2021

Gender Disparity in Studying Chemistry

Carlo Semerzier

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by
Carlo Semerzier

An Applied Dissertation Submitted to the
Abraham S. Fischler College of Education and
School of Criminal Justice in Partial
Fulfillment of the Requirements
for the Degree of Doctor of Education

Nova Southeastern University
2020

Approval Page

This applied dissertation was submitted by Carlo Semerzier under the direction of the persons listed below. It was submitted to the Abraham S. Fischler College of Education and School of Criminal Justice and approved in partial fulfillment of the requirements for the degree of Doctor of Education at Nova Southeastern University.

James Miller, PhD
Committee Chair

Shery Bennett, EdD
Committee Member

Kimberly Durham, PsyD
Dean

Statement of Original Work

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Carlo Semerzier
Name

April 26, 2020
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Acknowledgments

To God, be the glory!

To my mom, the late Jeanne Semerzier, who passed away two weeks before I wrote the final chapter of this dissertation, thank you for giving me life. I know that you always wanted me to complete this degree, as you always asked me, “Ki lè wap ban mwen twa ba-a?” when will you give me the three stripes? I did it, mom! You will always be my queen.

To my beautiful wife, Rachel, who took control of everything in the house in order for me to focus on my studies. Without your love, prayers, and support, I won’t make it through. I will always love you. Thank you, darling!

To my boys, Carl-EL and Ritchel, thank you for your love, support, and prayers. I did this for you as well, my dear sons.

To my brothers and sisters, Faddy, Guirlene, Evenns, Christine, and Sherlie, thank you for your love and prayers.

My gratitude goes to my colleagues at work, Dr. Stanley Dobias, Dr. Sebastian Farrell, Dr. Nadia Edwin, Dr. Roy Lukman, and Dr. Leana Araujo. Thank you for your supports!

To my church family, “Apopka Haitian Church,” thank you for your prayers.

To Dr. James Miller, dissertation chair and mentor, thank you for your continued support throughout the journey. You are a model of an exceptional leader.

I wish to express my sincere gratitude to Dr. Shery Bennett, the other member of my dissertation committee. You are an amazing woman and a great world model. Thank you for inspiring me through this journey!

Abstract

Gender Disparity in Studying Chemistry. Carlo Semerzier, 2020: Applied Dissertation, Nova Southeastern University, Abraham S. Fischler College of Education and School of Criminal Justice. Keywords: chemistry, gender disparity, discrimination, self-efficacy, math, learning styles

This applied dissertation was designed to determine if there is a difference between students' gender, ethnicity, and age and their performance in General Chemistry I at a Christian University in Florida. Many scientific studies reveal the existence of a gender performance gap in chemistry: women mostly underperform men. Certain factors reported by researchers and cited in this study that might contribute to this gap include self-efficacy, math ability, prior conceptual knowledge in chemistry, attitude toward chemistry, spatial ability, discrimination, learning styles, and exam types.

This quantitative research study used retrospective data from 113 students from eight sections (2016-2019) of a General Chemistry I course. Each participant was enrolled in one of the eight sections and was taught by the same instructor. The final course grade was the dependent numeric variable, and gender, ethnicity, and age were the independent categorical variables. For all statistical analyses, student's t-test and the analysis of variance (ANOVA) were used.

Data analysis revealed a significant difference in the final course grade between gender who study General Chemistry 1 in higher education. There was no significant difference in final course grades between the ages categories: younger than 21 years old and 21 years old and older. Additionally, there was no significant difference in final course grades between ethnicities. The findings suggest that female students underperformed their male counterparts in general chemistry I in higher education, and the final course grade in General Chemistry I was not affected by students' age and ethnicities.

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Chapter 1: Introduction

Chemistry is one of the many branches of science. It is often called the "central science" or the "mother of all sciences" because of its pivoting role in relation to other sciences (Brown, 2009; Goldsby & Raymond, 2013). It is the study of the structure, properties, and composition of the substances that make up the universe or matter and the different changes they experience. It has a huge impact on everything people use and do worldwide (Timberlake, 2015). Physical sciences, life sciences, and applied sciences such as medicine and engineering are all connected to chemistry. According to Jegede (2007), it is a fundamental subject for health science, textile science, printing technology, and technology. It also prepares students for professional careers in various areas, especially in medicine, biotechnology, agriculture, and pharmacy (Mihindo, Wachanga, & Anditi, 2017). Numerous researchers have investigated the field of chemistry for many years and provided evidence of the existence of a gender gap in favor of men (Estes & Felker, 2012; Dabney & Tai, 2014; National Science Board (2014); Ferrell & Barbera, 2015; Vincent-Ruz, Binning, Schunn, & Grabowski, 2018).

Statement of the Problem

Researchers have found a performance gap between female and male students in areas of study that require chemistry courses in higher education. Women frequently underperform their male counterparts on the Medical College Admission Test (MCAT), which relies on chemistry knowledge. This pattern is noticeable in data collected for the past decade (American Association of Medical Colleges, 2012). Also, gender discrepancy in physical science is well documented at the workplace and in graduate schools (Jena, Khullar Ho, Olenski, & Blumenthal, 2015; Su & Rounds, 2015; Leslie, Cimpian, Meyer,

& Freeland, 2015). Females represent a very small percentage of physical sciences professionals, including physics and chemistry (Ceci & Williams, 2007). Women represent less than one-fourth of all full-time faculty, including professors with tenure in physical sciences and engineering (National Science Foundation, 2013). Studying this gender gap is important to understand women's underrepresentation and underperformance in science, particularly in chemistry, to adjust women's treatment in the science field, and improve women's performance.

The topic. Chemistry, classified as a physical science (Spencer, Brush, & Osler, 2019), is the proposed study area. The different branches in chemistry include inorganic, organic, physical, analytical, biochemistry, and theoretical. This study mainly focuses on General Chemistry I, which was part of inorganic chemistry. Subjects include nature of matter, electron structure, chemical reactions, stoichiometry, thermochemistry, chemical bonding, molecular structures, solutions and gases properties. This topic addresses the differences between male and female students' performance in chemistry.

The research problem. Many students avoid taking chemistry courses during their educational journey, while others completely change their career path after taking chemistry. According to Barr, Gonzalez, and Wanat (2008), 85% of students who dropped premed revealed that the most frequent course that discouraged them from medicine was organic chemistry. When male and female students studied chemistry, they both had encountered some level of difficulty. They claimed that chemical concepts, nomenclature, various chemical reactions, and mole concepts were too difficult to comprehend (Gafoor & Shilna, 2013). However, female students seemed to have a greater challenge with the concepts and underperform their male counterparts. This finding demonstrates a gap between males and females in performance in chemistry.

Background and justification. Far more men continue to receive chemistry doctorates in the United States than women. Data from the US National Science Foundation shows that among 2,704 doctoral recipients in chemistry in YEAR, 63.4% were males, and only 36.6% are females. In chemical engineering, there were 923 doctorate recipients in YEAR, about 68% were males, and 32% were females (National Science Foundation, 2016). Despite the substantial progress of women in studying Science, Technology, Engineering, Mathematics, and Medicine (STEMM) subjects at the university, they are still a minority as senior faculty members and less often trained in elite research groups (Sheltzer & Smith, 2014). This trend also is visible in the workforce, where only 22% of STEMM scientists are women; whereas, 62 % in behavioral science are women (National Science Foundation 2015d). Women are more likely to leave STEMM careers than men (Shaw & Stanton, 2012; Sheltzer & Smith, 2014). Women authors represented a low percentage (less than 35%) in topics such as physics, computer science, mathematics, surgery, and chemistry. For example, in 2016, the percentage of women authors was 17% in Physics and 30% in chemistry (Holman, Stuart-Fox, & Hauser, 2018). The gender disparity is obvious, particularly related to women's performance and representation in chemistry.

