

# RELATIONSHIPS EXIST BETWEEN CHEMISTRY SELF-EFFICACY IN COLLEGE STUDENTS AND ACADEMIC OUTCOMES IN CHEMICAL EDUCATION

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## **Introduction**

Introductory and preparatory chemistry courses hold a particular importance to students across a wide range of academic specialties and majors. In addition to serving as a potential primer for students interested in the possibility of majoring in chemistry, introductory and preparatory chemical education has been actively integrated into the curriculum of other fields within the natural science spectrum (such as biology and physics). Additionally, under the umbrella of requisite coursework, it has gained a strong pertinence to applied sciences such as nursing, engineering, and exercise physiology (Tai, Sadler, and Loehr 2005).

Over the past few decades, the higher education system in the United States has witnessed deficient enrollment levels for individuals pursuing science-related majors. Additionally, a trend has risen at many institutions where attrition rates for first year STEM majors (science/technology/engineering/mathematics) have resulted in large proportions of the student body switching to other less science-heavy majors. In fact, while a study by Whalen and Shelley II (2010) noted that the trend seems to average at a summated 40% attrition rate over a given cohort's span from freshman to senior year, in some instances, attrition from STEM majors have reached as high as 45% in a single year. The possible dangers that could result in the future from a dearth of prospective science professionals in training today are numerous and hardly difficult to fathom. Shortages of appropriately trained engineers could limit future innovation and further catalyze the trend of native business entities seeking talent from other countries. This phenomenon could continue to the point that active recruitment by domestic academic engineering programs would be required to exponentially increase enrollment efforts, even at the risk of spreading departmental resources dangerously thin (Hutchison et al. 2006); a dearth of chemists could reduce the likelihood of discovering valuable drugs for the treatment of debilitating diseases, hinder the initiative for the future creation of environmentally safe products, and stunt the overall further development of the discipline (Lewis and Lewis 2007); a deficiency of exercise physiologists and nurses could render currently existing health-profession shortages to an even steeper gradient (Siela, Twibell and Keller 2009). Studies have shown that aggregated patient outcomes are less desirable in those hospital care environments which have higher proportions of nurses who have not sought and attained a bachelor's degree in nursing (Aiken et al. 2009). The importance of student success in preparatory and introductory chemistry curriculum, as these courses often serve as an academic gatekeeper of required

higher level curriculum for undergraduates in nursing bachelor's degree programs, is then paramount. If students seeking their bachelor's degree in an applied science have difficulty in introductory or preparatory level science classes, they may seek a means to reach their chosen career sans the successful completion of a bachelor's degree or possibly leave the field completely (Glossop 2001). This decision could come at the cost of decreased future earnings and/or lower patient/customer satisfaction.

Trying to accurately answer the question as to why the decline in science-related majors has taken hold cannot be easily encompassed by a singular motive. Rather, there are numerous factors that potentially play a role: the potential for higher paying careers in other sectors, a weakening of the academic advising system, and the internal self-efficacy beliefs (e.g. "I can [or cannot] do this successfully.") held by the given student concerning the field of study (Marra et al. 2009). Interestingly, self-efficacy has not only been supported in prior studies as a successful predictor of a student's academic major (and the respective retention within that major), but also bears a strong pertinence to future career decisions (Brown and Lent 2006). For the primary interests of this investigation, the remaining section of this paper will focus specifically on the subject of chemistry self-efficacy.

Attrition rates in preparatory chemistry classes are considerably high. At the referent four-year university where this study was conducted, out of the 998 students that were originally enrolled, only 644 remained enrolled through the end of the semester. Furthermore, only 379 of the original 998 received a final passing grade for the course, meaning that 62% of the original student population would need to either: retake the class, or seek an alternative major that did not require successful completion of the respective chemistry course.

Current research indicates one of the primary steps towards ameliorating the deficiency of students successfully obtaining degrees in the fields of science, engineering, technology, and mathematics is bettering introductory and preparatory level science classes offered to the students (Mervis 2010). More attention will be dedicated towards dissecting possible methods for improving entry-level chemistry courses in later sections of this paper.

One of the main goals of this study is to help expound upon what factors could have potentially played a role in the previously highlighted 62% of students that failed to successfully complete the course with a passing grade. Of primary interest is the exploration of the issue of self-efficacy was associated with the outcomes for the various groups of students. If self-efficacy were found to be relevant to the performance of the students in the course, then perhaps an effective way of improving future course outcomes could be found by improving self-efficacy across the student enrollment. Before proceeding, a preliminary discussion of what self-efficacy entails will follow.

