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Effects of a Computer-based Simulation on Chemistry Self-Efficacy

Yolanta V. Kornak-Bozza

The Graduate Center, City University of New York

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Effects of a Computer-based Simulation on Chemistry Self-Efficacy

by

Yolanta Kornak-Bozza

The Graduate and University Center

A dissertation submitted to the Graduate Faculty in Educational Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2017
EFFECT OF INTERVENTION ON SELF-EFFICACY

This manuscript has been read and accepted for the Graduate Faculty in Educational Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract
Effects of a Computer-based Simulation on Self-Efficacy

By
Yolanta V. Kornak-Bozza

Advisor: Bruce Homer, Ph.D.

Self-efficacy (SE) is a measure of belief in a person’s own ability to complete a task and reach a certain goal (Bandura, 2006). It is a significant area in the field of educational psychology because it can be used to predict performance in the area being measured. Chemistry represents a challenging field of study although the skills learned from it are necessary to move forward in STEM (Luzzo, Hasper, Albert, Bibby, Martinelli, 1999). It is not uncommon for students to enter this course with feelings of low SE. Increasing SE could result in improved educational outcomes and have a long-term impact for America’s economic stability.

One aim of the study was to construct a new self-efficacy scale specific to ideal gas laws since such a scale does not exist in the field. Many scales used to assess self-efficacy beliefs are too broad, and aren’t as useful in informing us about feelings of self-efficacy in a particular domain (Bandura, 2006). Self-efficacy scales were validated using exploratory and confirmatory factor analysis.

Another goal was to assess whether a computer-based simulation in ideal gas laws could increase feelings of SE. Simulations often provide learners with opportunities to have control over their environment in a safe space while practicing their skills. By
providing opportunities for mastery, students could potentially build upon their SE of the area being investigated.

Another area explored involved assessing self-efficacy beliefs of women and people of various racial and ethnic groups in the sciences. This was deemed an important area of investigation since these groups of individuals are known to opt out of sciences. We examined both sources of science self-efficacy beliefs and ideal gas laws self-efficacy beliefs to assess whether any differences existed between groups. We additionally assessed whether the order in which the ideal gas laws posttest was delivered influenced the feelings of self-efficacy that individuals had. Based on multiple regression analysis, several signification findings emerged. Compared to men, women had lower ideal gas laws self-efficacy beliefs both before and after the intervention. The order that the ideal gas laws chemistry posttest was delivered impacted the way that participants perceived their ability in chemistry. There were no differences in chemistry knowledge performance for any groups that are traditionally underrepresented in the sciences.
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CHAPTER 1

Introduction

Instruction and learning of the fields of science, technology, engineering and mathematics have collectively been established as STEM (Gonzalez & Kuenzi, 2012). This field of study received a great deal of attention in recent years particularly because of the value it holds for sustaining national and international prosperity. If the United States wants to remain at the forefront of scientific and technological advances, we must prioritize STEM education among our youth, according to President Obama’s Council of Advisors in Science and Technology (2012).

The United States is at risk of losing global leadership status in technology and science areas unless the number of college graduates in STEM (science, technology, engineering, and mathematics) increases. According to the 2009 Programme for International Student Assessment (PISA, 2009), US students are rated 23rd out of 64 ranked economies in science. Only 15.6 percent of US college graduates received STEM degrees while 46.7 percent were awarded in China and 38.7 percent in South Korea (Business Higher Education Forum, 2010). The US needs a more diverse pool of STEM educated workforce in order to keep up with global advances in science and technology (Xie & Shauman, 2003).

President Obama’s Council of Advisors in Science and Technology (2012) state that at least 1 million more STEM graduates are needed in the next 10 years. Yet it will be impossible to fulfill this goal with the current trend of student enrollment in STEM degree programs (National Science Board, 2008), without drawing heavily on talent from other countries.
The data gathered from National Assessment of Educational Progress (NAEP, 2012) also provides evidence that Americans are performing poorly in the area of science. According to the results from the NAEP assessment, only 1/3 of 8th grade students who took the exam in 2011 scored “proficient”, leaving 2/3 scoring below proficiency. These statistics provide enough evidence that there is an urgent need for better interventions in the area of science. Along with the Obama Administration pushing for STEM education with the Race to the Top initiative, it is a national priority to not only improve scores in science and mathematics, but to also encourage our citizens to demonstrate a greater interest in learning about science so they could eventually choose STEM based careers.

