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Exploring Achievement Emotions as Predictors of Students Success in a General Chemistry Course

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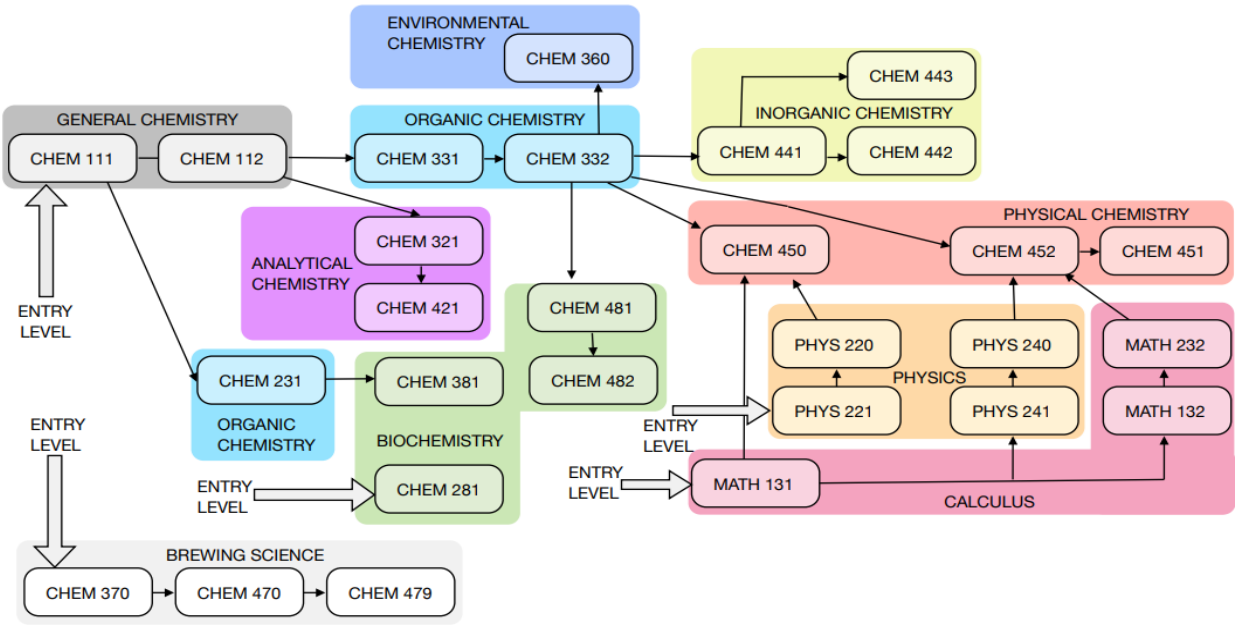
General Chemistry (Principles of Chemistry I, CHEM 111) is one of the first course for the science majors when they enroll at the university. This course is seen as the gateway to the other chemistry course as presented in the diagram presented by Figure 1. Students learn concepts and techniques that are foundational for their future chemistry courses and potentially in their career. This course is perceived by the students being difficult and a gatekeeper. This course historically has high attrition rates and often times students are leaving the STEM majors due to the difficulty in managing this course.

Fig 1: Department of Chemistry and Biochemistry Courses



The chemistry education literature describes a range of educational and cognitive (Tai *et al.*, 2005; Lewis and Lewis, 2007; Xu *et al.*, 2013, Seery, 2009; Xu *et al.*, 2013; Cracolice and Busby, 2015; Frey *et al.*, 2018) predictors of success in an undergraduate general chemistry course. Lately the importance and the potential impact and understanding of student's emotions as predictors of students' performance in the course it has been emphasized and remains an area of active research (Ferrell and Barbera, 2015, Hosbein and Barbera, 2020), remains an area of active research.

Much of the research in the area of emotions is prevalent in psychology. In order to be able to explore the affective domain in chemistry education, there is a need to develop or adapt the

appropriate instruments that measure the range of emotions students develop during a chemistry course especially general chemistry. Many of these instruments are adapted from the fields of psychology or other sciences. When an instrument is adapted from general language to specific (e.g. replacing 'science' with 'chemistry'), psychometric evidence must be provided for the functioning of the new adapted instrument.

Description of the Instrument:

Achievement emotions are emotions that students can experience that can affect and are affected by academic performance. These emotions, such as anxiety, have been extensively studied in recent years in relation to student performance and retention. One such instrument, the shortened Achievement Emotion Questionnaire (AEQ-S; Bieleke, 2019), was shown to reliably assess several of these achievement emotions in undergraduate students from various disciplines.