Deficiencies in the evidence. The current literature and statistical data regarding the underperformance of women in chemistry are limited. The very few studies that have been undertaken do not address why this performance gap exists between males and females in chemistry. Researchers have pointed to gender bias (Moss-Racusin, Sanzari, Caluori, & Rabasco, 2018) and a negative attitude toward chemistry (Widanski &

McCarthy, 2009) among factors that contribute to that discrepancy. It is important to study these and other factors that can explain the underperformance of women in chemistry.

Audience. Science teachers, especially those in chemistry, would be interested in and benefit from this study. The findings also would benefit students who plan to pursue a degree in chemistry or a related field. Researchers and graduate students can use the results of this study as a foundation for future research.

Setting of the Study

This study was conducted at a private university located in Central Florida, specializing in healthcare education. The university offers baccalaureate programs in Biomedical Sciences, Radiologic Sciences, Diagnostic Medical Sonography, Nuclear Medicine Technology, Nursing, master's degrees in Healthcare Administration, Nurse Anesthesia, Occupational Therapy, Physician Assistant Studies, and a doctoral degree in Physical Therapy. The majority of these programs require their students to have taken at least one course in chemistry. Biomedical Sciences, Physician Assistant, Physical Therapy, and Nuclear Medicine Technology programs require their students to have taken two trimesters of General Chemistry. Nursing only requires one trimester of Principles of Chemistry. There are two sections of Principles of Chemistry in this setting and one section of both General Chemistry I and General Chemistry II each trimester. On average, about 15 to 17 students are enrolled in each class.

Researcher's Role

The researcher was a faculty member at the university where this study took place. He was an assistant professor and teaching chemistry. He also was a doctoral candidate at Nova Southeastern University at the time of the study.

The researcher's role in this study was to gather, interpret and analyze data, draw conclusions from the evidence, and make relevant recommendations for future studies. The researcher did not teach any classes that were involved in this study.

Purpose of the Study

This study aimed to determine if there is a significant difference between male and female students' performance in general chemistry in higher education, and if so, what variables might contribute to this difference. Researchers suggest that the gender gap is related to women's chemistry competency beliefs. Improving their competency beliefs may positively influence their achievement in the classroom, thereby reducing the gender gap in chemistry performance (Vincent-Ruz, Binning, Schunn, & Grabowski, 2018).

Definition of Terms

The following terms are used in the context of the study:

Attitude. This term refers to a disposition towards or against a specified phenomenon, person, or thing (Dawson, 1992).

Concept mapping. This term refers to a two-dimensional graphic or schematic diagram illustrating the interconnections, and often the hierarchy, of a particular concept or topic (Llewellyn, 2007).

Gender bias. This term refers to an unequal representation of men and women as actors in test items or representation of members of each gender only in stereotyped roles (Childs, 1990).

Gender discrepancy. This term refers to the performance imbalance between male and female students (Ziegler & Heller, 2000).

Spatial Ability. This term refers to students' ability to manipulate chemical formulae into molecular structures, visualize possible 3-D configurations, and compare these configurations across different molecular structures. For example, students could use 3-D configurations to understand better the valence shell electron pair repulsion (VSEPR) theory (Merchant, Goetz, Keeney-Kennicutt, Cifuentes, Kwok, & Davis, 2013).

Second Life (SL). This term is best described as a virtual environment. They purposely serve to represent molecule structures in 3-D space. Second Life allows students to visualize the molecules and then interact with these structures to increase their knowledge and understanding of the VSEPR model (Merchant, Goetz, Keeney-Kennicutt, Cifuentes, Kwok, & Davis, 2013).

POGIL (process-oriented guided inquiry learning) is a set of activities designed to focus on core concepts and science processes that encourage a deep understanding of course material while developing higher-order thinking skills (Barthlow & Watson, 2014).

Stoichiometry. This term describes the quantities of reactants and products involved in a chemical reaction (Ebbing & Gammon, 2016).

Chapter 2: Literature Review

Introduction

This review contains current literature regarding the issue of gender performance in chemistry courses. Also included are several studies related to Science, Technology, Engineering, and Mathematics (STEM), rather than directly to chemistry. Since there is a clear correlation between STEM and chemistry, it is worth reviewing all of these studies. Chemistry is known as a base science for STEM undergraduate majors. Like other fundamental courses in the STEM field, students must pass chemistry successfully, demonstrating its importance for retaining students and advancing in STEM. Researchers point to chemistry for its important role as a *gatekeeper* course for STEM majors (Cohen & Kelly, 2018). This review also includes literature on several factors that may contribute to any disparity between male and female students in the study of chemistry.

The problem of female students' difficulty studying chemistry is grounded in the following theories: Socialization theory, Gender Differences theory, and Holland's theory. The first two are part of Feminist theory. Socialization theory focuses on the educational aspect of liberal feminist theory (Thompson, 2003). Theorists from this group argue that women are smart, confident, and creative as men. If they have the same educational opportunity as men, they will excel. They specify that mistreatment and discrimination against women in classrooms leads to a poor education given to women (Hall & Sandler, 1982).

Gender Difference theory focuses on women's culture, including education and the relational orientation associated with them (Thompson, 2003). Theorists from this group argue that women and men have the same mental ability but different ways of constructing knowledge. Both men and women often ended up with similar outcomes. These theorists advocate for different learning styles in classrooms (Raymond, 1985; Salner, 1989). For the most part, theorists from both Socialization and Gender Differences groups argue in favor of gender equality in education, workplace, and society (Thompson, 2003). Socialization and Gender theories provided explanations for the underrepresentation of women in chemistry. Barton (1997) explains that the conceptual framework of Feminist theory marks a very important change in the way people think in the science education environment. It shifts the reform focus from wide-ranging deficiencies for women or minorities to specific areas of deficiencies and discriminatory practices like science and education (Barton, 1997).

Holland's theory is called "The Theory of Vocational Choice." Originally developed by American psychologist John L. Holland (1959), this theory Holland identifies six personality types: artistic, realistic, enterprising, intellectual, social, and traditional. Each personality type corresponds to a specific career type (Rezaei, Qorbanpoor, AhmadiGatab, & Rezaei, 2011). It is primarily used to study vocational personalities and work environments (Nauta, 2010). Holland's theory stipulates that individuals chose to pursue certain careers and academic disciplines based on their attitudes, interests, values, personality type, and abilities. Holland's theory reveals the existence of a strong relationship between interests and occupational choices. If males and females are expected to be in science-related careers, they must show interest in the sciences. For example, women should show interest in chemistry if they expect to pursue a career in chemistry. The results of numerous studies (Brandriet, Xu, Bretz, & Lewis, 2011; Xu & Lewis, 2011; Narmadha, & Chamundeswari, 2013; Kahveci, 2015) support

Holland’s theory. They reveal that women show less interest or a more negative attitude towards chemistry than men. These findings probably explain women’s underperformance and underrepresentation in chemistry. It is important to note that women’s interest and attitudes toward sciences and chemistry are not the sole contributors to their underperformance and underrepresentation in that field. Other factors, such as discrimination against women in science, lack of preparation, mathematics ability, parents and teachers' influence, and learning environment, may also contribute to the underperformance and underrepresentation of women in chemistry.

Gender Discrepancy in STEM and Chemistry

Gender discrepancy has been demonstrated in many STEM (Science, Technology, Engineering, and Mathematics) studies (Su & Rounds, 2015; Stout, Grunberg, & Ito, 2016). Other studies revealed fewer women pursue careers in the physical sciences (chemistry, technology, engineering, and mathematics) than men (DiPrete & Buchmann, 2013; Aguinis, Ji, & Joo, 2018). Researchers have also reported that more women completed courses in biological and behavioral sciences than men (Stout, Grunberg, & Ito, 2016).

