establish face validity, ensuring that each item contained enough chemistry-specific language to evoke an achievement emotion that a student would experience in a chemistry setting. Interviews were also conducted with students to ensure that the meaning of each statement is clear and evokes an emotional response from a chemistry environment and not a general emotional state. Many statements were modified for clarity based on student feedback to secure evidence of response process validity. Some items of the AEQ-S also contain metaphorical language that students inconsistently interpreted; these items were modified accordingly based on qualitative interviews.

AEQ-GCHEM

The AEQ-S contained three achievement emotion settings: classroom, studying, and testing settings. For the AEQ-GCHEM, a laboratory setting was added alongside the existing settings. A laboratory course is a mandatory course taken alongside a General Chemistry course

in which students will obtain practical experience working with chemicals and writing experimental reports (Reid & Shah, 2007). Since it is a different setting than the three settings included in the AEQ-S, the laboratory setting could induce separate achievement emotions than the other settings. Interviews with students were conducted to ensure that experiences in the laboratory course are separate from the lecture course while still being a *chemistry* experience.

The AEQ-GCHEM contains nine emotion scales across four settings, for a total of 32 scales. The achievement emotions that were measured are as follows: enjoyment, hope, pride, anger, anxiety, shame, hopelessness, boredom, and relief. The four settings are the classroom setting, the learning setting, the test setting, and the laboratory setting. Boredom was measured in the test setting but was replaced with relief, which was only measured in the test setting. Each of these emotion-setting pairings creates one scale. Each scale is composed of four statements, each of which is a 5-point Likert scale (ranging from strongly disagree, scored as 1, to strongly agree, scored as 5). The total number of items in the survey was 128 items.

The preliminary wording changes and initial interviews with students and experts resulted in the development of the AEQ-GCHEM Version 1 (Appendix D). Further interviews were conducted with students after administration of the survey for the purpose of finding validity evidence until the survey produced data with an adequate amount of validity and reliability evidence. This resulted in next iteration of the instrument, AEQ-GCHEM Version 2 (Appendix E), and the final iteration of the instrument, the AEQ-GCHEM (Appendix F).

Participants

Participants were gathered at several time points during Phase One to aid in the further development and psychometric analysis of the AEQ-GCHEM. A full breakdown of the sampling during Phase One can be found in Table 3.1.

Quantitative Studies

The target population for the AEQ-GCHEM was students enrolled in a first-semester General Chemistry course. Convenience sampling was used in this study due to resource-based and logistical constraints, meaning student samples were gathered from first-semester General Chemistry courses at four universities described as one mid-sized university in the Rocky Mountain region of the United States (I1), one large university in the Midwest region of the United States (I2), and one small college in the Southern region of the United States (I3), and one large university in the Rocky Mountain region of the United States (I4). These universities were chosen so as to have the data produced by the study to be more representative of the overall population of students enrolled in a first-semester General Chemistry course. All four universities have similar demographic statistics in terms of ethnicity and gender.

Qualitative Studies

Interviews were conducted with students from the target population for the purpose of collecting evidence of response process validity and of test content validity. The last item of the AEQ-GCHEM contained a prompt that asked students to indicate if they would participate in a short interview regarding the survey. Some students were also recruited by announcements made in a lecture or lab setting. Students that accepted to be interviewed were contacted via their school email address which they provided in the survey. Thirty students (N=30) were

interviewed for this study, which has been shown to be enough qualitative interviews to have adequate data saturation (Guest et al., 2006).

Experts were chosen to be interviewed based on convenience sampling to the researcher for the purpose of collecting evidence of test content validity. Experts are defined as chemistry instructors or chemical education doctoral students that have experience in teaching chemistry.

Table 3.1.

Breakdown of Participant Recruitment During Phase One

Semester	Instrument	Sample Size
Fall 2021	AEQ-S	Quantitative – 119 (I1)
Spring 2022	AEQ-GCHEM Version 1	Quantitative – 94 (I1) Qualitative – 2 Experts and 2 Students
Fall 2022	AEQ-GCHEM Version 2	Quantitative – 258 (I1 = 187, I4 = 71) Qualitative – 17 Students
Spring 2023	AEQ-GCHEM Version 2	Quantitative – 136 (I1) Qualitative – 11 Students

Survey Data Collection

Survey data were collected at one point during the semester: within one week of the students receiving a grade on the first exam in their General Chemistry course. The purpose of this time of collection was to ensure that the students have experienced prospective, active, and retrospective achievement emotions in all four settings that the emotions are being measured in. The researcher made an announcement to the class regarding the purpose of the study, as well as relevant confidentiality information. In the case that the researcher was unable to make the

announcement, the instructor of the course was provided a script to read to the class (Appendix C). Students were encouraged to participate but were made aware that participation is voluntary. Each student was provided a link to the electronic survey, the first item of which is the consent form for the student to indicate whether they consent to allow the researcher to use their data. While the survey link was provided during class time, the students were instructed to complete the survey outside of class time to ensure that all students complete the survey in the same context.

Performance Data Collection

Final percentage grades for all participants were obtained from the instructors of the General Chemistry courses. While each of the institutions that students were sampled from used different metrics to determine the final course grade, this was accounted for in student interviews and data analysis.

Quantitative Data Analysis

Descriptives

Descriptive statistics were analyzed on all data to determine the mean score of each emotion-setting scale as well as the standard deviation. Reliability estimates for internal consistency were calculated as well by determining McDonald's ω for each scale. While Cronbach's alpha is more commonly used to estimate the reliability of similar instruments, Cronbach's alpha assumes that each item possesses equal factor loading for their respective construct, which might not be true. McDonald's ω has been reported to be a more accurate measurement of internal consistency compared to Cronbach's alpha when the factor loading of each item in the scale is not equal (Hayes & Coutts, 2020); therefore, it was chosen for this

analysis. The coding language and statistics program R (version 4.1.1) was used to conduct this and all other quantitative analyses.

Internal Structure Validity

CFA is a tool used to assess how well a proposed model fits a set of measured variables to establish evidence of internal structure validity. CFA has been used in many chemical education studies to develop and validate scales and instruments (Heredia & Lewis, 2012; Malinakova, 2022; Xu & Lewis, 2011). Each emotion-setting scale was considered a unique latent variable, with each item in the scale an indicator for that variable. As Pekrun et al. (2011) discussed, emotions across settings cannot be combined into larger, more-encompassing latent variables, since each emotion-setting pairing produces unique emotional experiences and is, therefore, a unique construct. Only complete data sets were included in the analyses; therefore, list-wise deletion was used for any missing data.

To determine the fit of the data to the hypothesized model, in order to find evidence of internal structure validity, several indices were used: root-mean squared error of approximation (RMSEA) (Steiger, 1990), non-normed fit index (also referred to as the Tucker-Lewis index, or TLI) (Tucker & Lewis, 1973), and the comparative fit index (CFI) (Bentler, 1990). A summary of these indices and appropriate values can be seen in Table 3.2. A non-significant result from these indices was desired, since that would indicate that there are not significant differences between aspects of the model.

Table 3.2

Summary of Factor Analysis Indices

Factor Analysis Index	Value indicative of good fit	Reference
RMSEA	< 0.05	Steiger, 1990
TLI	≥ 0.95	Tucker & Lewis, 1973
CFI	≥ 0.95	Bentler, 1990

Note. This table shows the indices that was used to analyze for good fit for factor analysis in this study, along with approximate values that indicate a good model fit and the references for the indices.

The RMSEA can range from 0 to infinity and is a measure of the approximate model fit in the population (Steiger, 1990). Since an exact fit of the model onto the population is impractical, the RMSEA is a measure of "close fit," and, in general, values < 0.05 are considered good and values < 0.08 are considered acceptable (Browne & Cudeck, 1992). TLI and CFI values range from 0 to 1, with values ≥ 0.95 indicating good fit (Hu & Bentler, 1999), where both indices use the chi-square values along with a baseline model to evaluate the data fit (Brown, 2006). The data were analyzed using these indices to establish evidence of internal structure validity and ensure that the data fit the CVT model used as the theoretical foundation for this study.

It is worth noting that the sample size requirements for any structural equation modelling (SEM), such as CFA, has been debated in the literature over the past several decades (White, 2022). However, some have found that the minimum sample size for SEM can vary, with a large number of factors and lower number of items per factor typically requiring a higher sample size for methods such as CFA; however, this same study found that as the factor loadings of the items approach 1, the minimum sample size required can drastically decrease (Wolf et al., 2013). Finally, some have proposed that the minimum sample size required for SEM is simply what has

been shown to be sufficient in previous similar studies (Bacchetti, 2010). This study uses this philosophy to justify its sample size, as the sample size used both for validation and data collection with this instrument is comparable to the sample sizes of published studies using similar instruments measuring achievement emotions (Bieleke et al., 2021; Peixoto et al., 2015; Pekrun et al., 2011; Raker et al., 2018).

Interview Participants

Interviews were conducted with students from the target population, as well as experts in the field of chemical education. For the students, the last item of the survey contained a prompt that asked students to indicate if they would participate in a short interview regarding the survey. Students were also recruited by announcements made in a lecture or lab setting. Students interviewed were contacted via their school email address that they provided in the survey. Experts were selected via convenience sampling and consisted of both faculty members and doctoral candidates in a chemistry education degree program that have experience teaching chemistry in either a lecture- or laboratory-based setting. This teaching experience was helpful in determining if the items of the AEQ-GCHEM were measuring achievement emotions that students might experience in their General Chemistry course.

Interview Design and Protocol

All interviews took place either in a private room or in a private Zoom call to ensure participant confidentiality. Prior to starting each interview, the participant was informed about the purpose of the study, the interview procedure, and the protocols for confidentiality. The consent form that participants agreed to can be seen in Appendix B.

For student interviews, all participants were administered the AEQ-GCHEM at some point prior to the interview. All interviews were audio recorded. A verbal probing interview

approach was used, where students were read aloud an item from the instrument, asked how they would answer the prompt, and explain their reasoning for their answer; students were also asked to comment on the readability of the items (Knafl et al., 2007). If the student's reasoning was deemed unclear or inaccurate to their item response, the researcher asked additional probing questions to clarify their interpretation. The interviews were approximately 20-30 minutes, depending on the participant's responses.

For the expert interviews, a verbal probing interview approach was used, in which the expert was asked to compare an unmodified item from the AEQ-S to a modified item from the AEQ-GCHEM. The goal of the interview was to ensure that the modified item contained enough chemistry-specific language to evoke achievement emotions specific to chemistry contexts. The expert was also consulted about the contexts that some survey items would be experienced in a chemistry context, for the purpose of weeding out items that do not evoke achievement emotions that would be experienced in chemistry contexts.

Interview Data Collection and Analysis

All interviews were transcribed and coded for significant statements and emergent themes based on individual items from the instrument (Creswell, 2013a). Items that showed a consistent pattern of poor readability or multiple possible interpretations were flagged as candidates for modification or removal from the instrument. Students should interpret all items of the instrument in similar ways, so as to provide evidence for validity based on response processes. All interviewees were asked to give a pseudonym during the interview, which was used to label the interview for confidentiality purposes.

Phase Two: Administration of the AEQ-GCHEM

Research Design

The research design employed in this stage of the study was a mixed-methods style of research, similar to Phase One. In this stage of the study, the quantitative data were the primary source of evidence, while the qualitative data were more supportive in nature to enhance the conclusions drawn from the quantitative data.

Participants

The target population for the AEQ-GCHEM was students enrolled in a first-semester General Chemistry course. The same sampling methods that were used in Phase One were used here as well. A breakdown of the participants for Phase Two can be found in Table 3.3.

Survey Data Collection

Survey data were collected at the same time point as was in Phase One.

Table 3.3

Breakdown of Participant Recruitment During Phase Two Using the AEQ-GCHEM

Semester	Sample Size
Fall 2023	Quantitative –346 (I1 = 119, I2 = 166, I3 = 61) Qualitative – 16 Students
Spring 2024	Quantitative – 138 (I1 = 77, I2 = 61)

Performance Data Collection

Final percentage grades for all participants were obtained from the instructors of the course. While each course students were sampled from used different metrics to determine the final course grade, this was taken into consideration for in student interviews and data analysis.

Quantitative Data Analysis

Descriptives

Descriptive statistics were analyzed on all data to determine the mean score of each emotion-setting scale as well as the standard deviation. Reliability estimates for internal consistency were calculated as well by determining McDonald's ω for each scale. McDonald's ω has been found to be a better measurement of internal consistency compared to Cronbach's alpha when the factor loading of each item in the scale is not equal (Hayes & Coutts, 2020); therefore, it was chosen for this analysis. The coding language and statistics program R (version 4.1.1) was used to conduct this and all other quantitative analysis.

Relations to Academic Performance

Regression analysis was used to determine which achievement emotion-setting pairings have the strongest relationship to academic performance. For the student's academic performance, the student's final letter grade in the General Chemistry lecture course was used. Final letter grade was chosen over final numerical grade since a major determining factor in student retention in a course is passing the course (receiving a A, B, or C letter grade) or not (receiving a D, F, or W letter grade).

Differences Between Groups

Analysis of variance (ANOVA) was used to determine if any significant differences exist between groups of subjects. The main groups of data that were analyzed were the differences

between groups based on the student's gender, race, sexual orientation, employment status, and status as a first-generation student. In the case that the ANOVA test returns a significant result, Tukey's Honest Significant Difference (HSD) *post-hoc* test was used to determine which groups differed significantly (Gray & Kinnear, 2012).

Interview Participants

Students were recruited to be interviewed in the same manner as in Phase One for the purpose of exploring the nature of how achievement emotions are experienced in a General Chemistry course. Some students were selectively sampled from the population of students that opted to be interviewed. Students were selected based on being a part of a subgroup of interest: low academic performance, a marginalized group of interest (based on gender, sexual orientation, race, employment status, and status as a first-generation student), and being an outlier in emotional data (e.g., reporting a much higher or lower amount of anxiety compared to the average student). Students selected in this manner were informed for the reason of their selection and were allowed to opt out if they chose to.

Interview Design and Protocol

All interviews took place either in a private room or in a private Zoom call to ensure participant confidentiality. Prior to starting each interview, the participant was informed about the purpose of the study, the interview procedure, and the protocols for confidentiality. All participants were administered the AEQ-GCHEM at some point prior to the interview. All interviews were audio recorded. A verbal probing interview approach was used, where students were read aloud an item from the instrument, asked how they would answer the prompt, and explain their reasoning for their answer. The student was asked to specifically relate their experience as a person of a marginalized group (if they were chosen to be interviewed for this

reason), or how they felt their emotional state was reflected in their academic performance (if chosen for this reason). If the student's reasoning was deemed unclear or inaccurate to their item response, the researcher asked additional probing questions to clarify their interpretation.

Interview Data Collection and Analysis

All interviews were transcribed and coded for significant statements and emergent themes based on individual items from the instrument (Creswell, 2013a). All interviewees were asked to give a pseudonym during the interview, which was used to label the interview for confidentiality purposes.