A major area of concern in STEM education is that there are achievement gaps involving gender, race and ethnicity. These achievement gaps are observed in disaggregated test scores, college/graduate degrees and occupations (Gonzalez & Kuenzi, 2012). More than half of college graduates are females, yet they are earning less STEM undergraduate and advanced degrees than their male peers. Compared to males, females obtained the smallest portion of BAs in physics, engineering, and computer science (National Science Foundation, 2013). In 2010, females earned 40% of the physical sciences bachelor’s degrees, and 32% of the physical sciences doctoral degrees (NSF, 2013). Only 29% of the math doctoral degrees were awarded to females. According to the US Census Bureau report (2013), only 13% of people in the engineering workforce in 2011 were females. Though enrollment has improved among these groups within the past decade, there continues to be underrepresentation.
The US is more ethnically and racially diverse than ever before (Gonzales & Kuenzi, 2012). Yet there continues to be large academic disparities between the performance of White and underrepresented minority (URM) students in reading and math, among many other content areas, with White students having an academic advantage. URM students face numerous obstacles in attaining education of good quality (Minority Access to Education in US, 2008). Even though the population is continuing to become more diverse, there is still a low representation of minorities in STEM education (Gandara & Maxwell-Jolly, 1999). In 2007, 18% of degrees across all fields were awarded to African American, Latino & Native American students. They received 15% of degrees in Biology and 11% in engineering while White students earned 67% of the total STEM degrees (Digest of Educational Statistics, 2008). Because of this, White students are likely to move forward in STEM careers more than any other race. Since so many White students are completing STEM degree programs, they are more likely to later pursue research careers as 69% of STEM faculty are White, 18% Asian American, 11% are URM, and 2% remain unknown (Nelson & Brammer, 2010). Having more minority students and individuals of low socioeconomic status in STEM could increase the pool of potential researchers and scientists to help lead out progress in STEM (DeWelde, Laursen, & Thiry, 2007).

A large problem is that minority students and females experience high rates of attrition in completing college degrees in STEM (Elliott, Strenta, Adair, Matier, & Scott, 1996; Britner & Pajares, 2001). Although their interest in pursuing STEM exists, somewhere along their scientific development they are choosing not to complete their degree in this field. Girls outperform boys in science and show enthusiasm in it when
they are in middle school (Britner & Pajares, 2001), but by the time they get to high school and college, they begin to lose interest. Additionally, those that earn degrees in STEM do not necessarily pursue jobs in this field. In 2010, 50.3% of bachelor’s degrees in science and engineering were awarded to females. However, the females in the US who choose STEM based occupations account for less than 25% of the workforce in the field (The State of Girls and Women in STEM, 2013; Gonzalez & Kuenzi 2012). Females represent approximately 48% of the total workforce (Landivar, 2013).

One of the reasons being identified as a culprit for this vast underrepresentation in STEM is poor math and/or science self-efficacy (Lent, Brown, Sheu, Schmidt, Brenner, Gloster, Treistman, 2005). Self-efficacy (SE) is a specific measure of belief in an individual’s ability to complete a task and reach a certain goal. SE measures have been developed to predict performance in a particular area (Bandura, 2006). The way math or science SE impacts student participation in STEM fields needs to be researched more (Shaw & Barbuti, 2010). With an increased sense of SE, more people may feel confident enough to pursue this important field. Chemistry SE for instance, could influence a person’s decision to pursue a STEM degree and thus is important to measure early on (Villafane, Garcia & Lewis, 2014).