There could be numerous reasons explaining this discrepancy between women and men in STEM. One of the principal reasons cited by certain social scientists is the lack of interest among highly qualified women. STEM is not considered as a primary career choice for them. Women enter the STEM fields at a much lower rate than their male peers (Mann and DiPrete 2013; Morgan, Gelbgiser, and Weeden 2013). Women prefer to pursue occupations in other fields instead of STEM (Ceci & Williams, 2010). The investigations reveal that computer science, physics, and engineering stereotypes are among many factors associated with weaker science identification and career aspirations among women and stronger science identification and career aspirations among men (Cundiff, Vescio, Loken, & Lo, 2013; Smyth & Nosek, 2015; O'Brien, Blodorn, Adams, Garcia, & Hammer, 2015). Although gender discrimination is not seen as the main cause of women's underrepresentation in STEM (Ceci, Ginther, Kahn, & Williams, 2014; Ceci & Williams, 2010), it is reported to be one of many obstacles for women. In general, women have experienced more discrimination than men in STEM (Cheryan, Ziegler, Montoya, & Jiang, 2017). Reuben, Sapienza, and Zingales (2014) revealed that the ability to perform an arithmetic task has been seen as a masculine's job. For example, both male and female subjects were two times more likely to have hired a male applicant than a female to perform such tasks, despite her having equal qualifications (Reuben, Sapienza, & Zingales, 2014). Also, there was substantial evidence that women scientists are victims of discrimination in higher education.

For example, researchers found that college students rated conference abstracts from female authors lower in scientific quality than male authors (Knobloch-Westerwick, Glynn, & Huge, 2013). Moss-Racusin, Dovidio, Brescoll, Graham, and Handelsman (2012) reported that female candidates were offered a smaller starting salary than male candidates, despite having the same qualifications for the job (Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012).

Other factors reported by researchers that demonstrated women's underrepresentation in STEM included labor market and institutional forces, peer support, and attitudes toward STEM (Cheryan, Ziegler, Montoya, & Jiang, 2017). Alon and DiPrete (2015) reported that women prefer a field mostly dominated by women, and they are less interested in external rewards. Men, on the other hand, prefer a competitive field that could have given them lucrative salaries. Studies revealed that the most competitive majors are the ones that gave men access to the highest average salaries, thus explaining in part why men enter STEM fields at a higher rate than women (Alon & DiPrete, 2015). Studies also suggested that students who have peer support pursue science with greater interest than those without that kind of support (Palmer, Maramba, & Dancy, 2011; Leaper, Farkas, & Brown, 2012; Robnett & Leaper, 2013). Cohen and Kelly (2018) showed that the lack of performance in chemistry is associated with STEM dropout. This study provided evidence that among courses that play essential roles in STEM, Chemistry is one. Researchers describe it as a gatekeeper course for STEM majors. Students often change to non-STEM majors because of chemistry. However, courses like General Biology and Anatomy and Physiology are associated with students remaining in STEM (Cohen & Kelly, 2018).

The science world had always been a male-dominant field (Miller, Eagly, & Linn, 2015). For generations, women have been underrepresented. Despite the recent efforts of women to reduce the gender gap (Holman, Stuart-Fox, & Hauser, 2018), the disparities remain significant in enrollment and degrees attained in engineering, mathematics, computer science, physical science disciplines, and chemistry.

In chemistry, women have reportedly closed the gender gap for bachelor's degree seekers in chemistry. However, women still face difficult challenges in overcoming gender differences in performance at the undergraduate level and participating in more advanced chemistry degrees (Stieff, Ryu, Dixon, & Hegarty, 2012; Matson, 2013). At the doctoral level, women are largely underrepresented in chemistry. In 2011, for example, the number of females who received their doctoral degrees in chemistry represented 1/3 of chemistry doctorates (National Science Board, 2014). An analysis across the STEM fields has shown that women in chemistry are underrepresented at a higher proportion than women in other STEM fields (Dabney & Tai, 2014). Numerous studies reveal that male students outperform their female counterparts in performance achievement (Ezeudu, Chiaha, Anazor, Eze, & Omeke, 2015; Veloo, Hong, & Lee, 2015; Matz, Koester, Fiorini, Grom, Shepard, Stangor, & McKay, 2017). Researchers have suggested that many factors contribute to gender disparity in chemistry, including self-efficacy. It has been reported that a linear relationship exists between self-efficacy and chemistry achievement. Students with high self-efficacy often have higher achievement in chemistry. Those with low self-efficacy have lower achievement in chemistry.

Female students have reported having lower self-efficacy and higher fear of not getting better results than male students, resulting in lower achievement in chemistry tests (Tenaw, 2013; Xu, Villafane, & Lewis, 2013). Other researchers who investigated self-efficacy and anxiety revealed that women had lower self-efficacy and higher anxiety when it came to chemistry. They concluded that these gender differences could have eventually impacted both participation and achievement in the subject (Sunny, Taasoobshirazi, Clark, & Marchand, 2017). Boz, Yerdelen-Damar, Aydemir, and Aydemir (2016) suggesting that self-efficacy could be improved by creating a relaxing and friendly environment where students could experience active learning (Boz, Yerdelen-Damar, Aydemir, & Aydemir, 2016). Other factors cited by researchers include math ability, prior conceptual knowledge in chemistry, and non-cognitive factors such as attitude toward chemistry. They suggest that these factors are key predictors for achievement in general chemistry (Xu, Villafane, & Lewis, 2013).

Researchers also reported that visuospatial ability is linked to achievement in chemistry (Devetak & Glažar, 2010) and problem-solving performance in organic chemistry (Lopez, Shavelson, Nandagopal, Szu, & Penn, 2014). Spatial ability was shown to be higher among male than female students (Estes & Felker, 2012; Pietsch & Jansen, 2012). Other researchers reported that gender differences in achievement in chemistry are associated with both spatial ability and spatial-analytic strategy use. Spatial ability is higher among male students (Estes & Felker, 2012; Pietsch & Jansen, 2012), but spatial-analytic strategy use is higher among female students (Stieff, Dixon, Ryu, Kumi, & Hegarty, 2014).

Harle and Towns (2010) found that achievement in chemistry could be increased if students could improve their spatial ability skills (Harle & Towns, 2010). In a study that used Second Life (SL), a three-dimensional (3-D) virtual world, as a model to have enhanced the spatial learning among undergraduate students' in chemistry, it was revealed that students with low spatial abilities who learned the Second Life model saw a significant improvement in their spatial abilities and their performance in chemistry. Researchers suggest that these findings are related to the students' abilities to think in a 3-D space developed with the Second Life model. Also, they had found that both male and female students achieved equally with the SL model. There was no statistical difference between the men and women regarding their performance on the parts related to the valence shell electron pair repulsion (VSEPR) theory test (Merchant, Goetz, Keeney-Kennicutt, Cifuentes, Kwok, & Davis, 2013).

Ethnicity and Achievement in STEM and Chemistry

Racial or ethnic academic achievement gaps continue to exist in society (Quinn & Cooc, 2015). In science, mathematics, and reading, researchers report that Black and Hispanic students underperformed compared to other ethnic groups. Meanwhile, white students continue their domination in performance achievement. They score higher on average than all other ethnic groups (National Center for Education Statistics, 2012; National Center for Education Statistics, 2013; Quinn & Cooc, 2015). Researchers report many factors are associated with the different gaps. Racial or ethnic academic achievement gaps are related to the socioeconomic status (SES) and the quality of schools attained by students. However, possible explanations for gender gaps in science are discrimination against females and stereotypes. These factors often serve as barriers to stop females from studying or pursuing careers in the science field (Hill, Corbett, & Rose, 2010). Researchers report that the racial or ethnic gaps created by socioeconomic status and school quality have been consequential in classrooms. Students who developed their mathematics and reading abilities at an early age have a significant advantage over those with lower math and reading skills (Quinn, 2015). In another study where researchers investigated the gaps between students with different socioeconomic status, results showed a similar gendered pattern of mathematics, reading, and science. In the most privileged class or the class of individually and contextually wealthy, it was found that females from all racial or ethnic groups, especially Black and Latina, underperformed white males in math and science. Black males underperformed all other ethnic groups in math and science. In reading, white females scored higher than white males and other ethnic groups. Results showed no differences in math scores across racial/ethnic and gender categories within the class of individually disadvantaged and contextually wealthy groups (Bécares & Priest, 2015).