CHAPTER IV

RESULTS AND DISCUSSION

The goal of this study was to develop an instrument that can be used to measure achievement emotions in students enrolled in a General Chemistry course. To accomplish this goal, an instrument was developed and evaluated to establish that the achievement emotions data possessed adequate evidence of validity and reliability, so as to ensure that the data produced can be analyzed for trends among the achievement emotions experienced in the target population. Therefore, this study consists of two phases. In Phase One, the instrument was developed and modified through analysis of the quantitative and qualitative data collected for the purpose of obtaining evidence of validity and reliability. In Phase Two, the final iteration of the instrument was used to collect more quantitative and qualitative data for the goal of discovering and exploring relationships between achievement emotions and academic performance and retention in students enrolled in a General Chemistry course. Due to this, this chapter will present the results followed by discussion for each individual Phase. During both Phases, data were collected from four institutions with similar student demographics. A breakdown of the demographics of data collected from each institution can be found in Table 4.1.

Phase One: Development of the AEQ-GCHEM

The goal of Phase One was to answer the first two research questions of this study:

Q1 What modifications of the Shortened Achievement Emotions Questionnaire are needed to produce a brief, general-chemistry-specific Achievement Emotions Questionnaire (AEQ-GCHEM) that measures enjoyment, hope, anger, pride, anxiety, shame, hopelessness, boredom, and relief?

Q2 What validity and reliability evidence supports the use of the AEQ-GCHEM with students in general chemistry?

To answer these questions, the modifications made to the AEQ-S to develop the AEQ-GCHEM, as well as further modifications made to the AEQ-GCHEM, were justified through quantitative and qualitative data collected for the purpose of finding evidence of validity and reliability through use of the instrument.

Validity Evidence

The validity of the data collected with this instrument have been investigated for evidence based on test content (through expert evaluation and student interviews), response processes (through student interviews), internal structure (through factor analysis), and relations to other variables (such as academic performance).

For the purpose of test content validity, interviews were conducted with experts and students to evaluate if the achievement emotions being measured by the instrument are achievement emotions that students in a General Chemistry course experience. In these interviews, emphasis was placed on if the achievement emotions between settings are separate constructs (i.e. do students experience anxiety differently in the classroom versus when taking a test) and on if the achievement emotions experienced in a General Chemistry course are experienced differently than achievement emotions in other academic courses. All experts and students interviewed agreed that achievement emotions in a General Chemistry course are

Table 4.1

Breakdown of Demographics of Participants from Each Institution

Institution	Ethnicity								Gender			First-Generation Status	
	Caucasian	African American	Latinx	Asian/ Asian American	Native American	Native Hawaiian / Pacific Islander	Multiple Ethnicities	Ethnicity Not Given	Male	Female	Nonbinary / Other	First-Gen	Non First-Gen
I1 (N=732)	446	32	144	22	11	22	28	27	224	471	37	399	333
I2 (N=227)	163	7	28	7	3	0	12	7	88	128	11	151	76
I3 (N=61)	35	3	2	10	0	0	5	6	15	40	6	53	8
I4 (N=71)	32	0	2	2	2	0	2	31	20	19	32	51	20

separate constructs from achievement emotions in other courses, as well as that achievement emotions between settings are separate constructs.

For the purpose of response process validity, interviews were conducted with students to evaluate if all items were being interpreted in a consistent manner in line with how the researcher intended the items to be interpreted. Through this process, many items in the survey were altered due to inconsistent interpretations from students. Specific items were targeted for modification due to having poor factor loading or contributing to poor reliability of the subscale. Once an item was selected through this process, it was discussed with interview participants. If the interviewees agreed that the item was poorly worded or difficult to read, alternatives were discussed in the interview. Most targeted items were found to be confusing or were misinterpreted by more than two-thirds of the students interviewed. Even though some of the targeted items were interpreted correctly by more than half of the students interviewed, the items were still altered due to their factor loadings or reliability statistics.

One example is that the item on the classroom-pride subscale "When I do well in my general chemistry class, my heart throbs with pride." was altered to be "When I do well in my general chemistry class, I am proud of myself." Students were not interpreting this item consistently due to the phrase "my heart throbs with pride"; the reasons being that many students either did not relate to the phrase, indicating that it is too strong of a feeling, or did not understand what the phrase was trying to convey. Another example is that the item on the testing-anger subscale "After the chemistry exam, I wish I could tell the teacher off." was altered to be "I resent having to take exams in my general chemistry class." Students did not respond to the original item as they did other items on the testing-anger subscale, indicating that the anger felt towards the instructor of the chemistry course is not necessarily related to the anger felt

towards the course subject. Similarly, the targeted item “I am irritated by the results of my efforts in my general chemistry course.” was altered due to students not responding to this item in the same way as the other classroom-anger items. Students found this statement to not be evocative of the anger they might feel in their chemistry course, citing the word “irritating” as being closer to a feeling of frustration or distress rather than anger. A full list of altered items and rationale can be found in Tables 4.2-4.3.

Confirmatory factor analysis (CFA) was used to gather evidence of the internal structure validity of the AEQ-GCHEM response data. CFA if generally used when there is an *a priori* hypothesis of the factor structure to be assessed. The original Achievement Emotions Questionnaire was designed to use all 24 subscales both collectively and individually. Therefore, the 32 subscales of the AEQ-GCHEM are evaluated likewise collectively and individually. The internal structure of each subscale is evaluated by confirmatory factor analysis of each subscale using the lavaan package (0.6-14) in the coding program R (4.1.1). The goodness-of-fit for each subscale is determined via a comparative fit index (CFI) of greater than 0.94 and a standardized root-mean squared residual (SRMR) and root-mean squared error of approximation (RMSEA) of less than 0.09 (Hu & Bentler, 1999). These statistics were calculated for every iteration of the AEQ-GCHEM, with the psychometrics for Versions 1 and 2 in Appendix G and the psychometrics on the final version the AEQ-GCHEM in Table 4.4.

Table 4.2

List of the Item Modifications to AEQ-CHEM Version 1 in Order to Create AEQ-GCHEM Version 2.

Scale	Original Item	Modified Item	Rationale
Classroom – Hope	I am full of hope in my general chemistry class.	When I am taught a new concept, I am confident that I will attain a basic understanding of it.	53% of students found the original statement too vague and did not interpret it consistently.
Classroom – Anger	I am angry in my general chemistry class.	My general chemistry class annoys me.	60% of students found the original statement too vague and did not interpret it consistently.
Learning – Pride	I am proud of myself in my general chemistry class.	I'm proud of how I study for my general chemistry class.	47% of students were not consistently using their Pride emotions from the Learning setting to answer the original prompt.
Testing – Pride	I am proud of myself in my general chemistry class.	I am proud of my performance on general chemistry exams.	70% of students were not consistently using their Pride emotions from the Testing setting to answer the original prompt.
Testing – Pride	After the chemistry exam, I feel ten feet taller because I am so proud of myself.	After the chemistry exam, I feel overjoyed because I am so proud of myself.	77% of students did not consistently understand or interpret the metaphor in the original prompt.
Testing – Anger	After the chemistry exam, I wish I could tell the teacher off.	I resent having to take exams in my general chemistry class.	93% of students found that the original statement elicited too strong of an emotion, and even those who responded positively to the other Testing-Anger prompts did not necessarily agree with this statement.

Table 4.3

List of the Item Modifications to AEQ-CHEM Version 2 in Order to Create the AEQ-GCHEM.

Scale	Original Item	Modified Item	Rationale
Classroom – Pride	I am proud of myself.	When I am in my chemistry class, I feel proud of myself.	40% of students found the original statement too vague and did not interpret it consistently.
Classroom – Anger	I am irritated by the results of my efforts in my general chemistry class.	I am angered by the results of my efforts in my general chemistry class.	77% of students did not respond to this prompt in the same manner as they did to the other Classroom-Anger prompts.
Learning – Hope	When my general chemistry studies are going well, it gives me a rush.	When doing my chemistry homework, I am in a good mood.	93% of students did not consistently interpret the metaphor "it gives me a rush" in the original prompt or thought that other students could easily misinterpret the statement.
Learning – Pride	Because I want to be proud of my accomplishments in my general chemistry class, I am very motivated.	I am very motivated because I want to be proud of my achievements in my general chemistry class.	80% of students found the original prompt to be difficult to read and understand. The modified prompt did not cause this difficulty for the same students.
Learning – Pride	When I excel at my general chemistry class, I swell with pride.	After having done my chemistry homework, I am proud of myself.	97% of students did not consistently interpret the metaphor "I swell with pride". Students also did not consistently relate the original prompt to the Learning Setting.
Testing – Enjoyment	Because I enjoy preparing for my general chemistry tests, I'm motivated to do more than is necessary.	Because I look forward to getting a good grade, I study hard for my chemistry test.	73% of students did not have a consistent idea of the relationship between enjoyment and motivation, leading to inconsistent responses.
Testing – Enjoyment	Before taking a chemistry exam, I sense a feeling of eagerness.	After taking a chemistry test, I often feel that things are going great.	67% of students did not have a consistent idea of the feeling of "eagerness" with interpretations ranging from giddiness (positive feeling) to anxiety (negative feeling).

Confirmatory factor analysis was also used to evaluate the complete AEQ-GCHEM using four distinct models (the same models were used to analyze the previous iterations of the AEQ-GCHEM and this analysis can be found in Appendix G). The first model proposes that all 32 subscales can be explained through a single emotion factor; this single-factory model does not result in a good fit of the data: CFI = 0.570, SRMR = 0.138, RMSEA = 0.161. The second model proposes that there are 9 individual correlating emotions factors; this emotion-centric model does not result in a good fit of the data: CFI = 0.714, SRMR = 0.118, RMSEA = 0.136. The third model proposes that there are 3 individual correlating setting factors; this setting-centric model does not result in a good fit of the data: CFI = 0.710, SRMR = 0.094, RMSEA = 0.133. The fourth model (Figure 4.1) proposes that there are nine emotion factors that correlate with residuals resulting from the four settings; this model results in an adequate fit of the data: CFI = 0.957, SRMR = 0.080, RMSEA = 0.062.

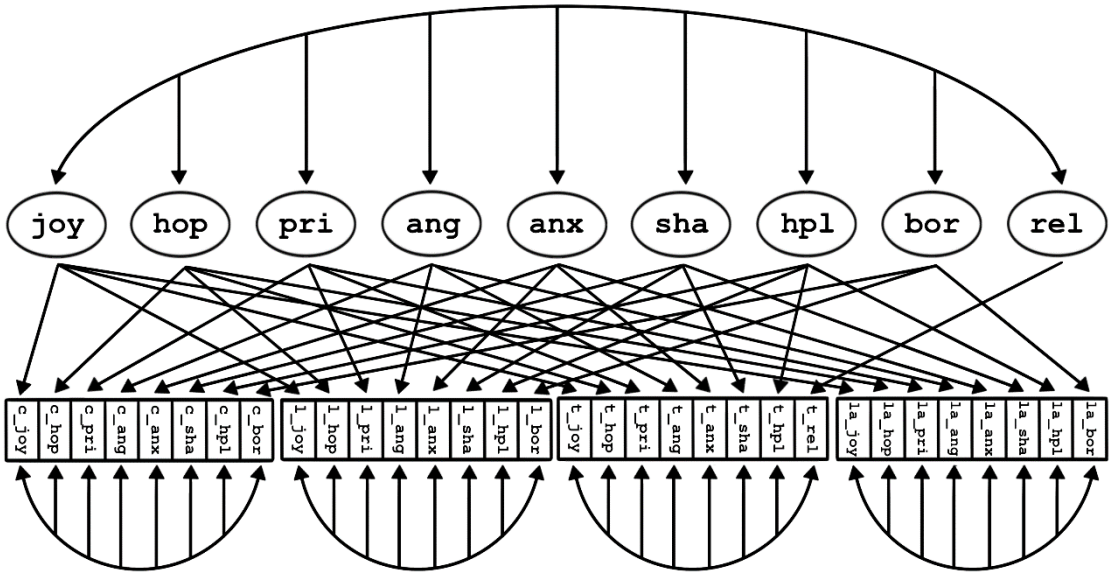
Table 4.4

CFI, SRMR, and RMSEA Values for Each Emotion, Separated by Setting.

Emotion	**Fit Indices (CFI, SRMR, RMSEA)**			
	Classroom	Learning	Testing	Laboratory
Enjoyment	1, 0.03, 0	0.997, 0.04, 0.05	0.984, 0.06, 0.11	1, 0.03, 0
Hope	1, 0.01, 0	1, 0.02, 0	1, 0.02, 0	1, 0.03, 0
Pride	1, 0.03, 0	0.984, 0.06, 0.08	1, 0.01, 0	0.997, 0.04, 0.05
Anger	0.996, 0.03, 0.05	0.992, 0.04, 0.08	0.997, 0.03, 0.05	1, 0.02, 0
Anxiety	1, 0.02, 0	1, 0.01, 0	1, 0.02, 0	1, 0.02, 0
Shame	0.999, 0.03, 0.03	1, 0.01, 0	0.999, 0.03, 0.04	1, 0.03, 0
Hopelessness	1, 0.02, 0	1, 0.01, 0	1, 0.02, 0	1, 0.02, 0
Boredom	0.998, 0.03, 0.06	1, 0, 0	-	0.998, 0.03, 0.05
Relief	-	-	0.995, 0.05, 0.08	-

Figure 4.1

The Best-Fitting Model for Relationships Between Achievement Emotions.



Note: c, l, t, and la denote the settings classroom, learning, testing, and laboratory, respectively. The emotions are abbreviated: joy = enjoyment, hop = hope, pri = pride, ang = anger, anx = anxiety, sha = shame, hpl = hopelessness, bor = boredom, rel = relief.

To evaluate the relations between variables for evidence of validity, the relationships between the achievement emotions and the settings were analyzed. Associations between the subscales are evaluated with the Spearman's rank-order correlation (Tables 4.5-4.8). Note that Spearman's correlations were used in favor over Pearson correlations due to the data violating normality assumptions.

Table 4.5

Spearman's Correlations Between AEQ-GCHEM Subscales in the Classroom Setting.

Variables		1	2	3	4	5	6	7	8
1	Enjoyment	1							
2	Hope	0.60	1						
3	Pride	0.60	0.65	1					
4	Anger	-0.61	-0.54	-0.44	1				
5	Anxiety	-0.40	-0.66	-0.42	0.54	1			
6	Shame	-0.31	-0.50	-0.37	0.43	0.67	1		
7	Hopelessness	-0.50	-0.72	-0.55	0.64	0.74	0.66	1	
8	Boredom	-0.60	-0.28	-0.37	0.53	0.26	0.26	0.32	1

For the classroom setting, correlations vary as expected with the proposed relationship between the emotions from previous studies, ranging from -0.72 to +0.67 (all correlations were significant, $p < 0.05$).

Table 4.6

Spearman's Correlations Between AEQ-GCHEM Subscales in the Learning Setting.

Variables		1	2	3	4	5	6	7	8
1	Enjoyment	1							
2	Hope	0.71	1						
3	Pride	0.58	0.63	1					
4	Anger	-0.56	-0.52	-0.35	1				
5	Anxiety	-0.47	-0.59	-0.31	0.64	1			
6	Shame	-0.50	-0.70	-0.42	0.57	0.73	1		
7	Hopelessness	-0.57	-0.75	-0.48	0.61	0.72	0.85	1	
8	Boredom	-0.54	-0.37	-0.45	0.55	0.30	0.25	0.35	1

For the learning setting, correlations range from -0.75 to +0.85 (all correlations were significant, $p < 0.05$).