Introducing more virtual instructional methods could increase SE in chemistry (Meluso, Zheng, Spires, & Lester, 2012). There is a great deal of research that supports the educational benefits of using technology in and out of the classroom. Computers, phones or tables, for instance, could be used as tools to hone children’s creativity and curiosity. These devices have become a new universal method of communicating and learning (Jackson, Witt, Games, Fitzgerald & von Eye, 2012). Games have been tied with
improved visual-spatial skills, which are known to be important prerequisites for skills in STEM (Green & Bavelier, 2006; 2007). Virtual based learning environments have been shown to engage players, bolster self-esteem and are increasingly used to facilitate classroom instruction in particular domains (Przybylski, Weinstein, Murayama, Lynch, & Ryan, 2012). Computer-based simulations, for instance, have been shown to improve academic outcomes. Plass et al. (2012) found that introducing simulations to high school chemistry classes could result in better learning outcomes. However, there has been little research on how interactive simulations could influence SE. Inquiry based learning, the type of learning honed when using interactive simulations, has been found in at least one study to promote children’s realistic sense of self and to increase confidence in science because students are able to gain ownership over the task, face and overcome challenges (Brickman, Gormally, Armstrong, & Hallar, 2009).

Bandura theorized that SE beliefs determine how people behave, think and feel (Bandura, 2006). SE has fundamentally stemmed from Bandura’s triadic model of reciprocal causation (Bandura, 2006). According to the theory, three factors influence one another to varying degrees: behavior, environment and personal factors (i.e., affective and cognitive state). These factors are constantly interacting with one another and impact the way we respond to the world.

Females and minority students interested in STEM need better interventions to help them feel confident and succeed in science and mathematics disciplines. A central focus of this study is to increase SE in chemistry learning since SE beliefs heavily influence cognitive states and learning outcomes. Perhaps one solution worth exploring is to evaluate the effects of technology based learning for minorities and women’s
chemistry SE. Based on the need to increase representation in STEM, studying the impact of chemistry-based simulations could be worth exploring since these instructional methods have been previously shown to improve learning outcomes (Plass et al., 2012).

In order to more accurately assess SE in ideal gas laws, a task-specific scale in this discipline is needed to help us understand the relationship that SE has with ideal gas laws performance. Bandura (2006) emphasized the importance of using domain-specific scales that include items related to the specific topic of study. Since SE is a construct that varies between tasks and domains, task specific scales are required in order to give us information about the relationship between SE and the corresponding domain. Thus, an ideal gas laws SE scale was constructed for this study.

**Purpose of current study**

In summary, the current study validated two self-efficacy measures to assess whether they may be used in future studies. This study also used a computer-based simulation to assess whether this form of instruction could influence students’ feelings of SE in chemistry. SE beliefs in any particular area are largely influenced by prior achievement and mastery. Students who have low SE could benefit from engaging with a science simulation that will help promote understanding in that area of science. The current study investigated the impact of a simulation intervention since SE judgments may be largely influenced by: 1) prior experience with chemistry; and 2) experience/performance during the simulation.

In addition to investigating how using a science simulation impacts participants’ ideal gas laws SE, the current study assessed to what extent student responses on SE surveys will predict performance on a chemistry test. We also investigated how the order
a Chemistry posttest was delivered could influence SE beliefs in Chemistry. Whether or not a person had access to a Chemistry posttest immediately following a lesson was deemed an important area of investigation since individual SE beliefs could be influenced by how they believe they performed on a test. Gender and ethnicity were further explored assessing to how groups differ in feelings of chemistry SE.
CHAPTER 2

Review of Literature

Theoretical Perspective

Bandura (1986) explains that humans learning stems from a dynamic interaction between personal, environmental and behavioral influences. Social cognitive learning begins with humans observing one another. Based on these observations, people form their own perceptions and feelings about what was witnessed. In order for effective modeling to occur, the following factors must be present: the observer must be paying attention, recall what was observed, reproduce the behavior and be motivated to imitate the behavior. Triadic Reciprocality is the notion that 3 important factors: 1) personal (cognitions, feelings, biological events), 2) behavioral and 3) environment are constantly interacting with one another and changing the way learning occurs. One key characteristic of this theory is that cognition plays a central role in how we evaluate observations, self-regulate, recall and model behaviors. Another key component is that humans are active agents in control of their own development. The self-beliefs that humans develop will further influence behaviors, thoughts and feelings (Bandura, 1986). Thus, not only are humans influenced by their environment, they also heavily influence their environment.