Researchers from a recent science, technology, engineering, and mathematics (STEM) study that was purposely designed to have examined the gender and the ethnic gaps between different racial or ethnic groups confirmed that women underperformed men in STEM. Their investigation also provided evidence of significant racial or ethnic group differences. Asian American students outperformed white, African American, and Hispanic in both mathematics and science achievement. African American students outperformed white students in terms of mathematics value (Else-Quest, Mineo, & Higgins, 2013).

In chemistry, researchers have found that a change in chemistry pedagogy could be key to improve academic achievement. The results of a study that incorporated Process-Oriented Guided Inquiry Learning method (POGIL) as a pedagogy to engage students in the learning process proved its effectiveness in addressing the ethnic achievement gap. Students who participated in POGIL pedagogy performed significantly better than those who used traditional pedagogy. African American students in the POGIL showed the highest post-test estimated margin mean among their Caucasian, Hispanic, and Asian peers (Barthlow & Watson, 2014). A recent study by Veloo and colleagues also revealed evidence of ethnic differences. They found a significant difference in chemistry achievement between different ethnic groups of Malay, Chinese, and Indian students. Malay students underperformed their Chinese and Indian counterparts. Chinese students outperformed other ethnic groups (Veloo, Hong, & Lee, 2015). Other researchers found that at-risk students, referring to those who scored in the

SAT-M bottom quartile, performed significantly worse on first-semester chemistry assessments. Students of the at-risk cohort included mostly those who identified themselves as Black/African American and Hispanic/Latino (Ralph & Lewis, 2018).

Parents and Teachers' Influences

One key objective and outcome of educational attainment is student achievement. Researchers suggest that student achievement at all grade levels can be measured through school, family, teacher performance, students' academic performance and language skills, attitudes, and healthy development (Epstein, 2018). Each stakeholder, including the student, school, teacher, and parent, has an important role in student achievement. Without their influences, student achievement will not be possible (McGrath & Van Bergen, 2015; Mikk, Krips, Säälik, & Kalk, 2016).

In considering parental involvement, researchers have reported that children's academic achievement is somehow related to their parents' involvement in their educational journey (Wilder, 2014; Badri, 2018). These aspects of involvement include parental goals and expectations for their children, parental supervision, parental participation in school activities, and parent-child communication about school-related matters (Jeynes, 2007). Some researchers who investigated the topic further suggest that family structure has a lot to do with children's academic achievement. They found that the family structure could exert either a positive or a negative impact on students' academic performance.

The studies investigated several different family structures: intact families or children living with both biological mom and dad, and fragile families or children living with a single biological parent, guardian, and/or stepparents (Wu, Schimmele, Hou, &

Ouellet, 2012). The study findings suggest that students living with both biological parents in the house often surpass those in the households with a single biological parent, stepparents, and/or guardian in terms of academic performance and achievement (Wu, Schimmele, Hou, & Ouellet, 2012; Sengul, Zhang, & Leroux, 2019). The findings from another research study revealed that science and mathematics achievement is directly connected to parents' ability to transfer the subjects' value to their children (Hong, Yoo, You, & Wu, 2010; Sun, Bradley, & Akers, 2012).

Researchers revealed that both the mother and father could influence their children's life choices, including their careers. For example, parents who speak highly of science with children would expect their children to explore the science fields and pursue a science career. The same study also investigated the effect of parents’ gender-based perceptions regarding their children’s abilities in the sciences. Researchers found that the parents’ perceptions in sciences that were communicated at home affected the development of their students’ gender-based self-perceptions in sciences. That, in turn, affected children’s choice and participation in sciences. Results also showed that males got a more positive message regarding their abilities to pursue science and its value than females (Makwinya & Hofman, 2015).

Teachers are highly viewed as playing a significant role in students’ lives (Roorda, Koomen, Spilt, & Oort, 2011; Wang, Hatzigianni, Shahaeian, Murray, & Harrison, 2016; Prewett, Bergin, & Huang, 2019). In their capacity to teach and transmit knowledge, they create supportive instructional contexts. Teachers influence their relationship with students within the instructional context by their beliefs and actions and their interactions. Researchers suggest this could be an important means to increase students' motivation and enhance learning (Ferguson & Braten, 2018). According to the *Social Cognitive Theory* of learning, it is expected that a positive relationship between teacher and student should have a positive effect in the classroom, subsequently leading to positive academic achievement. Some research in this area supports this theory. For example, researchers have shown that relationships between faculty and students had been found to significantly affect students' learning and motivation, which can lead to academic achievement. They also revealed that professors were irrefutably the most influential figures that shape students' academic path in higher education (Cole, 2010; O'Meara, Knudsen, & Jones, 2013).

In a different study, researchers suggested that positive social interaction skills and school engagement are associated with academic achievement, but the results were observed within the same school year. In a subsequent year, the prior year's achievement was not supported by that study. Therefore, researchers could not predict a change in achievement from one year to the next (Goble, Eggum-Wilkens, Bryce, Foster, Hanish, Martin, & Fabes, 2017).

Many studies have shown that a strong relationship exists between teachers' non-verbal expressions, such as mood, outfits, behavior, facial expressions, and students' academic achievement (Mehdipour and Balaramulu (2013); York 2015; Bambaeeroo and Shokrpour, 2017). A recent study found that chemistry teachers who displayed non-verbal expressions in the classrooms positively and statistically influenced the academic achievement of learners in chemistry (Irungu, Nyagah, & Mugambi, 2019).

Influence of Learning Styles and Classroom Environment

According to Ormrod (2020), “learning is a long-term change in mental representations or associations as a result of experience” (p. 4). Over the years, many learning theories had evolved. Among them are behaviorism, cognitivism, and constructivism. Behaviorists believe that learning can be objectively studied from people’s behaviors, known as responses, and the environmental events or stimuli that came before and after those responses. Learning can occur when learners behave in a certain way (Ormrod, 2020). Cognitive learning theory suggests that the learning process can be explained by analyzing the mental process first. Cognitivists believe that people’s behavior should be the focus of scientific inquiry. Knowledge, according to this group, must have been an organized process. Learning new material must be related to previously learned information. Some learning processes may be unique to human beings (Kay & Kibble, 2016; Ormrod, 2020). The theorists’ views of learning may vary, but the major differences among theories lie more in interpretation than in definition (West, 2018).

Learning styles and exam types are important for women’s achievement in chemistry (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995). The successful use of audio-visuals (e.g., film projectors, television sets) is considered a means of presenting clear and interesting content that fosters student learning. Apropos of visual objects in science, researchers found that students more easily solve exercises when the questions contained graphs and figures (Duran & Balta, 2014). Still, such devices should be used cautiously to avoid sacrificing student and teacher interactions.

In a study investigating attitudes and approaches to chemistry problem solving (AACPS), Duran (2016) revealed that female students scored higher on the AACPS scale than their male counterparts. They attributed this success to the female students' note-taking ability in classes, more regular attendance at classes, and paying closer attention than male students in classes. These findings suggest that female students would perform better in chemistry if chemistry teachers could change their problem solving (Duran, 2016).