Almost half a century ago, it was hypothesized and supported that a particular persuasive behavioral influence is determined by the respective individual's personally held belief network concerning their own abilities, as well as the corresponding results of their exertion (Bandura 1977). In other words, individuals interpret a self-analysis of their own abilities, and use that interpretation when deciding behavior. With time, Bandura went on to label the previously outlined beliefs as "Self-efficacy beliefs" (SEBs), and included them as a conceptual facet of his established social cognitive theory (1986). Analyzing his own studies, Bandura was the first to proclaim that SEBs play vital roles in the decisions people make

every day; self-efficacy affects choices to engage in or avoid a task, as well as the corresponding amount of effort that will be devoted towards fulfilling that decision. Furthermore, SEBs are utilized in an individual when internally deciding the level of difficulties one is willing to endure, as well as the levels of emotional pleasure/distress experienced during tasks (Usher and Pajares 2008).

On a similar note, SEBs have been shown to have a strong relationship with factors which affect motivational decisions: self-concept, anxiety levels, academic help-seeking, achievement goal orientation, and academic major orientation (Brown and Lent 2006). Additionally, past research by Schunk & Pajares has established that children who possess confidence in their own academic prowess engage in auxiliary tasks such as effective time management and demonstration of persistence; these traits increase the likelihood of academic success in comparison to fellow students with lower SEBs (2005). However, no insight as to how the results compare in college students engaging in preparatory chemistry curriculum has been procured.

Concerning collegiate education, extensive research has been conducted that supports that SEBs maintain a pertinence to students' success and achievement when engaging in particular curriculum: mathematics (Hall and Ponton 2005), engineering (Hutchison et al. 2006; Marra and Bogue 2006), nursing (McLaughlin, Moutray, and Muldoon 2008), robotics (Eric Zhi Feng, Chun Hung, and Chiung Sui 2010), legal studies (Christensen 2009), business (Elias 2008), and even social work (Rishel and Majewski 2009). Furthermore, it has been found that decreased (or relatively lower) levels of self-efficacy can lead to achievement-hindering effects in the classroom (Pajares and Urdan 2006).

With regards to satisfaction, Bandura found that SEBs can often positively impact a student's satisfaction levels, simply via techniques utilizing self-visualization of successfully completing difficult tasks and academic assignments (1997). On the other hand, general dissatisfaction with a course could potentially lead a student to attribute those feelings of discontent to low SEBs, even if they are not the true impetus. Furthermore, self-efficacy has a close bond with anxiety: high levels of class-specific anxiety can nullify the potential benefits of normally maintained positive self-efficacy towards particular tasks, thus rendering the student to doubt their own abilities (Usher and Pajares 2008). Therefore, a close mutual relationship is maintained in a dynamic state of existence within students among levels of anxiety, satisfaction, dissatisfaction, and SEBs. In many studies, the prior issues are considered and comparisons made about outcomes and levels of SEBs. Sometimes these analyses are even performed in very specialized academic fields with a narrow applicability to most college students. As an illustrating example of a narrow-focused niche, research conducted by Eric Zhi Feng et al. discovered that there is a connection between student satisfaction and self-efficacy in a collegiate cooperative robotics course (2010). On a tangential note, Hutchison et al. (2006) also establish that differences in SEBs do exist across the sexes in samples of students in certain instances of STEM curriculum. However, upon reviewing available literature, little was found as pertaining to self-efficacy and outcomes in chemical curriculum (regardless of chemistry's broad sweeping applicability to many college students and numerous important careers).

Nevertheless, there have been studies which involve chemistry and self-efficacy in certain frames of reference. Past investigations have been successfully

performed which identified instrumental scales which could be utilized for validly measuring self-efficacy in Turkish high school students (Aydin and Uzuntiryaki 2009). Additionally, a study by Smist explored aspects of the feasibility of increasing self-efficacy through laboratory experiments and exactly how self-efficacy compared in students at the end of the semester compared to at the beginning of the term (1993). No gender-based research has been found that specifically analyzes trends in self-efficacy levels and how they relate to academic predictive power and specific grade outcomes.

## **Purpose**

This study aimed to locate, observe, and analyze the generalized relationship between a student's self-efficacy rating and the respective academic outcomes: namely, the student's own beliefs pertaining to chemistry-based tasks/outcomes, such as utilizing chemical formulas and equations, completing homework problems correctly, understanding abstract chemical concepts, understanding theories presented in the textbook, and achieving a good grade in the class. Throughout the remaining length of this paper, relevant SEBs pertaining to chemistry will be referred to as "chemistry self-efficacy" (CSE).