Table 4.7

Spearman's Correlations Between AEQ-GCHEM Subscales in the Testing Setting.

Variables		1	2	3	4	5	6	7	8
1	Enjoyment	1							
2	Hope	0.78	1						
3	Pride	0.65	0.69	1					
4	Anger	-0.62	-0.62	-0.54	1				
5	Anxiety	-0.56	-0.59	-0.50	0.60	1			
6	Shame	-0.57	-0.64	-0.65	0.64	0.74	1		
7	Hopelessness	-0.66	-0.71	-0.69	0.73	0.70	0.81	1	
8	Relief	0.22	0.32	0.36	-0.14	-0.03*	-0.22	-0.25	1

*This correlation was not significant ($p > 0.05$)

For the testing setting, correlations range from -0.71 to +0.81 (all correlations were significant, $p < 0.05$, except for one Relief correlation, $p > 0.05$).

Table 4.8

Spearman's Correlations Between AEQ-GCHEM Subscales in the Laboratory Setting.

Variables		1	2	3	4	5	6	7	8
1	Enjoyment	1							
2	Hope	0.65	1						
3	Pride	0.62	0.66	1					
4	Anger	-0.62	-0.50	-0.35	1				
5	Anxiety	-0.37	-0.61	-0.33	0.48	1			
6	Shame	-0.42	-0.55	-0.41	0.51	0.72	1		
7	Hopelessness	-0.50	-0.58	-0.43	0.57	0.64	0.73	1	
8	Boredom	-0.60	-0.37	-0.33	0.62	0.30	0.37	0.42	1

For the laboratory setting, correlations range from -0.62 to +0.73 (all correlations were significant, $p < 0.05$).

Table 4.9

Spearman's Correlations Between Settings for Each Emotion.

	Classroom/ Learning	Classroom/ Testing	Classroom/ Laboratory	Learning/ Testing	Learning/ Laboratory	Testing/ Laboratory
Enjoyment	0.74	0.57	0.38	0.65	0.36	0.24
Hope	0.75	0.72	0.29	0.78	0.32	0.29
Pride	0.64	0.58	0.41	0.58	0.40	0.21
Anger	0.64	0.62	0.34	0.61	0.42	0.30
Anxiety	0.78	0.68	0.34	0.67	0.36	0.39
Shame	0.66	0.63	0.43	0.79	0.39	0.39
Hopelessness	0.84	0.76	0.34	0.81	0.41	0.37
Boredom	0.75	-	0.50	-	0.45	-

Associations between the settings for each individual emotion are evaluated with Spearman rank-order correlation (Table 4.9). Correlations range from 0.21 (testing-pride and laboratory-pride) to 0.84 (classroom-hopelessness and learning-hopelessness). The relationship between the achievement emotions and academic performance in General Chemistry was also explored (Table 4.10).

According to CVT, the positive emotions (enjoyment, hope, and pride) should correlate positively with academic performance, and the negative emotions (anger, anxiety, shame, hopelessness, and boredom) should correlate negatively with academic performance (Pekrun, 2006; Pekrun et al., 2011). These relationships are seen in the data collected with the AEQ-GCHEM. Also seen in this data and data collected from the original AEQ is that learning- and testing-related emotions have stronger correlations with academic performance than classroom-related emotions. Finally, the relationship between the same achievement emotion experienced in different settings shows that, while many of the correlations are strong, most achievement emotions do not show full collinearity, meaning that the same achievement emotion experienced in different settings are separate constructs (or separate aspects of the same construct).

Reliability Evidence

The reliability of the AEQ-GCHEM scales was determined by calculating McDonald's omega for each subscale. While Cronbach's alpha is typically used for determining the reliability of data, McDonald's omega is more appropriate for this data since it does not take into account the factor loadings of each individual item in regard to each subscale (Hayes & Coutts, 2020). All reliability values were found to be acceptable ($\omega > 0.70$) and can be seen in Table 4.11.

Table 4.10

Spearman's Correlation Between Subscales and General Chemistry Course Final Grade.

Achievement Emotions	Spearman Coefficient to Grade			
	Classroom	**Learning**	**Testing**	**Laboratory**
Enjoyment	0.14	0.23	0.33	-0.07
Hope	0.40	0.41	0.35	-0.09
Pride	0.13	0.13	0.51	-0.11
Anger	-0.30	-0.27	-0.35	0.01
Anxiety	-0.43	-0.34	-0.33	-0.08
Shame	-0.23	-0.48	-0.44	-0.16
Hopelessness	-0.44	-0.50	-0.44	-0.14
Boredom	-0.06	-0.16	-	-0.07
Relief	-	-	0.07	-

Table 4.11

McDonald's Omega Values for Each AEQ-GCHEM Subscale

	Classroom	**Learning**	**Testing**	**Laboratory**
Enjoyment	0.85	0.90	0.80	0.88
Hope	0.83	0.86	0.89	0.88
Pride	0.79	0.76	0.94	0.83
Anger	0.75	0.83	0.83	0.86
Anxiety	0.83	0.85	0.86	0.83
Shame	0.90	0.88	0.93	0.87
Hopelessness	0.86	0.92	0.94	0.91
Boredom	0.90	0.89	--	0.90
Relief	--	--	0.91	--

Summary of Phase One

To address the first research question, several modifications were required to develop this instrument. First, chemistry-specific language needs to be present in each item of the instrument. Through the process of obtaining test content validity, both experts and students agreed that achievement emotions relating to General Chemistry were separate constructs from achievement emotions relating to other academic subjects or general academics. Second, many items needed further alterations to ensure response process validity. Most commonly, many metaphors and idioms were replaced with more straightforward language to ensure that all participants were interpreting the items consistently in a common manner.

To address the second research question, the internal reliability and validity evaluations presented in this study support the AEQ-GCHEM and its subscale measures. McDonald's omega measures of reliability are all acceptable, which supports the internal consistency of each AEQ-GCHEM subscale. Confirmatory factor analyses of the AEQ-GCHEM and its subscales yielded acceptable goodness-of-fit values, supporting the internal structure of the instrument and each subscale. A summary of how each subscale's fit statistics from these analyses changed across each iteration of the instrument can be seen in Table 4.12. When considering the relationships between each AEQ-GCHEM subscale, our results reflect those proposed in CVT (Pekrun et al., 2011). While some of the associations between subscales approach collinearity (> 0.80), the overarching conclusion for these results supports the model that the nine achievement emotions in four contexts are distinct constructs. The qualitative interviews conducted with experts and students provided the evidence for test content validity and response process validity, providing the conclusion that the constructs the instrument was developed to measure are being interpreted consistently as intended.

This instrument also provided a novel set of subscales not seen in previous literature: subscales designed to measure achievement emotions in a chemistry laboratory setting. These laboratory subscales were not only capable of producing data with evidence of reliability and validity, but also provided data unique from subscales in the other settings. Qualitative data from interviews with students and experts agreed with the notion that achievement emotions experienced in a laboratory setting are a unique part of a chemistry course. Therefore, the creation of these laboratory subscales for this study can be used to provide insight into a previously unexplored aspect of achievement emotions experienced in chemistry students.

In summary, the goal of this Phase was to ensure that the data produced by the finalized AEQ-GCHEM showed adequate evidence of validity and reliability. Now that this evidence has been shown, the data collected with the evidence can be analyzed to explore relationships between achievement emotions and other latent constructs of interest to the researcher. In the case of this study, the AEQ-GCHEM was used to explore the relationships between achievement emotions and academic success in students enrolled in a General Chemistry course.

Table 4.12

CFI and McDonald's Omega Values for Each Version of the AEQ-GCHEM

	Version 1		Version 2		Final Version	
	CFI	**ω**	**CFI**	**ω**	**CFI**	**ω**
Classroom					1	
Enjoyment	0.948	0.84	1	0.87	1	0.85
Hope	0.993	0.89	1	0.87	1	0.83
Pride	1	0.82	1	0.77	0.996	0.79
Anger	1	0.79	0.991	0.83	1	0.75
Anxiety	0.986	0.86	0.962	0.87	0.999	0.83
Shame	1	0.93	0.967	0.90	1	0.90
Hopelessness	0.996	0.93	0.970	0.89	0.998	0.86
Boredom	0.983	0.92	0.938	0.91	0.998	0.90
Learning						
Enjoyment	0.992	0.84	0.970	0.83	0.997	0.90
Hope	1	0.90	0.976	0.86	1	0.86
Pride	0.968	0.82	0.844	0.73	0.984	0.76
Anger	0.999	0.84	0.965	0.87	0.992	0.83
Anxiety	1	0.91	0.992	0.90	1	0.85
Shame	0.994	0.93	0.974	0.87	1	0.88
Hopelessness	1	0.92	0.966	0.91	1	0.92
Boredom	1	0.90	1	0.90	1	0.89
Testing						
Enjoyment	0.974	0.83	0.969	0.86	0.984	0.80
Hope	1	0.92	1	0.89	1	0.89
Pride	0.988	0.93	0.936	0.86	1	0.94
Anger	1	0.80	0.977	0.89	0.997	0.83
Anxiety	1	0.88	1	0.87	1	0.86
Shame	0.928	0.94	0.979	0.92	0.999	0.93
Hopelessness	0.977	0.95	0.972	0.93	1	0.94
Relief	0.924	0.80	0.852	0.88	0.995	0.91
Laboratory						
Enjoyment	0.970	0.91	0.985	0.88	1	0.88
Hope	1	0.91	0.990	0.88	1	0.88
Pride	0.956	0.80	0.969	0.83	0.997	0.83
Anger	0.995	0.87	0.993	0.91	0.997	0.86
Anxiety	0.952	0.87	0.999	0.86	1	0.83
Shame	1	0.90	1	0.89	1	0.87
Hopelessness	1	0.94	0.992	0.92	1	0.91
Boredom	0.998	0.90	0.977	0.93	0.998	0.90

Phase Two: Administration of the AEQ-GCHEM

The goal of Phase Two was to answer research questions Q3, Q4, and Q5 of this study:

Q3 To what extent does a student's measured achievement emotions predict academic performance in a first-semester General Chemistry course?

Q4 To what extent do achievement emotions affect retention of students in their degree program that are enrolled in a first-semester General Chemistry course?

Q5 To what extent do students of different demographics, such as race, gender, sexual orientation, employment status, and being a first-generation student, experience achievement emotions differently in a first-semester General Chemistry course?

To answer these questions, the finalized AEQ-GCHEM was administered at four institutions to students enrolled in a General Chemistry course and the data collected analyzed. To outline this Phase, the descriptive statistics produced by the instrument are summarized to give a brief overview of the distribution of achievement emotion scores as well as provide more evidence of validity. Next, an analysis of the relationships between each achievement emotion subscale and academic performance in General Chemistry isconducted. This is followed up by a discussion on how the demographics of the student might have impacted the achievement emotion scores. Finally, the qualitative evidence collected in this Phase is analyzed to gain insight into the three research questions of this Phase.

Descriptive Statistics of the AEQ-GCHEM

Table 4.13 shows the mean, standard deviation, skewness, and the mean corrected item-total correlations for each subscale. While the data of most subscales demonstrated a non-normalized distribution, the mean is still provided in Table 4.13, as the median of each subscale would not provide substantive information due to all responses being on a scale of one to five. The skewness of the subscales shows that most of the subscales are skewed heavily, again

Table 4.13

Descriptive Statistics, Including the Mean, Standard Deviation, Skewness, and Mean Corrected Item-Total Correlations, of All 32 Subscales.

Subscale	Mean	SD	Skewness	Mean r*
Class-Joy	3.34	1.21	-0.48	0.69
Class-Hope	3.53	1.16	-0.31	0.64
Class-Pride	3.77	1.14	-0.62	0.56
Class-Anger	2.39	1.25	0.31	0.55
Class-Anxiety	2.73	1.45	0.06	0.64
Class-Shame	2.38	1.33	0.47	0.78
Class-Hopeless	1.79	1.10	1.05	0.70
Class-Boredom	2.61	1.27	0.25	0.78
Learn-Joy	3.38	1.18	-0.36	0.65
Learn-Hope	3.39	1.19	-0.29	0.71
Learn-Pride	3.68	1.14	-0.46	0.54
Learn-Anger	2.75	1.33	0.22	0.65
Learn-Anxiety	3.11	1.40	-0.29	0.69
Learn-Shame	2.36	1.40	0.52	0.74
Learn-Hopeless	2.12	1.27	0.63	0.81
Learn-Boredom	2.69	1.28	0.17	0.77
Test-Joy	2.83	1.39	0.15	0.56
Test-Hope	3.17	1.30	-0.22	0.74
Test-Pride	2.95	1.35	-0.04	0.84
Test-Anger	2.44	1.32	0.30	0.80
Test-Anxiety	3.45	1.46	-0.41	0.63
Test-Shame	2.50	1.46	0.52	0.71
Test-Hopeless	2.35	1.40	0.56	0.84
Test-Relief	3.58	1.28	-0.68	0.85
Lab-Joy	3.65	1.24	-0.61	0.71
Lab-Hope	3.62	1.16	-0.59	0.75
Lab-Pride	3.74	1.07	-0.53	0.65
Lab-Anger	2.38	1.32	0.62	0.71
Lab-Anxiety	2.59	1.40	0.30	0.66
Lab-Shame	1.89	1.23	1.18	0.72
Lab-Hopeless	1.68	1.03	1.35	0.79
Lab-Boredom	2.55	1.41	0.38	0.78

indicating that much of the data does not exhibit a normalized distribution. The mean corrected item-total correlations are excellent for all subscales, with none falling below the 0.30 threshold for this reliability measurement.

Looking at the mean of each subscale (where a score can range from 1 to 5, and a score of 5 indicates experiencing the emotion as strong as possible), we can see trends that we would expect among the achievement emotions experienced. Students in interviews typically agreed that the setting associated with their General Chemistry course that they felt the most positive emotions in was the Laboratory setting, followed by Classroom, Learning, and then Testing, which we see in the descriptive statistics. We also see trends in singular achievement emotions, such as Anxiety being reported the highest in the Testing setting, which we would expect.

Relationships Between Achievement Emotions and Academic Performance

To address the third research question, the relationship between achievement emotions and academic performance was explored using logistic regression with logistic least absolute shrinkage and selection operator (LASSO). To perform this, each student's academic performance was used as the outcome variable and each achievement emotion subscale was used as the predictor variables. Academic performance was set as a binomial pass/fail variable, where a 70% (C) or higher in the General Chemistry course was considered a pass, and lower than a 70% or withdrawing from the course was considered a fail. When conducting this analysis, three logistic regression models were used (Table 4.14). Model 1 used all 32 achievement emotion subscales as predictor variables. This model resulted in the worst fit of the three models tested and also runs the risk of overfitting the data, leading to potentially erroneous conclusions (Hawkins, 2004); therefore, this model was not used to determine which achievement emotions impact academic performance. Model 2 used all achievement emotion subscales except for the

lab-related emotions. Since the academic performance being used is related to the lecture portion of the General Chemistry course, the emotions in the Laboratory setting, being a separate course entirely from the lecture, have the weakest relationship to academic performance. This results in a slightly better fit than Model 1, but this model could still run the risk of overfitting the data. To eliminate the chance of overfitting, the LASSO selection technique was used to remove any achievement emotion subscales that do not significantly impact academic performance to reduce the amount of variance in the data. This method resulted in Model 3, which possesses the best fit of the three models tested.