In another study, researchers found that concept mapping was a more desirable technique than true-false questions in organic chemistry. Both female and male students obtained better results in organic chemistry when using concept mapping (Gafoor & Shilna, 2014). It also was revealed that males outperformed females on chemistry exams or quizzes in the form of stoichiometry questions. However, when the chemistry exams or quizzes were multiple-choice questions, the gender difference analysis showed that females generally performed slightly better than their male counterparts (Hudson, 2012). Active learning has been used by many in STEM and chemistry as an educational strategy to improve learning, which leads to student success (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014; Ryan & Reid, 2015; Bokosmaty, Bridgeman, & Muir, 2019). It allows students to control their learning and, afterward, increase their confidence levels (Schultz, Duffield, Rasmussen, & Wageman, 2014).

A study revealed that incorporating the peer-cooperative learning program into the student's curriculum improved introductory course grades, enhanced academic success, and increased the retention rate for chemistry and other STEM fields (Salomone & Kling, 2017). Another study showed that students from both sexes who self-selected into Peer-Led Team Learning (PLTL) had higher exam achievement scores in general chemistry than those who chose not to participate in that program (Chan & Bauer, 2015). Researchers recently found that peer-focused recitation was an excellent technique to increase general chemistry students' performance. Students who elected to participate in peer-group discussions or recitation led by students saw improved grades and successfully completed general chemistry. Improvement was seen for both male and female students from all ethnic and racial backgrounds (Perera, Wei, & Mlsna, 2019).

Science teachers have used electronic response pads known as clickers to increase students' engagement or active learning. Researchers studying the use of clickers reported that female students outperformed their male counterparts on the standardized final test they took at the end of the semester due to the inclusion of the new "clicker" learning strategy in classrooms. Being exposed to the material in a different style or being better prepared may have contributed to increased learning and success within chemistry science and a more positive view of chemistry among women (Niemeyer & Zewail-Foote, 2018). Researchers found that students' perception of a constructivist learning environment increased their self-efficacy beliefs and similarly increased their chemistry achievement. Female students reported having a higher perception than their male counterparts of the constructivist learning environment. Researchers suggested a constructivist classroom environment could lower the gender gap in chemistry (Boz, Yerdelen-Damar, Aydemir, & Aydemir, 2016).

In summary, teachers can use different methods to pass on their chemistry knowledge to students. Studies have shown that integrating other learning styles into classrooms improves learning and increases performance achievement among women. Similar results have been obtained with the inclusion of new question types into chemistry exams. Also, certain classroom environments have been shown to impact students' learning and performance achievement positively. Women prefer a relaxing learning environment, which contributes to their performance achievement in chemistry courses. These factors have shown to be effective in diminishing the gender gap in chemistry.

Attitude Toward Sciences

Attitude is defined as a feeling or a belief that someone has toward an object, person, place, or issue after evaluations (Cherry, 2019). Attitude could be learned because no individual is born with it. It is acquired throughout socialization in childhood and adolescence. People's attitudes influence their thoughts, actions, and behaviors. Attitudes involve desires and emotions. Some attitudes are stronger than others. Individuals can express their attitudes in many ways. They could love someone and hate other people; they could have also liked certain types of movies and disliked other types; or they could have expressed attraction for something or could have repugnance for other things (Perloff, 2016).

The ability to think scientifically is crucial for success in the sciences. Teachers can take numerous actions to help students in science develop the critical thought processes needed. Attitude toward science is suggested as one of the significant pieces in that process (Sumarni, Susilaningsih, & Sutopo, 2018). Several studies reveal that a linear relationship exists between attitude and achievement. Students with positive attitudes toward the sciences are often reported to have enhanced achievement in the sciences (Xu and Lewis, 2011; Ayyildiz, 2012; Narmadha and Chamundeswari, 2013).

Chemistry science researchers have found that students who had successfully taken previous chemistry courses developed higher intellectual and emotional attitudes toward chemistry (Kahveci, 2015). Researchers also found a significant gap between male and female students regarding their attitude toward the sciences. Female students were less inclined toward science (Valenti, Masnick, Cox, & Osman, 2016).

Furthermore, another study found that female students had more aptitude towards non-science related material than science material, but their critical thinking skills were more pronounced than their male counterparts. Additionally, female students were more adept at data analysis and interpretation than male students (Zhou, Jiang, & Yao, 2015). Another study revealed that women were people-oriented, and men were things-oriented. Researchers argued that such attitude influenced their career choices in STEM fields (Su & Rounds, 2015). Likely this is why researchers suggest that women’s interests must be considered to understand why they are underrepresented in STEM (science, technology, engineering, and mathematics) (Su & Rounds, 2015).

In chemistry, researchers had found that males had a higher positive attitude and self-concept than females (Chan & Bauer, 2015). Females were reported to have a less favorable attitude towards chemistry than males in considering these two factors: emotional satisfaction and intellectual accessibility (Brandriet, Xu, Bretz, & Lewis, 2011). In another study, researchers found that integrating certain classroom programs, such as Organic Chemistry in Action! (OCIA!), created a better learning environment for the students, and, therefore, positively influenced students’ attitudes towards organic chemistry (O'Dwyer & Childs, 2014). Such programs feature PowerPoint presentations, videos, assessment games, and assignments. Researchers suggested that women’s achievement in General Chemistry I, in particular, could be improved by helping them improve their chemistry competency beliefs (Vincent-Ruz, Binning, Schunn, & Grabowski, 2018).

Mathematics Influence

Mathematics is known as the queen and servant of the sciences (Atiyah, 1993). It has a unique ability to interact with other areas of science and engineering. These interactions are indispensable for other sciences because it offers the tools and insights needed for their advancement (National Research Council, 2013). Mathematics is extremely important in physical chemistry, especially in advanced topics such as quantum or statistical mechanics. For example, quantum mechanics depends for the most part on group theory and linear algebra. Mathematical and physical concepts like Hilbert spaces and Hamiltonian operators are crucial in quantum mechanics and have widespread applications in this field. Statistical mechanics also depends largely on probability theory (quantities with random distributions).

Other branches of chemistry, such as Spectroscopy, for example, also use a significant amount of math. Recent infrared radiation (IR) models and nuclear magnetic resonance (NMR) instruments used the mathematical function *Fourier Transform* to obtain spectra. Also, biochemistry has many important concepts, such as kinetics and binding theory, which rely heavily on math. For example, various biochemical assays require kinetic methods and instruments to measure the rate of reactions.

In the pharmaceutical industry, clinical data is crucial for the effectiveness and safety of new drugs. Analyzing that data requires mathematicians' expertise, further demonstrating the significant relationship between mathematics and chemistry.

Also, chemists greatly benefit from working alongside mathematicians to find solutions to certain problems and generate technological advancements. In the aftermath of an intense research laboratory computerization period, data production and collection have become easier. Research chemists have leveraged applied mathematics and statistical tools to extract useful chemical information from data (Kowalski, 2013). In some programs of study that require students to take chemistry courses, Mathematics is always used as a prerequisite. Both Principles and General Chemistry heavily depend on mathematical equations to solve numerous problems. For example, the mole, which is the amount of substance in elements, molecules, and compounds, requires students to use algebraic equations to solve related problems. Solving stoichiometric problems also requires some fundamental mathematical skills to balance chemical equations. Additionally, these foundational skills are needed for spatial reasoning, which is necessary to understand three-dimensional representations (Donaghy & Saxton, 2012) and organic chemistry concepts (Stieff et al., 2012). Furthermore, the reaction rate, various concentrations of chemical solutions, the mass of chemical species, and the concentration of hydrogen ions (pH) in solution require students to manipulate various mathematical equations to find answers to different problems.

As with gender differences in chemistry, women are shown to be underrepresented in the Mathematics field (Hill, Mammarella, Devine, Caviola, Passolunghi, & Szűcs, 2016; Carey, Hill, Devine, & Szücs, 2016). Researchers offer several explanations for the paucity of women in mathematics-intensive fields. Some argue that male brains can perform complex, abstract math, and spatial visualization in mathematics-intensive domains. Therefore, mathematics and spatial reasoning greatly favor males. Others also believe that stereotypes, cultural biases, and barriers play an important part in that situation, and those barriers prevent women from maximizing their potential and excelling in these domains.