To ensure a full elucidation upon the specific intentions of this investigation, focus was directed towards the following: 1) Locating and analyzing trends that exist between class-wide collective data on pre-semester self-efficacy ratings and student-predicted grades, as well as with actual final course grades; 2) Recognizing and analyzing trends that exist between class-wide aggregated data on actual final course grades and post-semester self-efficacy ratings; and 3) Analyzing any trends that exist between male pre-and post-self-efficacy ratings vis-à-vis female pre-and post-self-efficacy ratings, while making a coupled observation of each group's respectively aggregated academic outcomes. Each sought relationship in this study was tested for intensity and significance.

## **Methods**

### *Sampling Procedure*

In the fall of 2007, eight different class sections of the referent university's preparatory chemistry course was offered. Across the eight sections, a total of 998 students were initially enrolled and a total of 644 students were enrolled at the culmination of the term. During the first week of the semester, students were provided with an attitudinal questionnaire which, among several other measures, explored student CSE. Additionally, during the last week of classes, students were provided with the same attitudinal questionnaire and asked to complete it with their updated attitudes and opinions. Approval was obtained from the referent university's IRB. All student participants were notified that completion of the survey was optional and were concurrently provided with an understanding of the research's purpose. Furthermore, students were clearly informed on the means that would be taken to ensure their privacy and the anonymity of their responses.

Mirroring the common methodology of self-efficacy studies, each student that successfully completed the pre- and/or post-attitudinal questionnaires' CSE items had the answers coded numerically (a=1, b=2, c=3, d=4, e=5). Afterwards, the coded scores for the six items of each individual student were collated and subsequently added together in order to reach a total, and then the summation was divided by six (the dividing figure was derived from the six CSE items utilized in the questionnaire). Upon dividing, a "mean score of CSE" was now rendered for each participant and thus allowed for further statistical data analysis. Any and all potentially identifying information for each student participant was stored in a separate data location, ensuring anonymity.

*Pre-Semester Sample Description*

There were a total of 998 respondents to the initial administration of the questionnaire during the first week of the semester. However, only 750 valid observations were available for analysis in regards to the items of interest for this study and thus rendering a successful response rate of 75.2%. Invalid responses met one or more of the following flaws: a) nonresponse by subjects to variables of interest (n=239, 23.9%), and b) out-of-range responses (n=9, 0.9%).

Of the study's 750 pre-semester participants, 377 (50.3%) were male and 373 (49.7%) were female for a closely representative sample of both the referent university's overall student body male-to-female ratio (namely, 51.8% male to 48.2% female) and the original 998 students enrolled in the respective course (namely, 53.6% male to 46.4% female). Furthermore, the initial sample consisted of 677 (90.3%) individuals reporting their race as Caucasian, 40 (5.3%) of the individuals reporting as African American, 13 (1.7%) of the individuals reporting as Hispanic, 14 (1.9%) of the individuals reporting as Asian/Pacific Islander, and 6 (0.8%) of the individuals reporting as a race other than the ones listed above.

For a more in depth portrait of the sample, additional demographics obtained from the initial administration of the questionnaire are provided in Figure 1, such as a proportional analysis of the students' semester standings and a macroscopic view of the breadth and frequency of academic majors present in the sample.

*Figure 1, Initial Pre-Semester Sample Description of Student Participants by Gender, Race, Semester Standing, and Academic Major.*

<i>Sample (Pre-Semester Sample Description)</i>		<i>n=750</i>
GENDER:	Male 50.3% (377) Female 49.7% (373)	
RACE:	Caucasian 90.3% (677) African American 5.3% (40) Hispanic 1.7% (13) Asian/Pacific Islander 1.9% (14) Other 0.8% (6)	
SEMESTER:	First semester freshman 78.1% (586) Beyond first semester 21.9% (164)	
MAJOR*:	Natural Science 19.6% (147) Social Science 2.3% (17) Applied Science 67.6% (507) Formal Science 0.3% (2) Non-Science/Other 10.2% (77)	

\*Note: In order to efficiently analyze academic major presence, the following categorical framework was used:

*Natural Science*: biology, chemistry, earth sciences, physics

*Social Science*: anthropology, criminology, economics, history, psychology, and sociology

*Applied Science*: engineering and health sciences

*Formal Science*: mathematics, statistics, computer science

*Non-Science/Other*: business, philosophy, art, journalism, general education, etc.

*Post-Semester Sample Description*

At the end of the semester, an identical questionnaire was administered again to the students still enrolled in the course. Upon collection, a total of 315 valid observations were available for analysis in regards to the items of interest for this study. Again, invalid responses met one or more of the following flaws: a) nonresponse by subjects to variables of interest, and b) out-of-range responses.