Table 4.14

Fit Statistics of Each Regression Model Tested.

Model	Chi-squared (degrees of freedom)	p-value	AIC
1	102.88 (32)	< 0.001	265.54
2	97.964 (24)	< 0.001	254.46
3	55.835 (2)	< 0.001	252.58

Through this analysis, Model 3 determined that two emotion-setting pairings were found to influence the letter grade that a student received in their General Chemistry course: Classroom-Hopelessness and Testing-Pride.

Classroom-Hopelessness was found to have a negative effect on the odds of a student passing their General Chemistry course, meaning that students that scored higher on the Classroom-Hopelessness subscale was more likely to fail their General Chemistry course. Specifically, Model 3 estimates that for each point a student scored higher on the Classroom-Hopelessness scale, the student was 1.96 times more likely (95% CI 1.32 to 2.94) to fail their

General Chemistry course. Testing-Pride was found to have a positive effect on academic performance, where scoring higher on the Testing-Pride subscale increased the odds that a student passed their General Chemistry course. Specifically, for each point a student scored higher on the Testing-Pride subscale, the student was 1.83 times more likely (95% CI 1.31 to 2.60) to pass their General Chemistry course.

The effects of these subscales can be rationalized through the effect that we would expect and that we see in the correlations in Table 7, where the negative emotion has a negative effect on performance and the positive effects have a positive effect on performance.

Differences Among Demographics

To analyze the differences among demographics between each subscale, the Wilcoxon signed-rank test was used to determine any significant differences for each subscale. The Wilcoxon signed-rank test was chosen due to the data of each subscale not being normally distributed, and the p-values were adjusted using the Benjamini and Hochberg method to reduce the family-wise error rate of the analysis (Benjamini & Hochberg, 1995).

Gender

In analyzing the subscale statistics when separating for gender, there were several subscales where self-identified male students and self-identified female students scored significantly differently. Male students scored significantly higher on the Classroom-Hope, Learning-Hope, Test-Enjoyment, and Testing-Hope subscales, and female students scored significantly higher on all anxiety subscales (aside from Testing-Anxiety), all shame subscales (aside from Lab-Shame), all hopelessness subscales (aside from Lab-Hopelessness), and on Testing-Relief.

In interpreting these results, it should be noted that these differences are consistent with a vast literature showing that female students, on average, self-report higher amounts of emotions related to anxiety and shame than male students (Hembree, 1988; Zeidner, 1998). Given how consistently this finding occurs in the literature, these results can be treated as evidence of convergent validity of the AEQ-GCHEM subscales.

It should also be noted that data were collected from self-identified non-binary students, as well as students that did not consider their gender in any of these three categories. However, the sample size for these two demographics of gender were too small to form any conclusions.

Ethnicity

The subscale statistics were also analyzed based on ethnicity. While some trends were observed in the differences between the mean scores of Caucasian students versus African American/Black students and versus Hispanic/Latinx students, with Caucasian students experiencing more positive emotions (enjoyment, hope, pride) and less negative emotions (anger, anxiety, shame, hopelessness) across all settings, most of these differences were not found to be significant. The only exceptions to this being Classroom-Hope, which Caucasian students reported higher amounts of than Hispanic/Latinx students, and Lab-Anger, which Caucasian students reported higher amounts of than Hispanic/Latinx students. Other ethnicities did not show any statistical differences, most likely due to the low sample size of these groups.

First-Generation

Finally, the subscale statistics were analyzed when separating for first-generation status. First, the disaggregated data among the Classroom, Learning, and Testing subscales are discussed. In these settings, first-generation students experienced significantly more anxiety, shame, and hopelessness in all three settings, as well as significantly less Classroom-Hope,

Testing-Enjoyment, Testing-Hope, and Testing-Pride when compared to non-first-generation students. When comparing the final grades of first-generation students to non-first-generation students, first-generation students scored significantly lower in their General Chemistry courses. Through this lens, the analysis of the achievement emotions of this disaggregated data agree with the difference in academic performance, where experiencing less positive emotions and more negative emotions leads to a worse academic performance.

Other Demographics

Other demographics, such as sexual orientation and employment status, did not show any significant differences in achievement emotion scores among the groups.

Sources of Achievement Emotions

While the analysis of the data shows which achievement emotion subscales affect academic performance significantly, as well as how different groups of students may emotionally experience a General Chemistry course, qualitative data are needed to fully understand what causes these effects of and differences in achievement emotions. Therefore, interviews were conducted with students to elucidate potential sources for the achievement emotions that they experience in their General Chemistry course. Throughout these interviews, several common themes became apparent as sources of many of the achievement emotions: the use of an online learning platform, having prior chemistry experience, and status as a first-generation student.

Online Learning Platform

Two of the institutions that students were sampled from (I1 and I2) use an online learning platform to assign homework assignments to students and to provide practice problems and outside learning opportunities for the General Chemistry course. Several students found these online learning platforms to be a source of negative achievement emotions, especially anger. One

student, Jeffery, stated that he found the online learning platform to be “incredibly enraging” and “pedantic”. Sophie discussed her frustration with the platform due to repetitively failing practice problems, with these feelings of anger eventually leading to feelings of hopelessness, saying that she often gets to a point of “I want to be done with this”. Some students, like Tori, claimed that the online learning platform did not explain concepts and problems in the same manner as the instructor for the course, leading to frustration and a lack of understanding of the concepts being taught in class.

This universal sense of anger can be seen in the AEQ-GCHEM data, with the Learning-Anger subscale having the highest mean score of all of the anger subscales. Since these online learning platforms are typically used for homework assignments, the anger from these platforms would be seen specifically in the Learning setting. While anger itself does not directly lead to worse academic performance, anger does correlate strongly with the other negative achievement emotions, and the negative achievement emotions do correlate to worse academic performance.

Prior Chemistry Experience

Many students referred to having prior chemistry or science experience either in high school or prior post-secondary education, with these referrals evoking positive achievement emotions typically. Luna believed that her prior chemistry experience gave her “a leg up” on her classmates, evoking pride in her knowledge of chemistry and hope that she would be able to understand future topics. Yellow said that they “[felt] more confident going forward” due to the positive relationships that they’ve had with their prior instructors, and especially those in their post-secondary education. However, negative prior experiences can also affect the student’s current emotional experiences, with Tori experiencing more anxiety and shame due to being “bullied by a teacher for [having difficulty with math in chemistry]” in high school.

First-Generation Status

First-generation students remarked in several interviews that they felt they experience different emotions than their non-first-generation peers in their General Chemistry course. Tomie discussed feeling more stress and anxiety being a first-generation student, due to feeling that they need to "show that [they] can thrive in this [post-secondary] setting" and that they felt that "the pressure is on" them to succeed. These additional feelings of stress and anxiety led to stronger negative feelings when they struggled with the course material but did not result in stronger positive feelings when succeeding, since the success was expected of them.

Tori expressed the frustrations they felt with being a first-generation student, explaining how their day-to-day life is structured around this status:

> I believe, on all sides of my family, I am one of the only ones to go to college... I have two jobs and one seasonal job. I'm a full-time student with severe ADHD, unmedicated, [but am] able to prioritize things in a way that I'm doing it. I have tutoring full schedule. I'm full-time at both jobs. I'm at one right now... So it's difficult to get some of the things I need, because I do not have enough time like today. I'm up from 8 in the morning to 9 at night for school and work. I only have two and a half hours of break time, and that's split up in three different places… I don't have a lot of money in my life. I have to budget. I make paycheck to paycheck, even though I have two jobs… I am under a lot more pressure than most people, and I don't have a lot of money. I am fully funded by a single scholarship and a few grants, and I have to make sure to save that money. So if I ever have something bad happen, if that's the case, like I don't have an option to fail a class.

In Tori's case, the added pressure to succeed with being a first-generation student, combined with the stress from having to support themself with multiple jobs outside of school, led to an extreme amount of stress and anxiety that they felt their peers did not experience.

Effects on Retention

As a part of the interviews, all participants were asked to reflect on how their intention of taking more chemistry courses (if required by their degree program) had changed over the course of the semester. Many higher performing students indicated that they were looking forward to further chemistry classes, with Kenneth remarking that they were looking forward to going to more chemistry classes now that they "finally [had] a grasp on the concepts a little bit more" than they did at the start of their chemistry education. Mary indicated that they are under the impression from colleagues that have taken further chemistry class that the classes are "a little bit easier once you really go through general chemistry" as it "set you up for all of them". Sophie claimed that they were not looking forward to more chemistry classes at the start of their General Chemistry course, saying "I don't know how I'm going to do this… there's no way", but later in the semester became of the opinion that they "could build on [their chemistry knowledge] and do another harder chemistry class". It's worth noting that low-performing students also indicated that they were going to take future chemistry courses. Tori seemed unaffected by their negative emotions towards chemistry, saying that even though they felt "very, very worried and anxious and kind of scared for [future chemistry classes]", they need to keep down this academic career path as that is what they have set their sights on. Similarly, Motley, who was struggling to pass their General Chemistry course at the time of the interview, when asked about continuing to take more chemistry classes remarked "As silly as it is, I'm doing terrible at it, but that's all I want to do". In conclusion, while positive emotions tend to incline a student to pursue further chemistry

courses, negative emotions do not directly contribute to a student changing their academic path away from one involving chemistry courses. Students are most likely to continue pursuing chemistry courses if their personal academic goal requires them to, whether they have positive emotional experiences in their General Chemistry course or not.

Summary of Phase Two

To address the third research question, logistic regression with the LASSO method was used to determine which subscales measured achievement emotions with the strongest relationship to academic performance. From this analysis, it was determined that two subscales had significant relationships: Classroom-Hopelessness and Testing-Pride. Both subscales were found to roughly double the rate of failure or passing, respectively, of a student for each point higher on the items in the respective subscales.

To address the fourth research question, interviews were conducted with students in which their intention to pursue taking more chemistry course was explored. Both low-performing and high-performing students were interviewed for this reason; however, both groups of students shared the same sentiment of wanting to continue down their academic path and take chemistry courses. Some students that were interviewed were anticipating failing their current chemistry course, yet they still maintained that they would not transition to a different academic field or degree path. The main influencing factor was financially related, as students indicated that they would continue in their chosen academic career path (and continue to take chemistry courses) until it was not financially viable to do so.

To address the fifth research question, the disaggregated data were analyzed to find trends and patterns between various groups of different demographics. Many demographics did not result in different scores on the AEQ-GCHEM, with the only significant differences

appearing between self-identified men and women and between first-generation and non-first-generation students. Self-identified women reported experiencing more of the negative emotions and less positive emotions when compared to what self-identified men reported. While this finding agrees with the literature on emotional differences between men and women in academic settings (Hembree, 1988; Zeidner, 1998), men and women did not differ in relation to academic performance, indicating that these emotional differences might not have a significant impact in a chemistry course. Between first-generation and non-first-generation students, first-generation students were found to experience more negative emotions and less positive emotions than non-first-generation students. This can also be seen in the differences of academic performance of these two groups, where first-generation students had a significantly lower academic performance than non-first-generation students, as we would expect from a group that experiences more negative and less positive achievement emotions.

In summary, the Hopelessness a student experiences in the Classroom setting and Pride a student experiences in the Testing setting can be indicative of how likely a student is to pass or fail their General Chemistry course. While the other achievement emotion subscales do not directly significantly impact academic performance, all achievement emotions are correlated together, meaning that a student experiencing significantly more of one positive achievement emotion is likely to be experiencing more of the rest of the positive achievement emotions. Therefore, when using student demographics as a lens for the achievement emotion data, one cannot simply analyze the data from the two scales indicated previously. If one group experiences any positive or negative achievement emotion significantly more than another, then that group is more likely to experience all positive or negative emotions more as well. Finally,

retention in General Chemistry was found to be primarily based on the student's academic ambitions rather than emotional experiences in their General Chemistry course.

CHAPTER V

CONCLUSIONS

The achievement emotions that students experience have been connected to performance outcomes in many academic settings (Pekrun, 1992a, 1992b; Pekrun et al., 2011). However, before studies can explore the role of achievement emotions and their correlation to academic performance, an appropriate instrument is required. The purpose of this study was to design an instrument to explore the connections between achievement emotions and academic achievement of students enrolled in a first semester General Chemistry course, as well as evaluate how both achievement emotions and academic achievement affect student retention in chemistry. This study was conducted in two phases, and the results of both phases are summarized in this chapter.

Purpose of Phase One

In Phase One, both research questions were addressed through the development process to create the AEQ-GCHEM.

Q1 What modifications of the Shortened Achievement Emotions Questionnaire are needed to produce a brief, general-chemistry-specific Achievement Emotions Questionnaire (AEQ-GCHEM) that measures enjoyment, hope, anger, pride, anxiety, shame, hopelessness, boredom, and relief?

The Shortened Achievement Emotions Questionnaire (AEQ-S) was modified to contain chemistry-specific language to adapt the instrument from measuring achievement emotions in broad academic contexts to measuring achievement emotions in chemistry-specific contexts. Further modifications were also made to the instrument to remove many idioms and

metaphorical language that students inconsistently interpreted. Details of the development of the AEQ-GCHEM are presented in Appendices D-F.

Q2 What validity and reliability evidence supports the use of the AEQ-GCHEM with students in general chemistry?

Throughout this study, the reliability and validity of the data produced by the AEQ-GCHEM were measured in order to answer this question. McDonald's omega measures of reliability are all acceptable, which supports the internal consistency of each AEQ-GCHEM subscale. Confirmatory factor analyses of the AEQ-GCHEM and its subscales yielded acceptable goodness-of-fit values, supporting the internal structure of the instrument as a whole and of each individual subscale. When considering the relationships between each AEQ-GCHEM subscale, our results reflect those proposed in CVT (Pekrun et al., 2011). While some of the associations between subscales approach collinearity (> 0.80), the overarching conclusion for these results supports the model that the nine achievement emotions in four contexts are distinct constructs. The qualitative interviews conducted with experts and students provided the evidence for test content validity and response process validity, providing the conclusion that the constructs the instrument was developed to measure are being interpreted consistently as intended.

Purpose of Phase Two

In Phase Two, the final three research questions were addressed.

Q3 To what extent does a student's measured achievement emotions predict academic performance in a first-semester General Chemistry course?

The achievement emotions measured by the AEQ-GCHEM were found to correlate with academic performance as expected, where positive emotions showed a positive relationship with academic performance and negative emotions a negative relationship. Using logistic regression with the LASSO method, two achievement emotion subscales, Classroom-Hopelessness and

Testing-Pride, were found to have a significant ability to predict the odds that a student would pass or fail their General Chemistry course. Classroom-Hopelessness demonstrated a negative predictive ability, where scoring higher on this subscale indicated the student was more likely to fail the course, while the Testing-Pride subscale demonstrated a positive predictive ability.