Additionally, they claim that women are simply not interested in mathematics-intensive fields and prefer careers in social sciences because they were more people-oriented (Ceci & Williams, 2009). One study also revealed that females showed less interest in mathematics than males. Researchers in the same study went further to explore the engineering skills of female and male students. They revealed that male students exhibit higher engineering skills than their female counterparts (Riegle-Crumb & Moore, 2013). Ellis, Fosdick, and Rasmussen (2016) have found that women feel less confident in mathematics than men. However, these findings do not support the degree of women's mathematical ability. Researchers also found that women dropped out of Calculus II at a higher rate than men (Ellis, Fosdick, & Rasmussen, 2016). This finding may point to one cause of women's underrepresentation in STEM and other sciences such as chemistry that requires students to take Calculus II.

As revealed in the above studies, mathematics is imprinted in all the different chemistry areas. Darlington and Bowyer (2016) specified that undergraduate chemistry students who had learned different topics to satisfy their degree's mathematical requirements considered their preparation adequate. The different topics studied included proof, algebra and functions, coordinated geometry, trigonometry, sequences and series, exponentials and logarithms, calculus, vectors, statistical sampling, data presentation and interpretation, probability and statistical distributions, kinematics, forces, Newton's laws and moments, graphs and networks, algorithms, linear programming and game theory

(Darlington & Bowyer, 2016). Studies have shown that men generally have a higher mean score on the mathematics section of college admissions exams in the US, such as the SAT and ACT (Camara & Echternacht, 2000). This gender gap in SAT math scores is believed to influence women's achievement in chemistry significantly. Researchers who investigated that relationship suggest that the influence of SAT math performance on General Chemistry I could be explained through chemistry competency beliefs (Vincent-Ruz, Binning, Schunn, & Grabowski, 2018).

Influence of Age

The issue of age and academic achievement in chemistry has not attracted much attention from researchers for the past decade (2009-2019). The very few studies done in that area have not shown conclusively that age as a factor can influence academic achievement. The findings lack conformity among the studies. One study found that students over age 14 performed slightly better than those below 14 years in inorganic, physical, and petroleum or industrial chemistry (Onuekwusi, 2015). Another study investigating the effect of gender and age on academic achievement of college mathematics and sciences, including chemistry, suggests that gender is a better predictor of academic achievement than age (Abubakar & Oguguo, 2011).

Research Questions

The following research questions guided this study:

1. What is the difference in final grades between genders for General Chemistry I?
2. How do males' and females' ages affect the final course grade outcome in General Chemistry I?

3. How do ethnicities vary in their General Chemistry I final course grade for males and females?

Chapter 3: Methodology

The purpose of this quantitative research study is to determine if there is a significant difference between male and female students' performance in General Chemistry I in higher education. The study also seeks to find what variable or combination of variables might contribute to this gender difference if it exists. Previous studies have revealed the existence of certain factors such as self-efficacy (Tenaw, 2013), math ability, prior conceptual knowledge in chemistry, and attitude toward chemistry (Xu et al., 2013), spatial ability (Estes & Felker, 2012; Pietsch & Jansen, 2012), discrimination (Cheryan, Ziegler, Montoya, & Jiang, 2017), learning styles and exam types (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995), and attitude towards chemistry (Brandriet, Xu, Bretz, & Lewis, 2011) that may have contributed to this gap.

Participants

This study comprised male and female students who had completed the General Chemistry I course in higher education at the study site. Participants were selected based on the class rosters. Seven sections of General Chemistry I were chosen for the study: Fall 2017, Summer 2017, Fall 2018, Summer 2018, Fall 2019, Summer 2019, and Fall 2020. Each participant was enrolled in one of the seven sections and was taught by the same instructor. Each class period ran twice a week for a total of 4 hours each week.

The estimated population was 113 students. The sample size needed for a 95% confidence level is 95 students. This sample represents 84.1% of the population. Creswell (2015) mentions a large sample size from the population is highly recommended to minimize the potential error (Creswell, 2015). In this case, the entire student cohort of 113 students was used.

Instruments

The final course grade was used to assess performance in General Chemistry I in higher education. The different tests used in this study are copyrighted. The chemistry instructor obtained permission to use them for educational purposes. The tests included: Exam 1-4, Quiz 1-10, Worksheet 1-10, Homework assignments chapters 1-10. Approximately 75% of the exams and quiz questions were taken from a test bank with copyright from *General Chemistry1Test Bank by Ebbing and Gammon, 10th ed*. The course instructor prepared additional questions and worksheets according to the American Chemical Society standards and guidelines. Two other chemistry professors at the same institution reviewed those questions to ensure their clarity and content efficiency. Between 15 to 18 homework questions were assigned for each topic covered in each class. For each section of General Chemistry I under investigation, the final course grade for each student was computed using the following distribution: quizzes and worksheets (17.5%), homework assignments (17.5%), weekly tutoring (5%), two 3-hour exams (40%), and a final exam (20%). The total raw score for each student was used to compute the final grade for the course.

Procedures

Design. A comparative research design was used in this study. It was a type of non-experimental study. Comparative research aims to find differences and similarities between variables (Lewis-Beck, Bryman, & Futing Liao, 2004). This methodology was suitable because the main goal of this investigation was to study gender disparity in General Chemistry I. Data collected was analyzed using statistical procedures to determine whether any significant differences existed between variables and identify which variable - gender, age, ethnicity, or a combination of variables - was the best predictor of the final course grade or academic performance in General Chemistry I.

Data collection procedures. The following procedures were used to collect information on participants for this study. After the Institutional Review Board (IRB) of Nova Southeastern University initially approved the study, the researcher contacted the IRB and other individuals at the study site to obtain all necessary final approvals and permissions for the study. The researcher then met with the registrar's office personnel to collect the computerized data, which was transferred to a password-protected thumb drive.

Data Analysis

Data analysis procedures. Final course grades were computed for all participants, separated by gender. Three sets of statistical analyses were conducted in this research. The analysis of gender data for questions 1, 2, and 3 was computed using the Statistical Package for Social Sciences (SPSS) software. Inferential statistics were used to answer the three research questions. Question 1: What is the difference in final grades between genders for General Chemistry I? This question was answered by using a t-test to determine any significant gender differences in performance in the General Chemistry I course. Question 2: How do males' and females' age affect the final course grade outcome in General Chemistry I? A second t-test was used to determine the effect of age on the final course grade. Question 3: How do ethnicities vary in their General Chemistry I final course grade for males and females? The analysis of variance (ANOVA) was used to determine the effect of ethnicity on the final course grade. All three questions were answered using inferential statistics to determine each variable's predictive strength or combination and draw conclusions from the gender data.

Chapter 4: Results

This chapter presents the results of this quantitative research study. Archived data were collected and analyzed to find answers to the three research questions associated with this study. These data include students' final course grades in General Chemistry I, gender, age group, and ethnicity. Inferential statistics were used in the analysis of these data.

Data Analysis

Test scores were computed for all participants. Three sets of analyses were conducted in this research. First, test scores were separated into two categories (females and males). A t-test was used to answer research question 1. Second, test scores were separated into two age groups: below 21 years and 21 years and above. Another t-test was used to answer question 2. Third, test scores were separated into different ethnic groups. The analysis of variance, ANOVA was used to answer the research question 3.

Research Question 1. (RQ1):

What is the difference in final grades between genders for General Chemistry I? The following null and alternative hypotheses were generated from this research question:

The null hypothesis

$H_0 1$: There is no significant difference in the final course grade of males and females who study General Chemistry I in higher education.

The alternative hypothesis

H_a1: There is a significant difference in the final course grade of males and females who study General Chemistry I in higher education.