Of the 315 valid observations, 157 (49.8%) were male and 158 (50.2%) were female. In regards to race, 282 (89.5%) were Caucasian, 16 (5.1%) were African American, 6 (1.9%) were Hispanic, 6 (1.9%) were Asian/Pacific Islander, and 5 (1.6%) were reported as an race other than the ones listed above. Additional sample demographics are provided in Figure 2 and, again, include the students' semester standings and the presence of academic majors.

<i>Sample (Post-Semester Sample Description)</i>		<i>n=315</i>
GENDER:	Male 49.8% (157) Female 50.2% (158)	
RACE:	Caucasian 89.5% (282) African American 5.1% (16) Hispanic 1.9% (6) Asian/Pacific Islander 1.9% (6) Other 1.6% (5)	
SEMESTER:	First semester freshman 76.8% (242) Beyond first semester 23.2% (73)	
MAJOR*:	Natural Science 21.3% (67) Social Science 1.9% (6) Applied Science 68.6% (216) Formal Science 0.3% (1) Non-Science/Other 7.9% (25)	

Figure 2, Initial Post-Semester Sample Description of Student Participants by Gender, Race, Semester Standing, and Academic Major.

\*Note: In order to efficiently analyze academic major presence, the following categorical framework was used:

*Natural Science*: biology, chemistry, earth sciences, physics

*Social Science*: anthropology, criminology, economics, history, psychology and sociology

*Applied Science*: engineering and health sciences

*Formal Science*: mathematics, statistics, computer science

*Non-Science/Other*: business, philosophy, art, journalism, general education, etc.

### Instrumentation

The measure of CSE utilized for this research study was obtained from a previously established construct titled "The Science Self-Efficacy Questionnaire" (SSEQ) which was originally created and validated among high school students and then later largely validated for college students by Smist (1993). The original SSEQ items utilized by Smist contained an anchored ranking scale in regards to the student's self-rated confidence towards performing a certain behavior (A=Quite a lot of confidence to E=Very little confidence). Items numbered 3, 5, 16, 18, 22 and 23 from Smist's 27-item construct (titled "Science Questionnaire") were included for use in this study, and are respectively listed on Figure 3 in an accurate reproduced form. Slight modifications were made to Smist's response options as they were adapted to the more familiar Likert 5-point scale (a=strongly disagree, b=disagree, c=neutral (or neither agree nor disagree), d=agree, e=strongly agree). No other modifications were made to the utilized items or their response options. The remaining unused items of Smist's "Science Questionnaire" were not included as they directly pertained to other scientific fields of study (i.e. physics and biology).

Scale Anchors:	a = strongly disagree		d = agree		
	b = disagree		e = strongly agree		
c = neutral (or neither agree nor disagree)					
	Rating:				
	Strongly disagree			Strongly agree	
I am very confident in my ability to use chemical formulas and equations.	-a-	-b-	-c-	-d-	-e-
I am very confident in doing chemistry homework problems well.	-a-	-b-	-c-	-d-	-e-
I am very confident in asking questions in chemistry class.	-a-	-b-	-c-	-d-	-e-
I am very confident in understanding concepts in chemistry textbook.	-a-	-b-	-c-	-d-	-e-
I am very confident about getting good grades in chemistry.	-a-	-b-	-c-	-d-	-e-
I am very confident in understanding abstract chemical concepts.	-a-	-b-	-c-	-d-	-e-

Figure 3, CSE-related Items and Scaling Utilized on the Pre- and Post-semester Student Questionnaires.

Note: Items pertaining to chemistry self-efficacy were isolated from the in-class 40-item questionnaire completed at the beginning of the semester and the later repeated administration the end of the semester.

## Results

### *Pre-semester self-efficacy ratings and student self-predicted course grades*

The results from a comparison of the initial student sample's pre-semester self-efficacy ratings and their corresponding self-predicted outcome (e.g. final course grade) are outlined in Figure 4 (below). As depicted within Figure 5 (below), the Analysis of Variance (ANOVA) output proclaims that there was a significant difference present between the students' self-predicted grade outcomes and CSE ratings ( $p < .01$ ). A clear trend is visible when observing the gradient of students' pre-semester CSE (Pre-CSE Mean) against the progression of the students' self-predicted final grade for the course. More specifically stated, students that report-

ed higher self-predicted grades appear to correspond closely with students that simultaneously held relatively higher levels of initial CSE (i.e. the Pre-CSE Mean was 3.392 for students that anticipated an “A” at the start of the semester, while, on the other hand, the Pre-CSE Mean was comparatively only 2.720 for students that anticipated a “C” at the end of the term).