This theoretical underpinning leads to the construct of “self-efficacy”. Self-efficacy (SE), is a “person’s judgment of their ability to organize and execute courses of action required to attain designated types of performances (Bandura, 1977; p. 391). Bandura’s social cognitive theory led to the development of the SE construct- that humans have a sense of control over their actions which further leads to [desirable] outcomes.
SE beliefs are heavily developed through various sources of environmental, personal and behavioral factors. Bandura (1997) argues that students form judgments about their own abilities through the following four experiential sources: mastery experience, vicarious experience, social persuasion, and physiological states. Mastery experience, the most influential source on cognitive ability, is determined by how one perceives his or her own previous performance in a particular area. Positive performance achievement in SE increases academic success and confidence while failure decreases it (Bandura, 1999).

Vicarious experience occurs when one sees another perform on a task and makes an interpretation about how this would relate to his or her performance. Primarily, students are influenced by others with similar abilities; seeing similarly skilled individuals supports them to estimate their own performance. Individuals who perceive others having a similar ability or background will benefit from vicarious experiences. This is especially important to note for individuals who do not see similar peers represented in a field (i.e., females in engineering or URM in STEM).

Social Persuasion occurs when others make verbal and nonverbal judgments about a person’s ability and performance, and this influences self-perception. Social persuasion can be constructive when goals appear attainable and it is powerful because of the influence it can have on positive beliefs. If social persuasion is negative, however, it can reinforce feelings of incompetence, discourage and negate SE and lead to academic avoidance or giving up too early. Instructors, mentors, parents and peers play a critical role in influencing students’ SE, as they are directly in contact with student’s academic performances. One example is how stereotype threat is tied to females’ ability in math.
EFFECT OF INTERVENTION ON SELF-EFFICACY

(Spencer, Steele, & Quinn, 1999). Social persuasion alone will not determine SE beliefs but will be important in influencing it.

Physiological states play a role in shifting SE. Students may refer back to the mental state they were in (affect, mood states), as they completed a certain task. This in turn, may influence their perception of how they believe they will feel when they perform this task in the future. When one is feeling tense and anxious while completing a math assignment, he or she may anticipate failure in the future when completing other math assignments. Another may anticipate success when they have previously felt positive arousal while completing the same activity.

According to Bandura, feelings of SE are formed through these four sources of SE. In sum, many factors influence SE such as personal view of abilities, previous successes and failures, the inherent difficulty of the task, the effort required to complete the task, the level of social support provided and the changing physiological states.

**Group Differences in Self-Efficacy**

It is important to note that Bandura’s four sources of SE seem to affect groups of people differently. Gender appears to influence how one draws from SE beliefs (Matsui, Matsui, & Ohnishi, 1990; Lent & Lopez, 1996). For instance, some research argues that females are influenced socially when developing their SE beliefs. Female SE stems more from the encouragement of others and from experiencing vicarious learning through females (Zeldin & Pajares, 2000). Sawtelle, Brewe, and Kramer (2012) found that success in a physics course was predicted by mastery experiences in males, and vicarious experiences in females. Similar research also confirms that males draw their SE beliefs more from previous successes (Zeldin, Britner, & Pajares, 2008). This information is of
interest in the current study because it could potentially help educators develop specific interventions for targeted groups of people. It could also help us understand why different groups of people respond differently to STEM disciplines. To date, no empirical research has investigated how underrepresented minority groups draw from the four sources of SE differently. Therefore, for the purpose of the current study, there is a necessity to understand the extent to which sources of SE in chemistry affects people of various backgrounds in different ways.

It should be noted that other constructs (i.e., grit, persistence) also contribute to success in academics and have been recently studied. Grit, a construct defined by Dusckworth et al. (2007), is a trait level measure of one’s perseverance, persistence and passion for long-term goals despite the presence of failure and adversity. Persistence is the ability to overcome obstacles that are in one’s path and continue to pursue one’s goals. Dusckworth and colleagues argue that grit is a characteristic that all successful people hold and is even more important than IQ. Since the construct has been established, grit has been shown to be predictive of undergraduate GPA and choice in pursuing higher education (Duckworth et al., 2007; Duckworth & Quinn, 2009). Grit-based interventions could also potentially be used to promote success in STEM and should be compared to SE in future studies.