Results of the t-test were reported in Table 1 and Table 2. Both tables summarize the inferential statistics comparison of means and independent sample t-test for gender. Table 1 shows the mean test score and standard deviation for male and female participants. Table 2 shows the results of the independent sample t-test for gender scores.

Table 1

Mean and Standard Deviation of Test Scores for Male and Female

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Scores	Male	40	88.92	6.288	.994
	Female	73	85.26	7.897	.924

N = Number of participants

The sample size consisted of 113 participants, of whom 40 were males, and 73 were females. The mean test score for male participants in the sample was 88.92, with a standard deviation of 6.288. For female participants, the mean test score was 85.26, with a standard deviation of 7.897.

The assumption of equal variance was upheld (F = 1.976, p = .163). The obtained *t* value of 2.521 is associated with a *p* of .013, which is statistically significant. Therefore, the males achieved a significantly higher average of Chemistry scores than females. The null hypothesis was rejected.

Table 2

Independent Samples t-Test for Gender Scores

		Lavene's Test for Equality of Variances		t-Test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Score	Equal Variance assumed	1.976	.163	2.521	111	.013	3.655	1.450	.782	6.529

Male (M = 88.92, SD = 6.3) and female (M = 85.26, SD = 7.9) conditions; t (111) = 2.521, p = 0.013.

Research Question 2 (RQ2).

How does the age of males and females affect the final course grade outcome in General Chemistry I?

From this research question, the following null and alternative hypotheses were generated:

The null hypothesis

H_02: There is no significant difference in final course grade between the ages' categories (younger than 21 years old, 21 years older and older) of males and females who study General Chemistry I in higher education.

The alternative hypothesis

H_a2: There is a significant difference in final course grades between the ages' categories (younger than 21 years old, 21 years older and older) of males and females who study General Chemistry I in higher education.

Results of this t-test were reported in Table 3 and Table 4. Both tables summarize the inferential statistics comparison of means and independent sample t-test for participants' age group. Table 3 shows the mean and standard deviation of test scores for the two age groups: younger than 21 years old and 21 years old and older of male and female participants. Table 4 shows the results of the independent sample t-test for the age group of participants.

Table 3

Mean and Standard Deviation of Test Scores for Age Groups

	Age	N	Mean	Std. Deviation	Std. Error Mean
Scores	Younger than 21	42	87.39	7.240	1.117
	21 and older	71	86.06	7.729	.917

N = Number of Participants

The sample size consisted of 113 participants, for whom 42 were younger than 21years, and 71 were 21 years old and older. The mean test score for participants younger than 21 years in the sample was 87.39, with a standard deviation of 7.240. For participants aged 21 and older, the mean test score was 86.06, with a standard deviation of 7.729.

The analysis of data from independent sample t-test for age group of participants showed the following results: students younger than 21years old (M = 87.4, SD = 7.2) and students 21 years old and older (M = 86.1, SD = 7.7) conditions; t (111) = 0.903, p = 0.369. The assumption of equal variances was upheld (F = 0.126, p = .724). The obtained t value of 0.903 is associated with a p of .369, which is not statistically significant. Therefore, there is no significant difference in final course grade between the ages' categories (younger than 21 years old, 21 years older and older) of participants who study General Chemistry I in higher education. The null hypothesis was not rejected.

Table 4

Independent Samples t-Test for Age Group of Participants

		Lavene's Test for Equality of Variances		t-Test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Score	Equal Variance assumed	.126	.724	.903	111	.369	1.327	1.470	-1.586	4.241

Younger than 21years old (M = 87.4, SD = 7.2 and 21years old and older (M = 86.1, SD = 7.7) conditions; *t* (111) = 0.903, *p* = 0.369.

Research Question 3 (RQ3).

How do ethnicities vary in their General Chemistry I final course grade for males and females?

From this research question, the following null and alternative hypotheses were generated:

The null hypothesis

$H_0 3$: There is no significant difference in final course grade in General Chemistry I in higher education between ethnicities.

The alternative hypothesis

$H_a 3$: There is a significant difference in final course grade in General Chemistry I in higher education between ethnicities.

The analysis of variance, ANOVA, results were reported in Table 5, Table 6, and

Table 7. These tables summarize one-way analysis of variance, ANOVA of percent test score by ethnicity. Table 5 shows the percentage test score of various ethnic groups (Black, White, Spanish, and Others) in this study. Table 6 includes the results of the analysis of variance conducted for all four ethnic groups. Table 7 contains the results of three of the four ethnic groups: Black, White, and Spanish. The ethnic group labeled "Other" is excluded.

Table 5

One-Way ANOVA Frequency by Ethnicity

	Ethnicity	Frequency	Percent	Valid Percent	Cumulative Percent
	Black	35	31.0	31.0	31.0
	*Others	8	7.1	7.1	38.1
Valid	Hispanic	37	32.7	32.7	70.8
	White	33	29.2	29.2	100.0
	Total	113	100.0	100.0	

*Others = Filipino, Asian, and Arab

Table 5 shows the frequency of each ethnic group: 35 Black, 8 Others, 37 Hispanic, and 33 White. "Others" group is underrepresented in the distribution of ethnicity. According to Knapp (2017), there should be no group that is less than 30% of the others. Thus, One-Way ANOVA will be run twice, one with the 'Others" included and another with the 'Others' excluded.

Table 6 includes White, Black, Hispanic, and Other ethnic groups. It shows that there was not a significant effect of ethnic groups on test scores at the $p < 0.05$ level, [F

(3, 109) = 1.083, p = 0.359]. The differences failed to achieve statistical significance; therefore, the null hypothesis was not rejected.

Table 6

One-Way ANOVA of Grades in General Chemistry 1 by Ethnicity 1

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	184.623	3	61.541	1.083	.359
Within Groups	6192.700	109	56.814		
Total	6377.323	112			

Table 7 includes White, Black, and Hispanic ethnic groups. Group ‘Others’ is omitted. It shows that there was not a significant effect of ethnic groups on test scores at the $p < 0.05$ level, [F (2, 102) = 1.807, p = 0.169]. The differences failed to achieve statistical significance; therefore, the null hypothesis was retained.

The analysis of the data using inferential statistics revealed the findings below. An independent groups t-test revealed that General Chemistry I score of male (M = 88.92, SD = 6.3) differed from female (M = 85.26, SD = 7.9), as predicted, $t(111) = 2.521$, $p < .05$ which failed to reject the null hypothesis.

Table 7

One-Way ANOVA of Grades in General Chemistry 1 by Ethnicity 2

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	181.468	2	90.734	1.807	.169
Within Groups	5120.895	102	50.205		
Total	5302.363	104			

Summary

Female participants achieved significantly lower average scores in General Chemistry I than their male counterparts. A second independent t-test revealed that General Chemistry I scores of participants younger than 21 years old (M = 87.4, SD = 7.2 did not differ from 21 years old and older (M = 86.1, SD = 7.7), as predicted, t (111) = 0.903, $p > .05$. The null hypothesis was not rejected. Thus, there was no significant difference in General Chemistry I scores between the two age groups. A one-way analysis of variance (ANOVA) indicated no significant differences in General Chemistry I scores between all ethnic groups (Black, Hispanic, White, and Other) of participants in this study, $p < 0.05$ level, [F (3, 109) = 1.083, p = 0.359], the null hypothesis was not rejected. When one-way analysis of variance (ANOVA) was run without the “Other” ethnic group, the results showed; $p < 0.05$ level, [F (2, 102) = 1.807, p = 0.169] which did not reject the null hypothesis.