The instrument consists of nine achievement emotions being measured for three different settings, leading to a total of 24 scales. The three settings are classroom-emotions, study-emotions, and test-emotions. The nine achievement emotions being measured are enjoyment, hope, pride, anxiety, anger, shame, hopelessness, boredom (classroom- and study-settings only), and relief (test-setting only).

Each item of the instrument is a Likert scale, with four items on each scale. Achievement emotion scores are found by tallying the subjects' responses to these Likert scales.

Goal of the Study

There were two distinct goals of this research:

1. Modification of the AEQ-S instrument to create an achievement emotion-measuring instrument for General Chemistry and studies of validity/reliability of the data generated. There is a need to provide psychometric evidence of instrument functioning each time an instrument is used and before any comparisons are made of responses to different versions of the instrument.

2. Correlation of achievement emotions to the students' performance in the general chemistry course. Exploration of certain groups (genders, races, and ethnicities) of students' achievement emotions and performance in the course.

Methodology

The AEQ-S was modified to contain chemistry-specific language into the General Chemistry Achievement Emotion Questionnaire (AEQ-GCHEM). The modifications were made by changing phrases to include references to chemistry, i.e. changing "I enjoy being in class" to "I enjoy being in chemistry class". Further modifications were made based on participant feedback that included changing phrases or idioms that were being misunderstood or misconstrued, i.e. "When studying for chemistry, I feel anger well up inside me" to "When studying for chemistry, I get angry".

An additional setting was also added to the AEQ-S as a part of the modifications. Most students enrolled in a general chemistry course must also simultaneously enroll in a general chemistry laboratory course. Since this laboratory course is a near-universal experience for general chemistry students that is separate from the lecture course, the emotions experienced in this setting could provide valuable information that the original three settings cannot. The laboratory setting was created by altering items from the previous settings to contain laboratory-specific language, as well as through interviews with students to ensure that these items were measuring the emotion-setting pairing that they were designed to.

The survey was administered to students enrolled in a first-semester general chemistry course. The students were given the survey one week after they had received a grade for the first exam in the course; the goal for this administration timing was to ensure that the students had the chance to experience all possible emotions (retrospective, present, and prospective) in the course before taking the survey.

Results

The primary goal of this study was to analyze the ability of this novel instrument to produce valid and reliable data regarding achievement emotions in students enrolled in a general chemistry course.

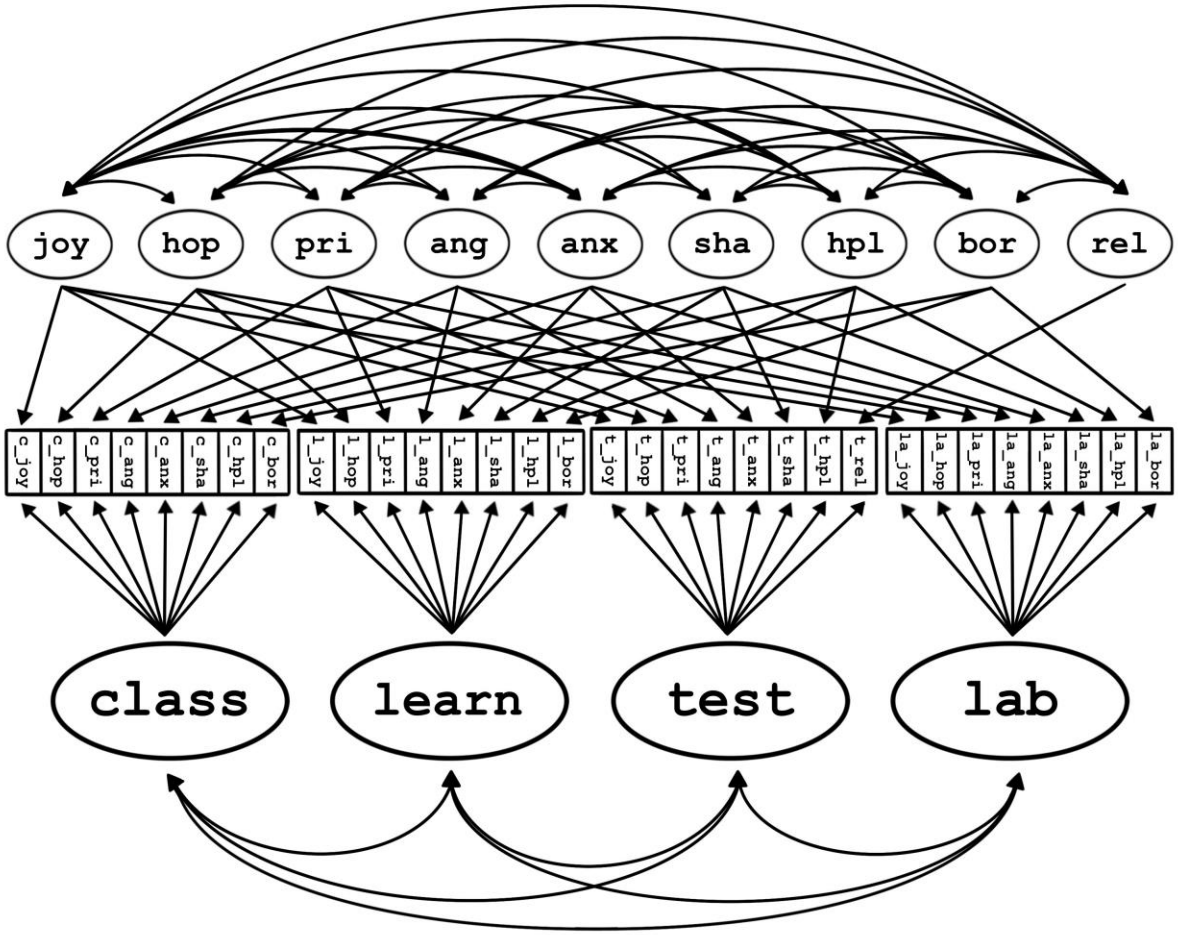
In regard to reliability, McDonald's omega was calculated for each subscale, that is each emotion-setting pairing, in the instrument. Each subscale was found to have acceptable omega values ($\omega > 0.70$), with most subscales having good omega values ($\omega > 0.80$). The few subscales that produced data with less than good omega values have been examined in qualitative interviews to determine the cause of the lower reliability and have been altered since the survey was administered based on the qualitative data collected from these interviews.