**The Relationship Between Self-Efficacy Beliefs and Learning**

Many researchers have recently studied the impact SE beliefs have on learning. Instruments used to assess SE are composed of questions that ask respondents to rate their confidence in their ability to complete something specific (i.e., Chemistry Homework SE). Countless research studies have emerged indicating a strong
relationship between SE and academic success. SE may serve to mediate the relationship between students’ learning environments and their achievement (Moriarty, Douglas, Punch, & Hattie, 1995; Bandura, 1997). It is a significant area of study in education because it has been shown to be a robust predictor of academic behaviors throughout different phases of school. Some of these academic behaviors influenced by SE include effort (Schunk & Zimmerman, 2006), use of cognitive strategies (Zimmerman, 2000), academic success and persistence (Lent, Brown, & Larkin, 1986).

Britner and Pajares (2006) found that self-efficacy beliefs were the only motivational variable that predicted science achievement in middle school students. Chemers, Hu, and Garcia (2001) found that students with high academic SE perform better academically, have better personal adjustment and are healthier during their first year of college. In a meta-analysis conducted by Robbins, Lauver, Le, Davis, Langley and Calrstrom (2004), academic SE was found to account for about 14% of variance in college GPA. Robins et al. additionally found that academic SE predicts college student retention more than traditional predictors, such as high school GPA and SAT scores. Torres and Solberg (2001) also found that academic self-efficacy is positively associated with the amount of time students’ study at home. Caution should be taken when reading about SE literature as measures begin to lose their predictive value when they are treated as a general measure rather than as a task-specific measure (Bandura, 1997; 2006).

To be effective, SE must work together with skill, aptitude and motivation to ensure success in a task. A learner must have a basic level of skill and interest in the task in order to have an improvement in SE (Betz & Schifano, 2000). The reciprocal nature of SE and performance is such that if a task is performed well by someone, their SE for that
task will be improved. If the performance for that task continues to be successful, challenging tasks will be welcomed. If challenging tasks are performed well, SE will continue to improve for that set of tasks (Beier & Rittmayer, 2008).

The most useful form of SE judgments occur when individuals slightly overestimate their abilities (Pajares, 2009). This fosters students’ ability to envision their outcome expectations so they are strong enough to overcome adversity. A balance, however, is needed between SE and performance. If there is an under or overabundance of SE, this could negatively impact future performance. An overabundance of SE in a student who earned a low grade will lead him or her to attribute the low grade to external factors (poor teaching) instead of ability (Pintrich, 2003; Vancouver & Kendall, 2006). A deficit of SE may prevent a student from studying because he or she may start off having a negative feeling about performance on a test. When a low grade is confirmed, SE continues to plummet and tasks will be further avoided (Eccles, 1998; Pajares, 2005, Beier & Rittmayer, 2008).

SE beliefs could influence thought processes, attitudes and actions (Bandura). Collins (1984) found that children who had a stronger sense of math SE were better at reworking problems that they did wrong and were more persistent in finding the answer. They were more likely to perform better than children with the same skills who had weaker math SE and self doubts in doing the problems. Collins also found that having a strong sense of SE was better at predicting positive attitudes towards math than math ability. Children who performed poorly and viewed ability as fixed and inherent experienced more problems. Performing poorly in their mind had to do with a lack of
intelligence over lack of effort/practice. On the other hand, children who viewed ability as an acquirable skillset saw failure as an opportunity to learn and try harder.

When a student attributes success to his or her own ability, it could be seen as internal, stable and controllable. When one attributes failure to something like bad luck, it is perceived as external, uncontrollable, and unstable. Wood and Bandura (1989) tested how students’ self perception influences their thought processes and actions. In the first group, the researchers told the students that the task required an inherent intellectual capacity. The second group was given the same task and told that with enough practice the task could be completed, and being successful did not have anything to do with having inherited intelligence. The students in the first group who experienced difficulties, had low SE for completing the task. Their analytical thinking was also adversely affected. The students in the second group faced challenges but gained a higher, resilient sense of SE. These students were better at using strategies to complete the task.