Predicted Grade	Pre-CSE Mean	N	Standard Deviation
4	3.392	364	.755
3	3.024	276	.607
2	2.720	91	.613
1	2.607	14	.876
0	1.533	5	.342
Total	3.148	750	.742

Predicted Grade Coding: 4=A, 3=B, 2=C, 1=D, 0=F

Figure 4, Comparison of Means for Student Self-Predicted Final Course Grades by the Student Reported Pre-Semester CSE Scores.

Predicted Grade	Sum of Squares	df	Mean Square	F	Significance
Between Groups	81.033	28	2.894	5.159	.000
Within Groups	404.434	721	.561		
Total	485.467	749			

Note: The mean difference is significant at the .01 level.

Figure 5, ANOVA: Comparison of Student Self-Predicted Final Course Grades by Student Pre-semester CSE.

*Pre-semester self-efficacy ratings and actual student final course grades*

The results obtained from comparing the means for the initial sample’s pre-semester self-efficacy scores with the sample’s actualized results [in regards to the preparatory course’s final outcomes] can be observed in Figure 6 (below). An ANOVA (see Figure 7) revealed that between the two points of interest, significant differences were present in the mean scores ( $p < .01$ ). Again, a clear trend exists between the level of CSE held by the initial student sample and the resulting outcomes. Specifically stated, the higher final grades were characterized by students that held higher CSE at the beginning of the semester, while students who performed com-



paratively worse in the course had lower pre-semester CSE ratings. The Pre-CSE Mean for students that received an “A” at the end of the semester was 3.491, while, on the other hand, the Pre-CSE Mean for students that earned a “C” at the end of the term was a lower score of only 3.192. Furthermore, the results showed that the selection of students from the initial sample that eventually withdrew (W) from the course displayed the lowest mean for Pre-semester CSE at a value of 2.969.

Final Grade	Pre-CSE Mean	N	Standard Deviation
4	3.491	56	.768
3	3.356	95	.685
2	3.192	158	.643
1	3.150	103	.786
0	3.125	93	.747
-1	2.969	245	.750
Total	3.148	750	.742

Final Grade Coding: 4=A, 3=B, 2=C, 1=D, 0=F, -1=W

Figure 6, Comparison of Means for Actualized Student Final Course Outcomes by Student Reported Pre-Semester CSE Scores.

Final Grade	Sum of Squares	df	Mean Square	F	Significance
Between Groups	150.426	28	5.372	1.978	.002
Within Groups	1958.589	721	2.716		
Total	2109.015	749			

Note: The mean difference is significant at the .01 level.

Figure 7, ANOVA: Comparison of Actualized Student Final Course Outcomes by Student Pre-semester CSE.

*Post-semester self-efficacy ratings and actual student final course grades*

Upon completing an analysis of the post-semester sample’s reported post-semester self-efficacy ratings vis-à-vis the students’ actual overall final course grades, the aggregated results set forth that the students which earned comparatively higher final grades in the course actually displayed relatively higher levels of post-semester CSE. The trend remained consistent between all five potential grade outcomes (A, B, C, D, and F) and is clearly depicted in Figure 8 (below). Students

that ended the course with an overall final grade of an “A” experienced a Post-CSE Mean of 3.542, while students that earned a final grade of an “F” displayed a Post-CSE Mean of only 2.889. The respective findings previously outlined were shown to be significant ( $p < .01$ ) via the results rendered via an ANOVA (see Figure 9).

Final Grade	Post-CSE Mean	N	Standard Deviation
4	3.542	48	.858
3	3.304	81	.773
2	3.167	107	.650
1	2.954	58	.697
0	2.889	21	.988
Total	3.202	315	.769

**Final Grade Coding: 4=A, 3=B, 2=C, 1=D, 0=F**

Figure 8, Comparison of Means for Student Self-Predicted Final Course Grade by the Student Reported Post-Semester CSE Scores.

Final Grade	Sum of Squares	df	Mean Square	F	Significance
Between Groups	70.699	23	3.074	2.587	.000
Within Groups	345.745	291	1.188		
Total	416.444	314			

Note: The mean difference is significant at the .01 level.

Figure 9, ANOVA: Comparison of Final Grade by Student Post-semester CSE.

*Male Pre-semester self-efficacy ratings vis-à-vis Female Pre-semester self-efficacy ratings*

A difference was found between the sexes within the initial student sample in regards to pre-semester self-efficacy ratings. Males showed the higher aggregated mean level of CSE possessed at a score of 3.222. On the other hand, females showed a lower aggregated mean level of CSE by rendering a score of only 3.073. Figure 10 (below) offers a complete view of the gender comparisons. The aforementioned results were shown to be statistically significant ( $p < .01$ ) via an administered ANOVA (see Figure 11).