Q4 To what extent do achievement emotions affect retention of students in their degree program that are enrolled in a first-semester General Chemistry course?

From student interviews, positive emotions played a role in influencing a student to continue pursuing chemistry courses. High-performing students that experienced more enjoyment, hope, and pride in their chemistry courses tended to look towards future chemistry classes. These students also were not predicting a high amount of anxiety or stress in their future in these classes. However, low-performing students did predict experiencing more anxiety and stress in future chemistry classes. Despite this, these lower-performing students did not let these anticipatory feelings or present emotional experiences in chemistry persuade them to change academic career intentions. While lower-performing students experience more negative emotions, which can impact their academic performance in their current chemistry course, these negative emotions did not directly impact their academic goals that involved taking future chemistry courses.

Q5 To what extent do students of different demographics, such as race, gender, sexual orientation, employment status, and being a first-generation student, experience achievement emotions differently in a first-semester General Chemistry course?

Self-identified men and women were found to experience significantly different achievement emotions in General Chemistry, with men experiencing more of the positive emotions and women experiencing more of the negative emotions. This is a trend with an abundance of literature detailing these differences existing in many academic fields; therefore,

these results can be treated as evidence of validity. No significant differences were found from the disaggregated race or sexual orientation data. First-generation students were found to experience negative emotions significantly more and positive emotions significantly less when compared to their non-first-generation peers. This observation correlates with first-generation students performing significantly worse academically. Qualitative interviews with first-generation students showed that this increase in negative achievement emotions experienced can, in part, be attributed to higher stress from familial standards and a lack of support system they feel other students have.

Implications for Research and Teaching

The General Chemistry Achievement Emotions Questionnaire (AEQ-GCHEM) is a 128-item, 32-subscale instrument designed to measure achievement emotions in general chemistry students. The AEQ-GCHEM produced data with acceptable validity and reliability measurements with a sample of students enrolled in a General Chemistry course. Associations between the achievement emotions and within contexts suggests that each subscale measures a separate, distinct construct. Our results support the use of the AEQ-GCHEM and its subscales, the subscales being each achievement emotion-setting pairing, for measuring achievement emotions in general chemistry contexts.

The AEQ-GCHEM creates opportunities for further research on achievement emotions in general chemistry contexts, including the relationships between achievement emotions and learning as well as how achievement emotions can be implemented into evidence-based teaching practices. Despite many studies concluding that affect is associated with achievement in chemistry contexts (Chan & Bauer, 2014; Reardon et al., 2010; Xu & Lewis, 2011), only a few studies have been conducted on how achievement emotions can affect student achievement in

chemistry contexts (Brown & Nedungadi, 2024; Raker et al., 2018). However, neither of these studies investigated achievement emotions in a general chemistry context.

The AEQ-GCHEM not only provides an example of how modifications can be made to existing instruments to measure achievement emotions in specific contexts, but also provides a tool for instructors to measure these achievement emotions in their own General Chemistry lecture and lab courses. We encourage chemistry instructors to utilize this instrument to evaluate the achievement emotions of the students in their courses. Also, the instrument can be used to explore how achievement emotions are impacted by novel teaching practices and equitable and inclusive instructional methodologies. If an instructor is seeking equitable practices in their teaching, they should be seeking to customize their practices to meet the individual needs of each student (White et al., 2020), which would include addressing the achievement emotions that each student experiences. Therefore, utilizing an instrument to measure achievement emotions is necessary to achieve the goal of having equitable and inclusive methodologies in a classroom.

In an ideal world, an instructor would administer the AEQ-GCHEM to the students in their course and then, after assessing the data, impose an intervention to affect the achievement emotions that some or all of the students were experiencing, in the hopes of increasing the positive achievement emotions and reducing the negative achievement emotions experienced. However, these methods of influencing achievement emotions, or emotions in general, are currently lacking and under-researched, in both chemistry education research and education research as a whole. While some chemistry education studies have shown some methods that can positively influence affect, such as student-oriented teaching practices (Vishnumolakala et al., 2017), novel technological instructional tools (Penn & Ramnarain, 2019), and simulated peer-to-peer classroom activities (Scott, 2014), all of these studies valued the academic performance

implications more than the emotional implications in both the intentions and outcomes of these studies. Some methods to alter negative emotions, such as anxiety, have been researched (Rozek et al., 2019; Zeidner, 1998), but methods to influence the positive achievement emotions have not be explored in any capacity. This lack of methods to influence affect is not for lack of ability to do so, as studies have found that both instructors and course content have the ability to influence a student's beliefs, values, and motivations (Ferrell et al., 2016; Grove & Bretz, 2007). Therefore, to utilize the AEQ-GCHEM to its fullest, more research must be conducted to discover how instructors can influence achievement emotions in the General Chemistry classroom.

Final Remarks

The AEQ-GCHEM is a novel instrument that measures achievement emotions in students enrolled in a General Chemistry course. The methods for the development and modification of this instrument were laid out in this study, as well as how to assess the instrument's ability to produce data with evidence of validity and reliability. This study demonstrated not only that measuring achievement emotions in a specific population required the development of an instrument for that population, but also the steps that one could take to develop an instrument for measuring achievement emotions in a different population of interest.

The achievement emotions of General Chemistry students were measured with this instrument, and the analysis conducted on the data showed that some achievement emotions that students experience can be used to predict their academic performance in their General Chemistry course. Interviews were also conducted with students to gain insight into the main factors influencing achievement emotions and retention in a General Chemistry course.

However, future research into how to influence achievement emotions in the General Chemistry classroom must be conducted to realize the full potential of the AEQ-GCHEM.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL LETTER FOR INTERVIEW STUDY

UNIVERSITY OF
NORTHERN COLORADO

Institutional Review Board

Date:	11/11/2021
Principal Investigator:	Alex Graves
Committee Action:	**IRB EXEMPT DETERMINATION – New Protocol**
Action Date:	11/11/2021
Protocol Number:	2110030582
Protocol Title:	Exploring and Understanding Student Emotional Experiences with AEQ
Expiration Date:	

The University of Northern Colorado Institutional Review Board has reviewed your protocol and determined your project to be exempt under 45 CFR 46.104(d)(702) for research involving

Category 2 (2018): EDUCATIONAL TESTS, SURVEYS, INTERVIEWS, OR OBSERVATIONS OF PUBLIC BEHAVIOR. Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met: (i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects; (ii) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or (iii) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by 45 CFR 46.111(a)(7).

You may begin conducting your research as outlined in your protocol. Your study does not require further review from the IRB, unless changes need to be made to your approved protocol.

As the Principal Investigator (PI), you are still responsible for contacting the UNC IRB office if and when:

UNIVERSITY OF
NORTHERN COLORADO

Institutional Review Board

- You wish to deviate from the described protocol and would like to formally submit a modification request. Prior IRB approval must be obtained before any changes can be implemented (except to eliminate an immediate hazard to research participants).
- You make changes to the research personnel working on this study (add or drop research staff on this protocol).
- At the end of the study or before you leave The University of Northern Colorado and are no longer a student or employee, to request your protocol be closed. *You cannot continue to reference UNC on any documents (including the informed consent form) or conduct the study under the auspices of UNC if you are no longer a student/employee of this university.
- You have received or have been made aware of any complaints, problems, or adverse events that are related or possibly related to participation in the research.

If you have any questions, please contact the Research Compliance Manager, Nicole Morse, at 970-351-1910 or via e-mail at nicole.morse@unco.edu. Additional information concerning the requirements for the protection of human subjects may be found at the Office of Human Research Protection website - http://hhs.gov/ohrp/ and https://www.unco.edu/research/research-integrity-and-compliance/institutional-review-board/.

Sincerely,

Nicole Morse
Research Compliance Manager

University of Northern Colorado: FWA00000784

APPENDIX B

STUDY CONSENT FORM

Consent Form for Human Participants in Research
Project Title: **Evaluation of Students' Achievement Emotions and Performance in the General Chemistry**

Researcher: Alex Graves
Phone number: (901) 626-6858 Email: alexander.graves@unco.edu
Research Advisor: Corina E. Brown
Phone number: (970)351-1285 Email: corina.brown@unco.edu

The primary goal of this research project is to evaluate students' emotional experiences relating to their General Chemistry lecture, lab, coursework, and exams. The study explores a potential relationship between the emotional experiences and the academic success. Due to this, agreeing to participate in this study will allow the researcher to access your final grade in your General Chemistry course. You may also be asked to be interviewed by the researcher as part of this study.

Achievement emotions (e.g., joy, anxiety, anger, etc.) will be measured by using an instrument composed of items designed to measure these set of emotions. The instrument used in this study will be evaluated in terms of the psychometric properties in the context of General Chemistry classes. If educators and researchers wish to make claims about students' emotional experiences in the classroom, a proper measurement tool must be used to obtain data that informs curricular impacts or research questions. Data generated from this mixed-methods study may inform future instructional strategies, helping to produce positive emotional experiences while limiting negative emotional experiences.

Any risk associated from participating in this study will be no different than what you may experience in a normal testing situation in a chemistry course. You may feel anxious or frustrated by completing the survey questions, but we hope to minimize these feelings.

If you allow us to use your survey responses and course grades in this research, your participation will be confidential and will not affect your grade in the course. Your instructor will not see your individual results on this survey or if you have declined to participate. Your instructor will be given a set of composite results for the class as a whole.

Confidentiality will be maintained during the course of data collection and analysis. Students' names will be stored separately from the data so that names cannot be linked to the information collected. Electronic data will be stored on a password protected computer. All data (both paper and electronic) will be destroyed once the study has been completed.

I understand that by agreeing to this consent form that I am allowing my responses to this assessment instrument and course grades to be used in this research study.

If you have any questions about the design or results of this study, or about the nature of your participation, you may contact the researcher or my advisor at any time using the phone numbers or email addresses indicated at the top of this form.

Participation is voluntary. You may decide NOT to participate in this study, and if you do begin participation, you may still decide to stop and withdraw at any time. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-2161.

Having read the above and having had an opportunity to ask any questions, please click “I Consent to Participate” if you agree to participate in this survey, or “I Do NOT Consent to Participate” if you do not consent.

APPENDIX C

STUDY RECRUITMENT SCRIPT

Instructions to be Read by Instructor in Lecture or Laboratory Course

The goal of this study is to discover and define the relationship between students' emotional experiences and academic performance in General Chemistry. For example, how do emotions such as anxiety and pride affect a student's final grade in their General Chemistry course?

The survey will just ask you to respond to a series of emotional prompts. For example, one prompt is "I enjoy being in chemistry class." to which you would respond using a scale from "Strongly disagree" to "Strongly agree". It is important to only think about your feelings towards your *chemistry* class. This research is currently only interested in how students' emotions affect their performance in General Chemistry; please try and ignore feelings you have towards other classes. The survey will go through prompts exploring emotions felt in three settings: during class (lecture), during times of learning (or studying), and during tests. There is also a section towards the end of the survey about your experiences in your chemistry lab; again, try to exclude any feelings you have towards other labs when answering those prompts.

There are some demographic questions at the end of the survey. If you are uncomfortable answering any of those questions, feel free to leave them blank. There is a question towards the end of the survey that asks if you would like to participate in future studies. The researcher will be interviewing some students that participate in the survey to obtain more insights into the emotions that students experience in General Chemistry. If you would like to be interviewed, leave a way to contact you (email address, for instance) at the prompt that asks for that.

By agreeing to participate in this survey, you will be allowing the researcher to obtain your final grade in your General Chemistry course.

If you have any questions, you can reach the researcher by the email address given on the consent form.

APPENDIX D

AEQ-GCHEM VERSION 1

AEQ-GCHEM Version 1

Start of Block: Consent Form

Evaluation of Students' Achievement Emotions and Performance in the General

Chemistry Researcher: Alex Graves
Phone number: (901) 626-6858
Email: alexander.graves@unco.edu

Research Advisor: Corina E. Brown
Phone number: (970)351-1285
Email: corina.brown@unco.edu

The primary goal of this research project is to evaluate students' emotional experiences relating to their general chemistry lecture, lab, coursework, and exams. The study explores a potential relationship between the emotional experiences and the academic success.

The following online survey will ask you to evaluate your own emotional experiences during your times of study. Specifically, you will be asked to recall how you felt while studying for your chemistry course, sitting in class for your chemistry course, and taking exams for your chemistry course. The questions will cover positive and negative emotional experiences. Please answer these questions as truthfully as possible using your own emotional experiences.

This survey will take roughly 20 minutes to complete. By agreeing to take and completing the survey, you are also giving permission to the researchers to access your final grade in the chemistry course you are enrolled in. The grade will be obtained from your current chemistry instructor.

Any risk associated from participating in this study will be no different than what you may experience in a normal testing situation in a chemistry course. You may feel anxious or frustrated by completing the survey questions, but we hope to minimize these feelings.

If you allow us to use your survey responses and course grades in this research, your participation will be confidential and will not affect your grade in the course. Your instructor will

not see your individual results on this survey or if you have declined to participate. Your instructor will be given a set of composite results for the class as a whole.

Confidentiality will be maintained during the course of data collection and analysis. Students' name will be stored separately from the data so that names cannot be linked to the information collected. Each participant shall have a random four-digit code assigned to them for confidentiality and data analysis purposes. Electronic data will be stored on a password protected computer. All data (both paper and electronic) will be destroyed once the study has been completed.

I understand that by agreeing to this consent form that I am allowing my responses to this assessment instrument and course grades to be used in this research study.

If you have any questions about the design or results of this study, or about the nature of your participation, you may contact the researcher or my advisor at any time using the phone numbers or email addresses indicated at the top of this form.

Participation is voluntary. You may decide NOT to participate in this study and if you do begin participation you may still decide to stop and withdraw at any time. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Research and Sponsored Programs, Nicole Morse at 970-351-1910.

Having read the above and having had an opportunity to ask any questions, please click "I Consent to Participate" if you agree to participate in this survey, or "I Do NOT Consent to Participate" if you do not consent.

- ○ I Consent to Participate (1)
- ○ I Do NOT Consent to Participate (2)

End of Block: Consent Form

Start of Block: Class-related Emotions

Attending classes at university can induce different feelings. The following questions refer to emotions you may experience when being in class at university. Before answering the questions, please recall some typical situations of being in chemistry class which you have experienced

during the course of your studies. Please indicate how you feel, typically, when being in chemistry class. Please read each statement carefully and respond using the scale provided.

For clarity, only consider your experiences in your general chemistry class for these questions.