Multiple methods were used to measure the validity produced by the instrument. Qualitative interviews were conducted with both general chemistry students and chemistry education experts to confirm that the emotions being measured in the survey were based on emotions that general chemistry students experience.

Factor analysis was also used to analyze the validity of the data. Factor analysis is a method to determine how well the constructs in the survey fit onto a model which exhibits how the researcher assumes the constructs relate to each other. In this case, several models were tried to analyze the relationship between constructs, and the model that produced the best fit (CFI > 0.95) can be seen in **Figure 2**. To explain the model, each box represents a subscale of the survey ("c_joy" represents the classroom-enjoyment subscale), and each circle represents a latent construct ("joy" represents the achievement emotion of enjoyment). The model that best fits the data shows that each subscale relates both to the emotion that it comes from but also to the setting that the emotion is felt. The student experiences several different emotions in each setting, but these emotions are also experienced differently depending on the setting they are experienced in.

Factor analysis was also conducted on each subscale individually, returning good model fits (CFI > 0.95). This indicates that each subscale (or a selection of subscales) can be used separate from the entire instrument if desired and still produce valid and reliable data on achievement emotions.

Fig 2: A model exhibiting the relationship between the items of the survey and each construct.



Note: the emotions are abbreviated and are as follows from left to right: enjoyment, hope, pride, anger, anxiety, shame, hopelessness, boredom, relief.

Some preliminary analysis was conducted on the predictive ability of these achievement emotions for success in a general chemistry course. The positive emotions (enjoyment, hope, and pride) were found to have weak positive correlations to a student's final grade in the course, while the negative emotions (anger, anxiety, shame, hopelessness, and boredom) were found to have weak negative correlations.

Analysis was also conducted on the differences between self-identified male and female students in general chemistry. Significant differences to note are that male students experience more positive emotions (enjoyment, hope, and pride) across the classroom, learning, and testing settings, while female students experience more anxiety, shame, and hopelessness across the same settings. The laboratory setting did not show any differences in emotions experienced between these two genders.

Future Direction

The AEQ-GCHEM will be further refined based on the data collected, as well as more qualitative interviews with students, to further improve the validity and reliability of the data produced.

More analysis will be conducted not only to further explore the difference between male and female students but also between different ethnicities of students and other various demographics. Specifically, the difference between first-generations students and non-first-generation students could elucidate important barriers that these students uniquely feel in general chemistry. Another demographic of concern will be students with full- or part-time jobs, and how these students experience a general chemistry course differently from students without employment.