Gender	Pre-CSE Mean	N	Standard Deviation
1	3.222	377	.745
2	3.073	373	.732
Total	3.148	750	.742

Gender Coding: 1=Male, 2=Female

Figure 10, Comparison of Means for Student Gender by the Student Reported Pre-Semester CSE Scores.

Gender	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.168	1	4.168	7.639	.006
Within Groups	408.104	748	.546		
Total	412.272	749			

Note: The mean difference is significant at the .01 level.

Figure 11, ANOVA: Comparison of Gender by Student Pre-Semester CSE.

*Male Post-semester self-efficacy ratings and Female Post-semester self-efficacy ratings vis-à-vis aggregated final grade outcomes*

A comparative analysis between the genders within the post-semester student sample showed that males possessed a higher level of overall CSE at the culmination of the course when matched up against the females within the sample. The male post-semester CSE rating's mean was 3.251 and the female post-semester CSE rating was ascertained across the sample at 3.153. In regards to final course grades, males showed a slightly less desirable grade average of 2.15 in comparison to the females' final grade average of 2.30 for the course. Simply stated, though females performed better in the course, males still presented themselves as feeling more confident, respective to their own abilities. However, upon completing a statistical analysis, neither of the contrasts between the genders [in respect to the mean differences between post-semester CSE ratings and final grades] were shown to be of statistical significance ( $p > .01$ ).

Gender	Post-CSE Mean	Final Grade
Mean	3.251	2.15
1 N	157	157
Std. Deviation	.744	1.150
Mean	3.153	2.30
2 N	158	158
Std. Deviation	.792	1.121
Mean	3.202	2.23
Total N	315	315
Std. Deviation	.769	1.136

Figure 12, Comparison of Means for Post-Semester CSE Ratings and Student Final Grades by Gender.

Gender Coding: 1=Male, 2=Female  
Final Grade Coding: 4=A, 3=B, 2=C, 1=D, 0=F

			Sum of Squares	df	Mean Square	F	Sig.
Post-CSE Mean * Gender	Between Groups	(Combined)	.750	1	.750	1.270	.261*
	Within Groups		184.811	313	.590		
	Total		185.560	314			
Final Grade * Gender	Between Groups	(Combined)	1.794	1	1.794	1.391	.239*
	Within Groups		403.749	313	1.290		
	Total		405.543	314			

\*Note: The mean difference is not significant at the .01 level.

Figure 13, ANOVA: Comparison of Post-Semester CSE Ratings and Student Final Grades by Gender. \*Note: The mean difference is not significant at the .01 level.

## Discussion

The findings of this investigation provide a new perspective as to how CSE exists across the student enrollment within preparatory level chemistry courses. The results also shed light on the manner in which initial levels of CSE relate to the students' own future outlook for themselves, as well as pertain to the actual end-of-semester outcomes realized by students. Furthermore, the results of this study show congruence with the research of Witt-Rose, where student-held SEBs were found to maintain a significant relationship with academic outcomes in a different collegiate science course, Anatomy & Physiology I (2003).

Further analysis of the statistical findings from this study on preparatory chemistry students revealed that the existing trends remain in harmony with several other important analogous studies relating to academics and self-efficacy: the phenomena that female students maintain lower science-related SEBs than their male counterparts (Smist 1994), high attrition rates still exist within entry-level courses of the hard sciences [i.e. physics, chemistry, etc.] (Mervis 2010), and students' personally held academic SEBs hold a significant relationship with academic performance (Hoffman and Spataru 2008). With the congruence between this respective investigation's discovery and those of the aforementioned studies, findings from studies in other STEM fields to entry-level chemical education are applicable to self-efficacy.

The importance of developing a strong presence of positive CSE in preparatory-level chemistry students early during the semester is of paramount interest to future research pursuits. Specifically, further investigation should be undertaken in order to offer a stronger support for the causal relationship between CSE and chemical education outcomes. It is vital to note that students who lack strong SEBs in academic settings do not merely sit passively on a metaphorical glass floor in regards, while students that do possess strong SEBs comparatively rise above the baseline. Instead, prior research shows that students that lack SEBs in academic settings can experience blatantly negative ramifications as a result of insufficient self-efficacy: a project performed by Klassen, Krawchuk, and Rajani found that undergraduates who lack strong academic-related SEBs concerning self-regulation displayed higher levels of procrastination in college (2008); an investigation by Walsh proclaimed that in a sample of nursing students enrolled in mathematics courses, academic-related anxiety was discovered in those students that did not

possess high levels of confidence in their own ability to solve mathematical problems (2008); similar results were found in a study by Bandalos and Yates specifically stating that students that did not possess high levels of academic self-efficacy were not merely neutral towards test outlook, but instead showed the presence of test anxiety (1995). Furthermore, research performed by Zajacova, Lynch and Espenshade found that students without high self-efficacy levels are more likely to have higher levels of academic related stress in their daily life (2005).