---

1. I enjoy being in my general chemistry class.
2. I am looking forward to learning a lot in my general chemistry class.
3. I am motivated to go to my general chemistry class because it is exciting.
4. I enjoy participating so much that I get energized.
5. I am confident when I go to my general chemistry class.
6. I am full of hope in my general chemistry class.
7. I am confident because I understand the material in my general chemistry class.
8. Being confident that I will understand the material motivates me.
9. I am proud of myself.
10. I think that I can be proud of what I know about chemistry.
11. Because I take pride in my accomplishments in my general chemistry course, I am motivated to continue.
12. When I do well in my general chemistry class, my heart throbs with pride.
13. I am angry in my general chemistry class.
14. When I think of the time I wasted in my general chemistry class, I get aggravated.
15. I wish I didn't have to attend my general chemistry class because it makes me angry.
16. I am irritated by the results of my efforts in my general chemistry class.
17. I feel nervous in my general chemistry class.
18. Even before my general chemistry class, I worry whether I will be able to understand the material.
19. Because I am so nervous, I would rather skip my general chemistry class.
20. I get tense in my general chemistry class.
21. I get embarrassed in my general chemistry class.
22. When I say anything in my general chemistry class, I feel like I'm making a fool of myself.
23. After I have said something in my general chemistry class, I wish I could crawl into a hole and hide.
24. Because I get embarrassed in my general chemistry class, I become tense and inhibited.
25. I feel hopeless in my general chemistry class.
26. I have lost all hope in understanding my general chemistry class.
27. Because I have given up, I don't have the energy to go to my general chemistry class.
28. I feel so hopeless that all of my energy is depleted after my general chemistry class.
29. I get bored in my general chemistry class.
30. The lectures in my general chemistry class bore me.
31. I think about what else I might be doing rather than sitting in my boring general chemistry class.

32. I get restless because I cannot wait for my general chemistry class to end.

End of Block: Class-related Emotions

Start of Block: Learning-related Emotions

Studying for your courses at university can induce different feelings. The following questions refer to emotions you may experience when studying for your chemistry course. Before answering the questions, please recall some typical situations of studying which you have experience during the course of your chemistry studies. Please indicate how you feel, typically, when studying. Please read each statement carefully and respond using the scale provided.

For clarity, only consider your experiences studying for your general chemistry course when answering these questions.

---

1. I enjoy the challenge of learning the material in my general chemistry class.
2. I enjoy dealing with the general chemistry material.
3. I am so happy about the progress I made that I am motivated to continue studying chemistry.
4. When my general chemistry studies are going well, it gives me a rush.
5. I feel confident when studying for my general chemistry course.
6. I feel confident that I will be able to master my general chemistry material.
7. I feel optimistic that I will make good progress at studying for my general chemistry.
8. My sense of confidence motivates me to do well in my general chemistry class.
9. I'm proud myself in my general chemistry class.
10. I think I can be proud of my accomplishments at studying for my general chemistry course.
11. Because I want to be proud of my accomplishments in my general chemistry class, I am very motivated.
12. When I excel at my general chemistry class, I swell with pride.
13. Studying for my general chemistry class makes me irritated.
14. I get annoyed about having to study for my general chemistry class.
15. I get so angry I feel like throwing my chemistry textbook out of the window.
16. When I sit at my desk and study general chemistry for a long time, my irritation makes me restless.
17. I get tense and nervous while studying for my general chemistry class.
18. I worry whether I'm able to cope with all of my work in my general chemistry class.
19. While studying for my general chemistry class, I feel like distracting myself in order to reduce my anxiety.
20. Worrying about not completing the general chemistry material makes me anxious.
21. I feel ashamed when I study for my general chemistry class.
22. I feel ashamed when I realize that I lack the ability to learn the material in my general chemistry class.

23. Because I have had so much trouble with the general chemistry material, I avoid discussing it.
24. When somebody notices how little I understand the chemistry material, I avoid eye-contact.
25. I feel helpless when I think about my general chemistry class.
26. I'm resigned to the fact that I don't have the capacity to master the general chemistry material.
27. I feel so helpless that I can't give my chemistry studies my full efforts.
28. My lack of confidence makes me exhausted before I even start studying for my general chemistry class.
29. Studying for my general chemistry class bores me.
30. The chemistry material is so boring that I find myself daydreaming while studying.
31. I would rather put off my boring general chemistry coursework until tomorrow.
32. While studying chemistry, I seem to drift off because it's so boring.

End of Block: Learning-related Emotions

Start of Block: Test-related Emotions

Test and exams can induce different feelings. The following questions refer to emotions you may experience when taking chemistry tests or exams at university. Before answering the questions, please recall some typical situations of test-taking or exams in your chemistry course(s) which you have experienced. Please indicate how you feel, typically, when taking a chemistry test or exam. Please read each statement carefully and respond using the scale provided.

For clarity, only consider your experiences from taking tests/exams in your general chemistry course.

---

1. I enjoy taking general chemistry exams.
2. For me, the chemistry test is a challenge that is enjoyable.
3. Because I enjoy preparing for my general chemistry tests, I'm motivated to do more than is necessary.
4. Before taking a chemistry exam, I sense a feeling of eagerness.
5. I am optimistic that everything will work out fine in my general chemistry class.
6. I am very confident in my ability to take exams in my general chemistry class.
7. I think about my chemistry exams optimistically.
8. My confidence motivates me to prepare well for my general chemistry exams.
9. I am proud of myself in my general chemistry class.
10. I am proud of how well I mastered the chemistry exam.
11. Pride in my knowledge fuels my efforts in taking the chemistry exam.
12. After the chemistry exam, I feel ten feet taller because I am so proud of myself.

13. After a chemistry exam, I feel relief.
14. After a chemistry exam, I feel freed.
15. After a chemistry exam, the tension in my stomach dissipates.
16. After a chemistry exam, I can finally breathe easy again.
17. I get angry during my chemistry exams.
18. I get angry about the chemistry instructor's grading standards.
19. After a chemistry exam, I wish I could tell the teacher off.
20. I get frustrated taking exams in my general chemistry course.
21. I am very nervous during my general chemistry exams.
22. I worry about whether the chemistry test will be too difficult.
23. I get so nervous that I wish I could just skip the chemistry exam.
24. At the beginning of the chemistry exam, my heart starts pounding.
25. I feel ashamed during my general chemistry exams.
26. I get embarrassed because I cannot answer the questions correctly on my chemistry exams.
27. I get so embarrassed during and after my chemistry exams that I want to run and hide.
28. Because I am ashamed, my pulse races during my chemistry exams.
29. I feel hopeless when taking a chemistry exam.
30. I start to think that no matter how hard I try I won't succeed on the chemistry test.
31. I feel like giving up when I'm taking a chemistry exam.
32. I feel so resigned that I have no energy during my chemistry exams.

End of Block: Test-related Emotions

Start of Block: Lab-related Emotions

Working in a laboratory setting can evoke many emotions. The following questions refer to emotions you may experience when participating in chemistry laboratory courses at university. Before answering the questions, please recall some typical situations of laboratory settings in your chemistry course(s) which you have experienced. Please indicate how you feel, typically, when participating in and completing a chemistry lab. Please read each statement carefully and respond using the scale provided

For clarity, only consider your experiences from general chemistry-related laboratory settings.

---

1. I enjoy being in chemistry labs.
2. I look forward to learning a lot in my chemistry labs.
3. Because I enjoy chemistry labs, I am motivated to prepare well for them.
4. When I obtain good lab results, I feel a rush of energy.
5. I am confident when I go to my chemistry lab.
6. I feel confident that I will obtain good results in my chemistry lab.
7. I am confident that I understand the chemistry lab procedure.
8. Being confident in my ability to perform the chemistry lab motivates me.
9. I am proud of myself.
10. I am proud of how well I prepared for my chemistry lab.
11. Because I take pride in my lab results, I feel motivated.
12. When I excel in chemistry lab, I swell with pride.
13. I get angry in my chemistry lab.
14. When I think of the time I waste in my chemistry lab, I get aggravated.
15. I wish I didn't have to attend my chemistry lab because it makes me angry.
16. The lab reports in my chemistry lab make me angry.
17. I feel nervous in my chemistry lab.
18. Before I go to my chemistry lab, I worry that I do not understand the lab procedure.
19. I am so nervous that I would rather skip my chemistry lab.
20. Worrying about not obtaining results in my chemistry lab makes me tense up.
21. I feel ashamed in my chemistry lab.
22. I get embarrassed if I have to ask a question in my chemistry lab.
23. I feel so embarrassed that I would rather perform the lab incorrectly than ask the instructor for help.
24. I get so embarrassed in my chemistry lab that I want to run and hide.
25. I feel hopeless in my chemistry lab.
26. I often feel that I have lost all hope in obtaining good results in my chemistry lab.
27. I feel so helpless that I cannot give my chemistry lab my full efforts.
28. I am resigned to the fact that I do not have the capacity to obtain good results in my chemistry lab.
29. I get bored in my chemistry lab.
30. The chemistry lab is so boring that I find myself daydreaming.
31. I think about what else I could be doing rather than being in my chemistry lab.
32. I get restless because I cannot wait for my chemistry lab to end.

End of Block: Lab-related Emotions

Start of Block: Demographic Form

Please answer the following demographic questions truthfully to the best of your knowledge. If you are uncomfortable answering a question, you may skip it.

What is your full name that is on-file with the school?

_____

What year did you graduate from high school?

- ○ 2021 (1)
- ○ 2020 (2)
- ○ 2019 (3)
- ○ Other (please list year) (4)

_____

What is your year of study?

- ○ Freshman (1)
- ○ Sophmore (2)
- ○ Junior (3)
- ○ Senior (4)
- ○ Returning for second degree (5)

What is your academic major?

- ○ Chemistry/Biochemistry (1)
- ○ Biology/Pre-health (2)
- ○ Sports and Exercise Science (3)
- ○ Dietetics (4)
- ○ Other (please list your major) (5)

_____

How many years of science education have you had since graduating high school?

- ○ 0 (1)
- ○ 1 (2)
- ○ 2 (3)
- ○ More than 2 (4)

Did you take any AP chemistry classes in high school?

- ○ No (1)
- ○ I took at least one science- or math-based AP class, but not AP chemistry. (2)
- ○ I took AP chemistry. (3)

What chemistry course(s) are you enrolled in? Select all that apply.

- ☐ CHEM 103 (1)
- ☐ CHEM 111 (2)
- ☐ CHEM 112 (3)
- ☐ CHEM 281 (4)
- ☐ CHEM 381 (5)
- ☐ CHEM 481 (6)
- ☐ CHEM 482 (7)
- ☐ Other (please list) (8)

_____

If you are returning for your second degree, what was your first degree?

_____

What gender do you identify as?

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary (3)
- ○ Prefer not to say (4)
- ○ Option not listed (5) _____

What is your sexual orientation?

- ○ Straight (1)
- ○ Gay (2)
- ○ Bisexual (3)
- ○ Prefer not to say (4)
- ○ Option not listed (5) _____

What is your ethnicity?

- ○ Caucasian (1)
- ○ African or African-American (2)
- ○ Latino or Hispanic (3)
- ○ Asian or Asian-American (4)
- ○ Native American (5)
- ○ Native Hawaiian or Pacific Islander (6)
- ○ Two or more ethnicities (7)
- ○ Other (list if comfortable) (8)
- ○ Prefer not to say (9)

Do you have a job aside from being a student?

- ○ Full-time (1)
- ○ Part-time (2)
- ○ No (3)

Why did you decide to major in what your are currently majoring in?

_____

Did any of your primary caregivers receive a bachelor's degree or higher educational degree?

- ○ Yes (1)
- ○ Maybe (2)
- ○ No (3)

Would you like to be interviewed to help the researchers fine-tune and adjust the survey? This interview would take approximately 30 minutes. If you select “Yes”, you may be reached out to at a later date by email (please provide your email).

- ○ Yes (provide student email address) (1) _____
- ○ No (2)

End of Block: Demographic Form

APPENDIX E

AEQ-GCHEM VERSION 2

AEQ-GCHEM Version 2

Start of Block: Consent Form

Evaluation of Students' Achievement Emotions and Performance in the General

Chemistry Researcher: Alex Graves
Phone number: (901) 626-6858
Email: alexander.graves@unco.edu

Research Advisor: Corina E. Brown
Phone number: (970)351-1285
Email: corina.brown@unco.edu

The primary goal of this research project is to evaluate students' emotional experiences relating to their general chemistry lecture, lab, coursework, and exams. The study explores a potential relationship between the emotional experiences and the academic success.

The following online survey will ask you to evaluate your own emotional experiences during your times of study. Specifically, you will be asked to recall how you felt while studying for your chemistry course, sitting in class for your chemistry course, and taking exams for your chemistry course. The questions will cover positive and negative emotional experiences. Please answer these questions as truthfully as possible using your own emotional experiences.

This survey will take roughly 20 minutes to complete. By agreeing to take and completing the survey, you are also giving permission to the researchers to access your final grade in the chemistry course you are enrolled in. The grade will be obtained from your current chemistry instructor.

Any risk associated from participating in this study will be no different than what you may experience in a normal testing situation in a chemistry course. You may feel anxious or frustrated by completing the survey questions, but we hope to minimize these feelings.

If you allow us to use your survey responses and course grades in this research, your participation will be confidential and will not affect your grade in the course. Your instructor will

not see your individual results on this survey or if you have declined to participate. Your instructor will be given a set of composite results for the class as a whole.

Confidentiality will be maintained during the course of data collection and analysis. Students' name will be stored separately from the data so that names cannot be linked to the information collected. Each participant shall have a random four-digit code assigned to them for confidentiality and data analysis purposes. Electronic data will be stored on a password protected computer. All data (both paper and electronic) will be destroyed once the study has been completed.

I understand that by agreeing to this consent form that I am allowing my responses to this assessment instrument and course grades to be used in this research study.

If you have any questions about the design or results of this study, or about the nature of your participation, you may contact the researcher or my advisor at any time using the phone numbers or email addresses indicated at the top of this form.

Participation is voluntary. You may decide NOT to participate in this study and if you do begin participation you may still decide to stop and withdraw at any time. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Research and Sponsored Programs, Nicole Morse at 970-351-1910.

Having read the above and having had an opportunity to ask any questions, please click "I Consent to Participate" if you agree to participate in this survey, or "I Do NOT Consent to Participate" if you do not consent.

- ○ I Consent to Participate (1)
- ○ I Do NOT Consent to Participate (2)

End of Block: Consent Form

Start of Block: Class-related Emotions

Attending classes at university can induce different feelings. The following questions refer to emotions you may experience when being in class at university. Before answering the questions, please recall some typical situations of being in chemistry class which you have experienced

during the course of your studies. Please indicate how you feel, typically, when being in chemistry class. Please read each statement carefully and respond using the scale provided.

For clarity, only consider your experiences in your general chemistry class for these questions.

---

1. I enjoy being in my general chemistry class.
2. I am looking forward to learning a lot in my general chemistry class.
3. I am motivated to go to my general chemistry class because it is exciting.
4. I enjoy participating so much that I get energized.
5. I am confident when I go to my general chemistry class.
6. When I am taught a new concept, I am confident that I will attain a basic understanding of it.
7. I am confident because I understand the material in my general chemistry class.
8. Being confident that I will understand the material motivates me.
9. I am proud of myself.
10. I think that I can be proud of what I know about chemistry.
11. Because I take pride in my accomplishments in my general chemistry course, I am motivated to continue.
12. When I do well in my general chemistry class, my heart throbs with pride.
13. My general chemistry class annoys me.
14. When I think of the time I wasted in my general chemistry class, I get aggravated.
15. I wish I didn't have to attend my general chemistry class because it makes me angry.
16. I am irritated by the results of my efforts in my general chemistry class.
17. I feel nervous in my general chemistry class.
18. Even before my general chemistry class, I worry whether I will be able to understand the material.
19. Because I am so nervous, I would rather skip my general chemistry class.
20. I get tense in my general chemistry class.
21. I get embarrassed in my general chemistry class.
22. When I say anything in my general chemistry class, I feel like I'm making a fool of myself.
23. After I have said something in my general chemistry class, I wish I could crawl into a hole and hide.
24. Because I get embarrassed in my general chemistry class, I become tense and inhibited.
25. I feel hopeless in my general chemistry class.
26. I have lost all hope in understanding my general chemistry class.
27. Because I have given up, I don't have the energy to go to my general chemistry class.
28. I feel so hopeless that all of my energy is depleted after my general chemistry class.
29. I get bored in my general chemistry class.
30. The lectures in my general chemistry class bore me.