Chapter 5: Discussion

For many years, women have been part of the minority in STEM (Su & Rounds, 2015; Stout, Grunberg, & Ito, 2016) and chemistry (Stieff, Ryu, Dixon, & Hegarty, 2012; Matson, 2013). This study was designed to study gender disparity in chemistry. Three research questions were asked to confirm the existence of the gap and determine possible variables that could contribute to it. RQ1. What is the difference in final grades between genders for General Chemistry 1? RQ2. How do males' and females' age affect the final course grade outcome in General Chemistry I? RQ3. How do ethnicities vary in their General Chemistry I final course grade for males and females? The data for this research was derived from a small university in central Florida. Seven sections of archived data were obtained from participants who took General Chemistry I. The study sample consisted of 113 participants. A quantitative research method was used. Inferential statistics such as independent samples t-test and analysis of variance (ANOVA) were used to analyze the data and determine the answers to the research questions.

Summary of Findings

The following findings were presented in the previous chapter.

RQ1: What is the difference in final grades between genders for General Chemistry I? It was found that the mean test score of male participants was greater than the mean test score of female participants. The t value of 2.521 was associated with a $p < .05$.

RQ2: How do males' and females' age affect the final course grade outcome in General Chemistry 1? The findings revealed that the mean test score of participants younger than 21 years old was slightly above the mean test score of 21 years old and older but was not statistically significant. The t value of 0.903 was associated with a $p > .05$.

RQ3: How do ethnicities vary in their General Chemistry I final course grade for males and females? It was found that test scores in General Chemistry I between all ethnic groups: Black, Hispanic, White, and “Other” in this study was not statistically significant, $p < 0.05$ level, [$F(3, 109) = 1.083$, $p = 0.359$] all ethnic groups included; $p < 0.05$ level, [$F(2, 102) = 1.807$, $p = 0.169$] without the “Other” ethnic group.

Interpretation of Findings

In RQ1, the results of the independent samples t-test revealed that there was a significant difference between gender in the final course grades in General Chemistry I. On average, male participants scored significantly higher than their female counterparts. These findings were anticipated and consistent with several prior studies, which revealed that women underperformed men in chemistry

In RQ2, the absence of a significant difference suggested that, on average, participants of the two age categories considered in this study equally or almost equally performed in General Chemistry I. Thus, the final course grades in General Chemistry I were not affected by male and female participants' age. These findings were congruent with other studies in that field.

In RQ3, the absence of a significant difference suggested that, on average, participants of the different ethnic groups in this study equally or almost equally performed in General Chemistry I. Thus, in General Chemistry I, the final course grades were not affected by both male and female participants' skin color. These findings were unexpected based on previous studies suggesting ethnicity is associated with performance in chemistry and that Black and Latino students underperformed white students. It was also revealed that Chinese students performed better than their peers.

Context of Findings

This study is linked to a growing list of other studies that have reported the underperformance of women in chemistry (Ezeudu, Chiaha, Anazor, Eze, & Omeke, 2015; Veloo, Hong, & Lee, 2015; Matz, Koester, Fiorini, Grom, Shepard, Stangor, & McKay, 2017). Other studies also report on the challenges women face in overcoming the gap in chemistry (Stieff, Ryu, Dixon, & Hegarty, 2012; Matson, 2013).

One ethnicity-focused study found that Chinese students outperformed other ethnic groups such as Indian and Malay (Veloo, Hong, & Lee, 2015). Researchers from another study found that at-risk students (Black/African American and Hispanic/Latino) underperformed in chemistry assessment (Ralph & Lewis, 2018). The absence of a significant difference in final course grades in chemistry between different ethnic groups makes it difficult to link this study to any of the studies mentioned above. However, in a study where POGIL was incorporated as a pedagogy to engage students in the learning process, it was found that there was no significant difference between achievement in chemistry and ethnicity (Barthlow & Watson, 2014).

Concerning age, the literature did not find conclusive evidence that the participants' age influenced their final course grade in chemistry (Abubakar & Oguguo, 2011; Onuekwusi, 2015). This study was consistent with other studies in the literature. There is no significant evidence that final course grades in General Chemistry I were influenced by the age category of participants.

Implications of Findings

Although the findings revealed that women underperformed in General Chemistry I, some aspects of both Feminist and Holland theories could not be explained. One of the

Feminist theorists' main arguments is that women and men have the same mental ability but different ways to construct knowledge. Giving them different learning style opportunities, they end up with similar outcomes (Raymond, 1985; Salner, 1989). Studies revealed that women performed better when other learning styles and active learning were included in their pedagogy (Barthlow & Watson, 2014; Niemeyer & Zewail-Foote, 2018; Perera, Wei, & Mlsna, 2019). This study's outcome might have been different if the chemistry teacher had considered employing multiple learning styles. Holland's theory focused on attitudes, interests, values, personality type, and individuals' abilities to pursue careers. It implied that women should show interest in chemistry if they are expected to pursue a chemistry career. The findings did not explain the "interested" choice of women as it is related to chemistry.

This study also revealed that age categories and ethnicity do not significantly impact the final course grades. This is great for science and society in general. It reaffirms that the capacity to learn is not limited by the skin color or the age of an individual.

This research was primarily focused on determining the gender gap in General Chemistry I. Thus, factors associated with the gap were not studied. Researchers could use this study's findings as a foundation for other studies in the field and enrich the literature.

Implications for practice: This study's findings could have implications for the university community where this study was done. The student population at this institution is diverse; women (mostly Black and Hispanic) are in the majority. By adjusting their curriculum to include different learning styles and active learning activities, chemistry teachers will foster learning and give everyone an equal opportunity to succeed. Also, the university should develop programs to promote the success of minority students in science. Even though this study's results cannot be generalized to other universities, all chemistry teachers can use it to promote and include active learning and other learning styles in their classrooms. It will decrease the gender gap in chemistry.

Limitations of the Study

The results of this study may have been affected by several limitations. The study was limited to one university; therefore, the conclusions may not be generalizable to other institutions. It is also possible that students interpreted the instructions to complete tests differently between terms. The sample size was a convenience sample, but it was still too small to get significant answers to the three research questions. Potential confounders, such as the family environment and community, also could have influenced the outcomes. Additionally, a student’s financial circumstances or the need to work while concurrently enrolled in classes could have impacted chemistry performance. These limitations could be threats to the internal validity of this study.

Future Research Directions

There are many areas to explore in light of these findings. The data of this study came from a small university in Central Florida. Having a larger sample size from multiple universities will help to understand the gender gap better. Several factors such as participants’ socioeconomic status, demography, attitude towards chemistry, parental influence, the influence of other sciences, the influence of learning styles, and the interested choice of women related to chemistry should be explored in future studies to understand this gender gap better. Some studies have found that ethnicity affected grades in chemistry. It will be appropriate to study this variable further in future research.

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Appendix

Approved IRB Letter From the Study Site

Approved IRB Letter From the Study Site

AdventHealth UNIVERSITY

Date: March 31, 2020

To: Carlo Semerzier MS., Principal Investigator

Department of Health and Biomedical Sciences

Re: HBS2120 Gender Disparity in Studying Chemistry

Dear: Carlo Semerzier,

The proposed research project "**Gender Disparity in Studying Chemistry**" has been approved by the AHU's Institutional Review Board (IRB).

As determined by DHHS regulations [45 CFR §46] and FDA regulations [21 CFR 50 and 56], the Principal Investigator accepts responsibility to comply with all Federal, State, and University policies regarding the rights and welfare of human and/or animal subjects.

If you wish to change the protocol of your research study, you must submit subsequent changes for review. As the principal investigator, you are required to notify the Research Office which will notify the IRB and the Office of Compliance of any adverse events resulting from this study. All significant protocol deviations must be reported to the Research Office and you must await approval from IRB prior to implementing the revised protocol.

- [x] Approved
- [ ] Expedited
- [ ] Exempted from IRB Review
- [ ] New Submission
- [ ] Change Request
- [ ] Multicenter Study

Sincerely,

Len Archer, Ph.D.
Chair, Institutional Review Board

Cc:Leana Araujo, Ph.D., Research Officer

Institutional Review Board 671 Winyah Drive Orlando, Florida 32803 Phone: 407-303-5619 Fax: 407-303-5671