The aforementioned studies help to elucidate the absence of positive SEBs in a student. Its lack is not merely a situation that leads to neutral outcomes at the expense of only notable benefits, but rather the mere absence of positive SEBs has the potential to actively instill several severe negative outcomes instead. In light of these facts, it should be clear that the chemistry departments at academic institutions should not only try to maintain students' internal beliefs. Students should surpass a survival-only mentality, and replace it with an attitude geared toward excellence.

According to this investigation's results, students that entered the chemistry course with high levels of CSE were more likely to earn a higher grade at the end of the semester. Furthermore, those students that earned the higher final grades in the course had larger consequential increases to their own level of CSE at the end of the respective semester compared those students with less desirable grades and lower levels of CSE (aggregated). The cyclical reaction between achievement and self-efficacy appears to be viable. The level of post-semester CSE attained from a preparatory chemistry class essentially sets the stage for the initial level of CSE in a subsequent chemistry course, and likely impacts its eventual outcome. Perhaps the hardest part of the figurative equation is simply getting students started in the correct direction, toward CSE instead of away from it.

As the results of this study show, female students tend to have lower levels of CSE in comparison to males at the start of introductory level chemistry courses (see Figure 10). As previously outlined, across the spectrum science disciplines, females maintain lower levels of SEBs, which when observing female actual course outcomes to male outcomes, appears to be illogical. While, the specific findings outlined in Figure 12 did not show statistical significance ( $p > .01$ ), they do nevertheless appear fascinating in nature: females maintained a lower level of post-semester CSE than males, yet concurrently maintained the higher mean grade outcome between the two genders. Future experimentation is needed to further explore this anomalous occurrence. However, one possible explanation is that females hold themselves to a higher standard than males as to what qualifies as satisfactory or unsatisfactory performance/ability (Correll, 2004).

To ameliorate the circumstances of female students holding lower levels of initial CSE, chemistry departments should strive to provide its students with strong support that both sexes can excel in the field of chemistry. A possible demonstration of this fact could include a brief, unorthodox lecture or assignment early in the semester where students learn about notable female chemists and proceed by writing a short essay about how being female and being successful in chemistry are not mutually exclusive. However, it should be noted that Wyer et al. (2007) found that such class-based attempts at influencing gender perception did not render any major results when applied in an undergraduate ecology course. Nevertheless, further research would be needed to expound upon the fruitfulness of its implementation in a chemistry classroom.

It remains pertinent to mention that while students with higher levels of CSE are more likely to successfully complete a preparatory chemistry course with a grade of A, B, or C – that fact does not ensure the successful matriculation into the next sequence of introductory-level chemistry courses. In other words, effort must still be given by the academic institution's chemistry department towards accurately guiding students that completed the preparatory course towards the logically following step. A study performed by Jones and Gellene found that even after successfully completing a preparatory chemistry course, approximately 53% of the students changed their major to a field that did not require any further chemistry curriculum (2005). Why this large proportion of the successful students decided to change majors is not known with absolute certainty, but a reasonable hypothesis is that at least some of the students were simply avoiding future requisite chemical education due to some facets of a science curriculum, such as intra-classroom competition and harsh grading curves (Seymour & Hewitt, 2000). In which case, it is a result that may have been lessened if the successful students had increased CSE during and after their respective remedial course.

Regarding techniques for raising student-held CSE, it is appropriate to introduce to the discussion valid research that has been shown to be effective in improving self-efficacy in general academic settings. Luzzo and Hasper performed an investigation that demonstrated the comparison of effects from two particular means of increasing self-efficacy in a student sample (1999). The first method Luzzo and Hasper utilized was based off of "vicarious learning" (VL). Essentially, VL can be encompassed by the act of an individual learning a new task, or new perspectives, by simply watching someone else perform. Luzzo and Hasper offered a video presentation about two college graduates whom were originally indecisive concerning their pursuit of a science-based major, yet after working hard and succeeding, both graduates excelled in their science curriculum, graduated and are now highly successful in their occupational endeavors. From merely watching the video, the student observers were provided with new perspectives of how experiencing difficulties in science curriculum can be expected and does not necessarily mean that they should immediately seek another field. The other technique used by Luzzo and Hasper focused on the facet of performance accomplishment (PA), differentiated from VL in the sense that the increase in self-efficacy arises from actual participation in a given activity. An example of PA would be to improve a person's self-efficacy pertaining to mathematical tasks by working with them to solve progressively harder problems and making certain that the student is cognizant of their progression to more complex problems. The researchers found that between the two methods outlined, while VL was useful, PA was more effective.