31. I think about what else I might be doing rather than sitting in my boring general chemistry class.
32. I get restless because I cannot wait for my general chemistry class to end.

End of Block: Class-related Emotions

Start of Block: Learning-related Emotions

Studying for your courses at university can induce different feelings. The following questions refer to emotions you may experience when studying for your chemistry course. Before answering the questions, please recall some typical situations of studying which you have experience during the course of your chemistry studies. Please indicate how you feel, typically, when studying. Please read each statement carefully and respond using the scale provided.

For clarity, only consider your experiences studying for your general chemistry course when answering these questions.

---

1. I enjoy the challenge of learning the material in my general chemistry class.
2. I enjoy dealing with the general chemistry material.
3. I am so happy about the progress I made that I am motivated to continue studying chemistry.
4. When my general chemistry studies are going well, it gives me a rush.
5. I feel confident when studying for my general chemistry course.
6. I feel confident that I will be able to master my general chemistry material.
7. I feel optimistic that I will make good progress at studying for my general chemistry.
8. My sense of confidence motivates me to do well in my general chemistry class.
9. I'm proud of how I study for my general chemistry class.
10. I think I can be proud of my accomplishments at studying for my general chemistry course.
11. Because I want to be proud of my accomplishments in my general chemistry class, I am very motivated.
12. When I excel at my general chemistry class, I swell with pride.
13. Studying for my general chemistry class makes me irritated.
14. I get annoyed about having to study for my general chemistry class.
15. I get so angry I feel like throwing my chemistry textbook out of the window.
16. When I sit at my desk and study general chemistry for a long time, my irritation makes me restless.
17. I get tense and nervous while studying for my general chemistry class.
18. I worry whether I'm able to cope with all of my work in my general chemistry class.
19. While studying for my general chemistry class, I feel like distracting myself in order to reduce my anxiety.
20. Worrying about not completing the general chemistry material makes me anxious.

21. I feel ashamed when I study for my general chemistry class.
22. I feel ashamed when I realize that I lack the ability to learn the material in my general chemistry class.
23. Because I have had so much trouble with the general chemistry material, I avoid discussing it.
24. When somebody notices how little I understand the chemistry material, I avoid eye-contact.
25. I feel helpless when I think about my general chemistry class.
26. I'm resigned to the fact that I don't have the capacity to master the general chemistry material.
27. I feel so helpless that I can't give my chemistry studies my full efforts.
28. My lack of confidence makes me exhausted before I even start studying for my general chemistry class.
29. Studying for my general chemistry class bores me.
30. The chemistry material is so boring that I find myself daydreaming while studying.
31. I would rather put off my boring general chemistry coursework until tomorrow.
32. While studying chemistry, I seem to drift off because it's so boring.

End of Block: Learning-related Emotions

Start of Block: Test-related Emotions

Test and exams can induce different feelings. The following questions refer to emotions you may experience when taking chemistry tests or exams at university. Before answering the questions, please recall some typical situations of test-taking or exams in your chemistry course(s) which you have experienced. Please indicate how you feel, typically, when taking a chemistry test or exam. Please read each statement carefully and respond using the scale provided.

For clarity, only consider your experiences from taking tests/exams in your general chemistry course.

---

1. I enjoy taking general chemistry exams.
2. For me, the chemistry test is a challenge that is enjoyable.
3. Because I enjoy preparing for my general chemistry tests, I'm motivated to do more than is necessary.
4. Before taking a chemistry exam, I sense a feeling of eagerness.
5. I am optimistic that everything will work out fine in my general chemistry class.
6. I am very confident in my ability to take exams in my general chemistry class.
7. I think about my chemistry exams optimistically.
8. My confidence motivates me to prepare well for my general chemistry exams.
9. I am proud of my performance on general chemistry exams.

10. I am proud of how well I mastered the chemistry exam.
11. Pride in my knowledge fuels my efforts in taking the chemistry exam.
12. After the chemistry exam, I feel overjoyed because I am so proud of myself.
13. After a chemistry exam, I feel relief.
14. After a chemistry exam, I feel freed.
15. After a chemistry exam, the tension in my stomach dissipates.
16. After a chemistry exam, I can finally breathe easy again.
17. I get angry during my chemistry exams.
18. I get angry about the chemistry instructor's grading standards.
19. I resent having to take exams in my general chemistry class.
20. I get frustrated taking exams in my general chemistry course.
21. I am very nervous during my general chemistry exams.
22. I worry about whether the chemistry test will be too difficult.
23. I get so nervous that I wish I could just skip the chemistry exam.
24. At the beginning of the chemistry exam, my heart starts pounding.
25. I feel ashamed during my general chemistry exams.
26. I get embarrassed because I cannot answer the questions correctly on my chemistry exams.
27. I get so embarrassed during and after my chemistry exams that I want to run and hide.
28. Because I am ashamed, my pulse races during my chemistry exams.
29. I feel hopeless when taking a chemistry exam.
30. I start to think that no matter how hard I try I won't succeed on the chemistry test.
31. I feel like giving up when I'm taking a chemistry exam.
32. I feel so resigned that I have no energy during my chemistry exams.

End of Block: Test-related Emotions

Start of Block: Lab-related Emotions

Working in a laboratory setting can evoke many emotions. The following questions refer to emotions you may experience when participating in chemistry laboratory courses at university. Before answering the questions, please recall some typical situations of laboratory settings in your chemistry course(s) which you have experienced. Please indicate how you feel, typically, when participating in and completing a chemistry lab. Please read each statement carefully and respond using the scale provided

For clarity, only consider your experiences from general chemistry-related laboratory settings.

---

1. I enjoy being in chemistry labs.
2. I look forward to learning a lot in my chemistry labs.
3. Because I enjoy chemistry labs, I am motivated to prepare well for them.
4. When I obtain good lab results, I feel a rush of energy.
5. I am confident when I go to my chemistry lab.
6. I feel confident that I will obtain good results in my chemistry lab.
7. I am confident that I understand the chemistry lab procedure.
8. Being confident in my ability to perform the chemistry lab motivates me.
9. I am proud of myself.
10. I am proud of how well I prepared for my chemistry lab.
11. Because I take pride in my lab results, I feel motivated.
12. When I excel in chemistry lab, I swell with pride.
13. I get angry in my chemistry lab.
14. When I think of the time I waste in my chemistry lab, I get aggravated.
15. I wish I didn't have to attend my chemistry lab because it makes me angry.
16. The lab reports in my chemistry lab make me angry.
17. I feel nervous in my chemistry lab.
18. Before I go to my chemistry lab, I worry that I do not understand the lab procedure.
19. I am so nervous that I would rather skip my chemistry lab.
20. Worrying about not obtaining results in my chemistry lab makes me tense up.
21. I feel ashamed in my chemistry lab.
22. I get embarrassed if I have to ask a question in my chemistry lab.
23. I feel so embarrassed that I would rather perform the lab incorrectly than ask the instructor for help.
24. I get so embarrassed in my chemistry lab that I want to run and hide.
25. I feel hopeless in my chemistry lab.
26. I often feel that I have lost all hope in obtaining good results in my chemistry lab.
27. I feel so helpless that I cannot give my chemistry lab my full efforts.
28. I am resigned to the fact that I do not have the capacity to obtain good results in my chemistry lab.
29. I get bored in my chemistry lab.
30. The chemistry lab is so boring that I find myself daydreaming.
31. I think about what else I could be doing rather than being in my chemistry lab.
32. I get restless because I cannot wait for my chemistry lab to end.

End of Block: Lab-related Emotions

Start of Block: Demographic Form

Please answer the following demographic questions truthfully to the best of your knowledge. If you are uncomfortable answering a question, you may skip it.

What is your full name that is on-file with the school?

_____

What year did you graduate from high school?

- ○ 2021 (1)
- ○ 2020 (2)
- ○ 2019 (3)
- ○ Other (please list year) (4)

_____

What is your year of study?

- ○ Freshman (1)
- ○ Sophmore (2)
- ○ Junior (3)
- ○ Senior (4)
- ○ Returning for second degree (5)

What is your academic major?

- ○ Chemistry/Biochemistry (1)
- ○ Biology/Pre-health (2)
- ○ Sports and Exercise Science (3)
- ○ Dietetics (4)
- ○ Other (please list your major) (5)

_____

How many years of science education have you had since graduating high school?

- ○ 0 (1)
- ○ 1 (2)
- ○ 2 (3)
- ○ More than 2 (4)

Did you take any AP chemistry classes in high school?

- ○ No (1)
- ○ I took at least one science- or math-based AP class, but not AP chemistry. (2)
- ○ I took AP chemistry. (3)

What chemistry course(s) are you enrolled in? Select all that apply.

- ☐ CHEM 103 (1)
- ☐ CHEM 111 (2)
- ☐ CHEM 112 (3)
- ☐ CHEM 281 (4)
- ☐ CHEM 381 (5)
- ☐ CHEM 481 (6)
- ☐ CHEM 482 (7)
- ☐ Other (please list) (8)

_____

If you are returning for your second degree, what was your first degree?

_____

What gender do you identify as?

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary (3)
- ○ Prefer not to say (4)
- ○ Option not listed (5) _____

What is your sexual orientation?

- ○ Straight (1)
- ○ Gay (2)
- ○ Bisexual (3)
- ○ Prefer not to say (4)
- ○ Option not listed (5) _____

What is your ethnicity?

- ○ Caucasian (1)
- ○ African or African-American (2)
- ○ Latino or Hispanic (3)
- ○ Asian or Asian-American (4)
- ○ Native American (5)
- ○ Native Hawaiian or Pacific Islander (6)
- ○ Two or more ethnicities (7)
- ○ Other (list if comfortable) (8)
- ○ Prefer not to say (9)

Do you have a job aside from being a student?

- ○ Full-time (1)
- ○ Part-time (2)
- ○ No (3)

Why did you decide to major in what your are currently majoring in?

_____

Did any of your primary caregivers receive a bachelor's degree or higher educational degree?

- ○ Yes (1)
- ○ Maybe (2)
- ○ No (3)

Would you like to be interviewed to help the researchers fine-tune and adjust the survey? This interview would take approximately 30 minutes. If you select “Yes”, you may be reached out to at a later date by email (please provide your email).

- ○ Yes (provide student email address) (1) _____
- ○ No (2)

End of Block: Demographic Form

APPENDIX F

AEQ-GCHEM FINAL VERSION

AEQ-GCHEM

Evaluation of Students' Achievement Emotions and Performance in General Chemistry
Researcher: Alex Graves
Phone number: (901) 626-6858
Email: alexander.graves@unco.edu

Research Advisor: Corina E. Brown
Phone number: (970)351-1285
Email: corina.brown@unco.edu

The primary goal of this research project is to evaluate students' emotional experiences relating to their general chemistry lecture, lab, coursework, and exams. The study explores a potential relationship between the emotional experiences and the academic success.

The following online survey will ask you to evaluate your own emotional experiences during your times of study. Specifically, you will be asked to recall how you felt while studying for your chemistry course, sitting in class for your chemistry course, and taking exams for your chemistry course. The questions will cover positive and negative emotional experiences. Please answer these questions as truthfully as possible using your own emotional experiences.

This survey will take roughly 20 minutes to complete. By agreeing to take and completing the survey, you are also giving permission to the researchers to access your final grade in the chemistry course you are enrolled in. The grade will be obtained from your current chemistry instructor.

Any risk associated from participating in this study will be no different than what you may experience in a normal testing situation in a chemistry course. You may feel anxious or frustrated by completing the survey questions, but we hope to minimize these feelings.

If you allow us to use your survey responses and course grades in this research, your participation will be confidential and will not affect your grade in the course. Your instructor will not see your individual results on this survey or if you have declined to participate. Your instructor will be given a set of composite results for the class as a whole.

Confidentiality will be maintained during the course of data collection and analysis. Students'

names will be stored separately from the data so that names cannot be linked to the information collected. Each participant shall have a random four-digit code assigned to them for confidentiality and data analysis purposes. Electronic data will be stored on a password protected computer. All data (both paper and electronic) will be destroyed once the study has been completed.

I understand that by agreeing to this consent form that I am allowing my responses to this assessment instrument and course grades to be used in this research study.

If you have any questions about the design or results of this study, or about the nature of your participation, you may contact the researcher or my advisor at any time using the phone numbers or email addresses indicated at the top of this form.

Participation is voluntary. You may decide NOT to participate in this study and if you do begin participation you may still decide to stop and withdraw at any time. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Research and Sponsored Programs, Nicole Morse at 970-351-1910.

Having read the above and having had an opportunity to ask any questions, please click “I Consent to Participate” if you agree to participate in this survey, or “I Do NOT Consent to Participate” if you do not consent.

- ○ I Consent to Participate
- ○ I Do NOT Consent to Participate

Start of Block: Class-related Emotions

Attending classes at university can induce different feelings. The following questions refer to emotions you may experience when being in class at university. Before answering the questions, please recall some typical situations of being in chemistry class which you have experienced during the course of your studies. Please indicate how you feel, typically, when being in chemistry class. Please read each statement carefully and respond using the scale provided.

For clarity, only consider your experiences in your general chemistry class for these questions.

1. I enjoy being in my general chemistry class.
2. I am looking forward to learning a lot in my general chemistry class.
3. I am motivated to go to my general chemistry class because it is exciting.
4. I enjoy participating so much that I get energized.
5. I am confident when I go to my general chemistry class.
6. When I am taught a new concept, I am confident that I will attain a basic understanding of it.
7. I am confident because I understand the material in my general chemistry class.
8. Being confident that I will understand the material motivates me.
9. I am proud of myself.
10. I think that I can be proud of what I know about chemistry.
11. Because I take pride in my accomplishments in my general chemistry course, I am motivated to continue.
12. When I do well in my general chemistry class, my heart throbs with pride.
13. My general chemistry class annoys me.
14. When I think of the time I wasted in my general chemistry class, I get aggravated.
15. I wish I didn't have to attend my general chemistry class because it makes me angry.
16. I am irritated by the results of my efforts in my general chemistry class.
17. I feel nervous in my general chemistry class.
18. Even before my general chemistry class, I worry whether I will be able to understand the material.
19. Because I am so nervous, I would rather skip my general chemistry class.
20. I get tense in my general chemistry class.
21. I get embarrassed in my general chemistry class.
22. When I say anything in my general chemistry class, I feel like I'm making a fool of myself.
23. After I have said something in my general chemistry class, I wish I could crawl into a hole and hide.
24. Because I get embarrassed in my general chemistry class, I become tense and inhibited.
25. I feel hopeless in my general chemistry class.
26. I have lost all hope in understanding my general chemistry class.
27. Because I have given up, I don't have the energy to go to my general chemistry class.
28. I feel so hopeless that all of my energy is depleted after my general chemistry class.
29. I get bored in my general chemistry class.
30. The lectures in my general chemistry class bore me.
31. I think about what else I might be doing rather than sitting in my boring general chemistry class.
32. I get restless because I cannot wait for my general chemistry class to end.