Applying both the VL and PA methodologies successfully to a chemistry course could prove beneficial for increasing student self-efficacy early in the semester. Different routes could be pursued for VL depending on the level of complexity or interaction desired by the academic institution. An entire lecture could be dedicated to a Q&A session with successful graduate students and/or professional chemists concerning their own personal backgrounds, academic hurdles, and how they decided to pursue a degree in chemistry. A 10-minute video could also be shown during the beginning of a lecture outlining and offering similar positive material to the students. Likewise, different techniques could be utilized to pursue the route of PA. Similar to the option available to VL, the amount of time

and effort spent towards the pursuit is dependent upon the respective institution. Approaches could range from the impromptu dedication of a portion of a single lecture towards engaging in PA tasks with the entire class, to consistent, outside-of-class small group meetings to practice tasks.

The previously mentioned application of enacting established group tutoring sessions is of high effectiveness and has been shown to improve outcomes among students under the premise that the tutoring entities are properly trained in ways to help struggling students and help boost SEBs (Margolis 2005). Simple techniques for potential tutors include seating the students in a round-table fashion so they can see and easily interact with each other, keep the meeting discussions on point and pertinent to the material of interest, and encouraging questions and active listening practices (Margolis and McCabe 2006). However, it is important to stress that if computer technology is to be utilized for any of the self-efficacy building exercises, it should be confirmed that each student possesses the needed level of computer and/or technological literacy required to successfully complete the tasks without any difficulties. As McCoy found, students that do not possess their own computer at home are often less proficient at operating a computer system and, if prescribed, negative effects upon SEBs can take place if the student is unable to effectively use the said technology (2010).

### **Ongoing and Future Research**

Concerning the aims of future research, of primary interest are studies to further validate the findings of this investigation as well as explore additional relationships involving CSE. Additional insight should be sought as to if and how individual academic majors relate to student CSE in preparatory-level chemistry courses. A large sample, representative of a broad range of academic majors, may offer further information as to which particular undergraduate fields of study are more at risk for performing poorly in entry-level chemistry courses compared to other majors.

Additionally, further research should be sought to provide a more in depth, representative sample of races to analyze the potential relationship between a student's racial background and CSE. This study might offer deeper insight into the plausible association between student race and likelihood of success in introductory level chemistry curriculum.

In order to gain understanding into the seemingly curious results between males and females concerning post-semester CSE levels and final grade outcomes, future studies should seek an additional explanation of what might be causing these unexpected results. Factors such as differences between the sexes in regards to self-recognition of achievement levels could be causing the discrepancy.

Further investigations concerning the goal of increasing student CSE via new teaching techniques utilized by the professor may prove fruitful. In 2009, Akinsola and Awofala found that significant differences in outcomes occurred within a sample of mathematics student when one group was offered personalized instruction and the other group was offered non-personalized instruction; the personalized instruction had more positive outcomes. These findings raise the question if personalizing the instruction in preparatory chemistry courses would

result in more positive student outcomes, in direct comparison to standardized, non-personalized chemical instruction. Using computer adaptive homework and/or assignments which mirror the dynamic nature of the other computer based testing technologies, such as that used by the Graduate Record Examination (GRE) could achieve this personalization: students start the test with a moderately difficult question and the difficulty of subsequent questions depends on if the previous answer was correct or incorrect – at the end of the administration the resulting score is scaled appropriately in accordance with the difficulty level of questions correct. Extrapolating the techniques of the GRE to chemistry education could provide students with more pinpointed feedback as to their strengths and weaknesses concerning the assigned course material.

On another note, the development of novel and valid instruments for accurately measuring cognitive items such as CSE is imperative for offering new modes of interpreting data across dynamic sample populations. As demonstrated in the instrumental study of Silver, Smith Jr. and Greene (2001, extensive study efforts towards constructing new measures bestows greater variety to researchers concerning a wider breadth of applicable tools (such as what Smist achieved by remolding the SSEQ), and serves the useful function of offering further support for results that utilized alternative instrumental measures.

Lastly, future research should aim to offer predictive insight in regards to preparatory level chemistry education outcomes via the administration and analysis of additional cognitive measures such as perceived competence, learning self-regulation (intrinsic and extrinsic), and attributions of success.

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**Abbreviations**

CSE - Chemistry self-efficacy

GRE - Graduate record examination

PA - Performance accomplishment

SEBs - Self-efficacy beliefs

SSEQ - Science Self-Efficacy Questionnaire

STEM - Science/Technology/Engineering/Mathematics

VL - Vicarious learning