End of Block: Class-related Emotions

Start of Block: Learning-related Emotions

Studying for your courses at university can induce different feelings. The following questions refer to emotions you may experience when studying for your chemistry course. Before answering the questions, please recall some typical situations of studying which you have experienced during the course of your chemistry studies. Please indicate how you feel, typically, when studying. Please read each statement carefully and respond using the scale provided.

For clarity, only consider your experiences studying for your general chemistry course when answering these questions.

---

1. I enjoy the challenge of learning the material in my general chemistry class.
2. I enjoy dealing with the general chemistry material.
3. I am so happy about the progress I made that I am motivated to continue studying chemistry.
4. When my general chemistry studies are going well, it gives me a rush.
5. I feel confident when studying for my general chemistry course.
6. I feel confident that I will be able to master my general chemistry material.
7. I feel optimistic that I will make good progress at studying for my general chemistry.
8. My sense of confidence motivates me to do well in my general chemistry class.
9. I'm proud of how I study for my general chemistry class.
10. I think I can be proud of my accomplishments at studying for my general chemistry course.
11. Because I want to be proud of my accomplishments in my general chemistry class, I am very motivated.
12. When I excel at my general chemistry class, I swell with pride.
13. Studying for my general chemistry class makes me irritated.
14. I get annoyed about having to study for my general chemistry class.
15. I get so angry I feel like throwing my chemistry textbook out of the window.
16. When I sit at my desk and study general chemistry for a long time, my irritation makes me restless.
17. I get tense and nervous while studying for my general chemistry class.
18. I worry whether I'm able to cope with all of my work in my general chemistry class.
19. While studying for my general chemistry class, I feel like distracting myself in order to reduce my anxiety.
20. Worrying about not completing the general chemistry material makes me anxious.
21. I feel ashamed when I study for my general chemistry class.

22. I feel ashamed when I realize that I lack the ability to learn the material in my general chemistry class.
23. Because I have had so much trouble with the general chemistry material, I avoid discussing it.
24. When somebody notices how little I understand the chemistry material, I avoid eye-contact.
25. I feel helpless when I think about my general chemistry class.
26. I'm resigned to the fact that I don't have the capacity to master the general chemistry material.
27. I feel so helpless that I can't give my chemistry studies my full efforts.
28. My lack of confidence makes me exhausted before I even start studying for my general chemistry class.
29. Studying for my general chemistry class bores me.
30. The chemistry material is so boring that I find myself daydreaming while studying.
31. I would rather put off my boring general chemistry coursework until tomorrow.
32. While studying chemistry, I seem to drift off because it's so boring.

End of Block: Learning-related Emotions

Start of Block: Test-related Emotions

Tests and exams can induce different feelings. The following questions refer to emotions you may experience when taking chemistry tests or exams at university. Before answering the questions, please recall some typical situations of test-taking or exams in your chemistry course(s) which you have experienced. Please indicate how you feel, typically, when taking a chemistry test or exam. Please read each statement carefully and respond using the scale provided.

For clarity, only consider your experiences from taking tests/exams in your general chemistry course.

---

1. I enjoy taking general chemistry exams.
2. For me, the chemistry test is a challenge that is enjoyable.
3. Because I enjoy preparing for my general chemistry tests, I'm motivated to do more than is necessary.
4. Before taking a chemistry exam, I sense a feeling of eagerness.
5. I am optimistic that everything will work out fine in my general chemistry class.
6. I am very confident in my ability to take exams in my general chemistry class.
7. I think about my chemistry exams optimistically.

8. My confidence motivates me to prepare well for my general chemistry exams.
9. I am proud of my performance on general chemistry exams.
10. I am proud of how well I mastered the chemistry exam.
11. Pride in my knowledge fuels my efforts in taking the chemistry exam.
12. After the chemistry exam, I feel overjoyed because I am so proud of myself.
13. After a chemistry exam, I feel relief.
14. After a chemistry exam, I feel freed.
15. After a chemistry exam, the tension in my stomach dissipates.
16. After a chemistry exam, I can finally breathe easy again.
17. I get angry during my chemistry exams.
18. I get angry about the chemistry instructor's grading standards.
19. I resent having to take exams in my general chemistry class.
20. I get frustrated taking exams in my general chemistry course.
21. I am very nervous during my general chemistry exams.
22. I worry about whether the chemistry test will be too difficult.
23. I get so nervous that I wish I could just skip the chemistry exam.
24. At the beginning of the chemistry exam, my heart starts pounding.
25. I feel ashamed during my general chemistry exams.
26. I get embarrassed because I cannot answer the questions correctly on my chemistry exams.
27. I get so embarrassed during and after my chemistry exams that I want to run and hide.
28. Because I am ashamed, my pulse races during my chemistry exams.
29. I feel hopeless when taking a chemistry exam.
30. I start to think that no matter how hard I try I won't succeed on the chemistry test.
31. I feel like giving up when I'm taking a chemistry exam.
32. I feel so resigned that I have no energy during my chemistry exams.

Start of Block: Lab-related Emotions

Working in a laboratory setting can evoke many emotions. The following questions refer to emotions you may experience when participating in chemistry laboratory courses at university. Before answering the questions, please recall some typical situations of laboratory settings in your chemistry course(s) which you have experienced. Please indicate how you feel, typically, when participating in and completing a chemistry lab. Please read each statement carefully and

respond using the scale provided
For clarity, only consider your experiences from general chemistry-related laboratory settings.

1. I enjoy being in chemistry labs.
2. I look forward to learning a lot in my chemistry labs.
3. Because I enjoy chemistry labs, I am motivated to prepare well for them.
4. When I obtain good lab results, I feel a rush of energy.
5. I am confident when I go to my chemistry lab.
6. I feel confident that I will obtain good results in my chemistry lab.
7. I am confident that I understand the chemistry lab procedure.
8. Being confident in my ability to perform the chemistry lab motivates me.
9. I am proud of myself.
10. I am proud of how well I prepared for my chemistry lab.
11. Because I take pride in my lab results, I feel motivated.
12. When I excel in chemistry lab, I swell with pride.
13. I get angry in my chemistry lab.
14. When I think of the time I waste in my chemistry lab, I get aggravated.
15. I wish I didn't have to attend my chemistry lab because it makes me angry.
16. The lab reports in my chemistry lab make me angry.
17. I feel nervous in my chemistry lab.
18. Before I go to my chemistry lab, I worry that I do not understand the lab procedure.
19. I am so nervous that I would rather skip my chemistry lab.
20. Worrying about not obtaining results in my chemistry lab makes me tense up.
21. I feel ashamed in my chemistry lab.
22. I get embarrassed if I have to ask a question in my chemistry lab.
23. I feel so embarrassed that I would rather perform the lab incorrectly than ask the instructor for help.
24. I get so embarrassed in my chemistry lab that I want to run and hide.
25. I feel hopeless in my chemistry lab.
26. I often feel that I have lost all hope in obtaining good results in my chemistry lab.
27. I feel so helpless that I cannot give my chemistry lab my full efforts.
28. I am resigned to the fact that I do not have the capacity to obtain good results in my chemistry lab.
29. I get bored in my chemistry lab.
30. The chemistry lab is so boring that I find myself daydreaming.
31. I think about what else I could be doing rather than being in my chemistry lab.
32. I get restless because I cannot wait for my chemistry lab to end.

End of Block: Lab-related Emotions

Start of Block: Demographic Form

Please answer the following demographic questions truthfully to the best of your knowledge. If you are uncomfortable answering a question, you may skip it.

What is your full name that is on-file with the school?

_____

What year did you graduate from high school?

- ○ 2021
- ○ 2020
- ○ 2019
- ○ Other (please list year) _____

What is your year of study?

- ○ Freshman
- ○ Sophomore
- ○ Junior
- ○ Senior
- ○ Returning for second degree

What is your academic major?

- ○ Chemistry/Biochemistry
- ○ Biology/Pre-health
- ○ Sports and Exercise Science
- ○ Dietetics
- ○ Other (please list your major)

_____

How many years of science education have you had since graduating high school?

- ○ 0
- ○ 1
- ○ 2
- ○ More than 2

Did you take any AP chemistry classes in high school?

- ○ No
- ○ I took at least one science- or math-based AP class, but not AP chemistry.
- ○ I took AP chemistry.

What chemistry course(s) are you enrolled in? Select all that apply.

- [ ] CHEM 103
- [ ] CHEM 111
- [ ] CHEM 112
- [ ] CHEM 281
- [ ] CHEM 381
- [ ] CHEM 481
- [ ] CHEM 482
- [ ] Other (please list) _____

If you are returning for your second degree, what was your first degree?

_____

What gender do you identify as?

- ○ Male
- ○ Female
- ○ Non-binary
- ○ Prefer not to say
- ○ Option not listed _____

What is your sexual orientation?

- ○ Straight
- ○ Gay
- ○ Bisexual
- ○ Prefer not to say
- ○ Option not listed _____

What is your ethnicity?

- ○ Caucasian
- ○ African or African American
- ○ Latino or Hispanic
- ○ Asian or Asian-American
- ○ Native American
- ○ Native Hawaiian or Pacific Islander
- ○ Two or more ethnicities
- ○ Other (list if comfortable)
- ○ Prefer not to say

Do you have a job aside from being a student?

- ○ Full-time
- ○ Part-time
- ○ No

Why did you decide to major in what you are currently majoring in?

_____

Did any of your primary caregivers receive a bachelor's degree or higher educational degree?

- ○ Yes
- ○ Maybe
- ○ No

Would you like to be interviewed to help the researchers fine-tune and adjust the survey? This interview would take approximately 30 minutes. If you select “Yes”, you may be reached out to at a later date by email (please provide your email).

- ○ Yes (provide student email address)

_____

- ○ No

End of Block: Demographic Form

APPENDIX G

GOODNESS-OF-FIT INDICES FOR ITERATIONS OF THE AEQ-GCHEMDEVELOPED IN PHASE ONE

AEQ-GCHEM Version 1:

Table G.1.

Factor Analysis Indices of Individual Setting-Emotion Scales.

Emotion	Setting (Classroom, Learning, Testing, Laboratory)		
	CFI	SRMR	RMSEA
Enjoyment	(0.948, 0.992, 0.974, 0.970)	(0.04, 0.03, 0.04, 0.03)	(0.22, 0.09, 0.15, 0.22)
Hope	(0.993, 1, 1, 1)	(0.02, 0.02, 0.01, 0.01)	(0.09, 0, 0, 0)
Pride	(1, 0.968, 0.988, 0.956)	(0.02, 0.04, 0.02, 0.07)	(0, 0.16, 0.15, 0.19)
Anger	(1, 0.999, 1, 0.995)	(0.02, 0.03, 0.01, 0.02)	(0, 0.05, 0, 0.08)
Anxiety	(0.986, 1, 1, 0.952)	(0.03, 0.01, 0.02, 0.04)	(0.12, 0, 0.06, 0.24)
Shame	(1, 0.994, 0.928, 1)	(0.01, 0.02, 0.04, 0.01)	(0, 0.10, 0.41, 0)
Hopelessness	(0.996, 1, 0.977, 1)	(0.02, 0, 0.02, 0.01)	(0.08, 0, 0.23, 0)
Boredom	(0.983, 1, -, 0.998)	(0.02, 0.01, -, 0.03)	(0.16, 0, -, 0.15)
Relief	(-, -, 0.924, -)	(-, -, 0.08, -)	(-, -, 0.29, -)

Confirmatory factor analysis was used to evaluate the AEQ-GCHEM Version 1 using four distinct models. The first model proposes that all 32 subscales can be explained through a single emotion factor; this single-factory model does not result in a good fit of the data: CFI = 0.548, SRMR = 0.151, RMSEA = 0.180. The second model proposes that there are 9 individual correlating emotions factors; this emotion-centric model does not result in a good fit of the data: CFI = 0.690, SRMR = 0.140, RMSEA = 0.155. The third model proposes that there are 3 individual correlating setting factors; this setting-centric model does not result in a good fit of the data: CFI = 0.662, SRMR = 0.122, RMSEA = 0.157. The fourth model proposes that there are 9 emotion factors that correlate with residuals resulting from the four settings; this model results in the best fit of the data: CFI = 0.910, SRMR = 0.144, RMSEA = 0.097.

AEQ-GCHEM Version 2:

Table G.1.

Factor Analysis Indices of Individual Setting-Emotion Scales.

Emotion	Setting (Classroom, Learning, Testing, Laboratory)		
	CFI	SRMR	RMSEA
Enjoyment	(1, 0.970, 0.969, 0.985)	(0.01, 0.04, 0.04, 0.03)	(0, 0.16, 0.18, 0.13)
Hope	(1, 0.976, 1, 0.990)	(0.01, 0.03, 0, 0.02)	(0, 0.15, 0, 0.10)
Pride	(1, 0.844, 0.936, 0.969)	(0.01, 0.10, 0.07, 0.04)	(0, 0.31, 0.28, 0.15)
Anger	(0.991, 0.965, 0.977, 0.993)	(0.02, 0.04, 0.03, 0.02)	(0.08, 0.20, 0.16, 0.10)
Anxiety	(0.962, 0.992, 1, 0.999)	(0.04, 0.02, 0.01, 0.02)	(0.20, 0.10, 0.02, 0.03)
Shame	(0.967, 0.974, 0.979, 1)	(0.03, 0.03, 0.02, 0.01)	(0.20, 0.16, 0.18, 0)
Hopelessness	(0.970, 0.966, 0.972, 0.992)	(0.03, 0.03, 0.03, 0.02)	(0.19, 0.21, 0.22, 0.11)
Boredom	(0.938, 1, -, 0.977)	(0.04, 0.01, -, 0.02)	(0.29, 0, -, 0.19)
Relief	(-, -, 0.852, -)	(-, -, 0.09, -)	(-, -, 0.45, -)

Confirmatory factor analysis was used to evaluate the AEQ-GCHEM Version 1 using four distinct models. The first model proposes that all 32 subscales can be explained through a single emotion factor; this single-factory model does not result in a good fit of the data: CFI = 0.533, SRMR = 0.143, RMSEA = 0.178. The second model proposes that there are 9 individual correlating emotions factors; this emotion-centric model does not result in a good fit of the data: CFI = 0.722, SRMR = 0.116, RMSEA = 0.143. The third model proposes that there are 3 individual correlating setting factors; this setting-centric model does not result in a good fit of the data: CFI = 0.633, SRMR = 0.122, RMSEA = 0.159. The fourth model proposes that there are 9 emotion factors that correlate with residuals resulting from the four settings; this model results in the best fit of the data: CFI = 0.932, SRMR = 0.092, RMSEA = 0.082.