In sum, SE influences the course of action one takes relating to that task/goal and outcome expectations. SE impacts other cognitive and behavioral processes that all work toward achieving a task or goal. These feelings help individuals work toward proximal goals (doing well on homework, doing well in classes) and this helps them achieve end goals (choosing a degree in a specific area) (Bandura, 1991). Regardless of the type of personal goal (whether to do well in their chemistry course or to complete a triathlon) SE works in the same way.

Individuals with high academic SE will place more effort in learning, view complex problems as challenges to be mastered, are more persistent, bounce back quicker from roadblocks and form a commitment to the task. They choose self-regulatory
strategies to enhance the learning process and achieve more than those with lower SE (Bandura, 2001; 1986, Pajares, 2005; 2000; Zimmerman & Bandura, 1994; Zimmerman, 2000; Schunk & Meece, 2006). When students have better self-regulatory strategies, they are better about solving problems and managing the time they have (Pajares, 2005; Zimmerman, 2000). Positive feelings of SE, motivation, performance and outcome monitoring must all work together for students to be successful in school.

Students who have strong feelings of SE also have greater feelings of self-confidence and are more likely to opt to have more responsibility in completing a task (Zimmerman & Kitsantas, 2005). Students with strong SE are more likely to enroll in courses that are challenging. This is because they view the difficulty of the courses as a challenge rather than a threat. Such students have a higher internal locus of control and attribute failures and successes to things that are in their control, such as [in]adequate studying (Chan & Lam, 2010). For people who have limited experience in a certain task, watching others complete the task will affect their own SE for the it – this is the information that people use to assess their own performance in that task (Huang, 2013).

Students with low SE may focus on previous experiences of negative outcomes and avoid tasks they find to be too challenging. They may feel less confident in their ability to complete the given task and feel threatened by difficult tasks (Margolis & McCabe, 2006). They often inaccurately perceive a task by exaggerate the difficulty and avoiding it all together (Britner & Pajares, 2006). This will lead to feelings of learned helplessness and creates a negative thinking pattern. SE beliefs influence affective state when completing the task/goal. Feelings of low SE are linked to vulnerability, anxiety and depression (Bandura, 1993). Students who have a low academic SE could be more
prone to experiencing anxiety in school. Previous academic failure may have a great deal to do with academic stressors and anxiety (Bandura, 1993). High anxiety is associated with poor SE and outcomes associated with the task (Bandura 1977, 1986, Huang, 2013).

Therefore, since SE is a critical topic in the area of educational psychology and we need a deeper understanding on the role that SE has in STEM education, the current study will address the important issues relating to Chemistry SE, women and underrepresented minority students.

**SE Measurement Issues**

Although self-efficacy is a broad concept, it is important to clarify that certain scales are more useful than others in predicting academic performance in a particular domain of interest. Many types of SE scales exist in the literature ranging from general SE, academic SE to domain or task specific SE scales. An abundance of research studies have used general SE scales to measure SE. Many of these scales were used to predict performance in GPA (Maropamabi, 2014), college outcomes (Lindley & Borgen, 2002) and course grades (Bong, 2001). However, researchers leading the field report that these studies have mis-measured SE because global SE judgments weaken the effects of the construct (Pajares, 1996; Zimmerman, 1996). Not surprisingly, these general SE measurements were either weekly correlated or not significantly correlated with the outcome variable (i.e., a weak correlation was reported between general SE and GPA \( r = .013 \) [Maropamabi, 2014]). Although academic SE seems to be more related to the outcome variables for which it is measuring (i.e., GPA) (Brown, Lent, Larkin, 1989), it is still too broad to determine its predictive value on a specific domain.
General SE is more limited in predictive power because it cannot generalize to all other domains and skills (Pajares, 1996). Bandura argued that during scale construction, precision must be made when measuring variables and items should include more narrow, pointed and task specific questions. SE scales that fail to include questions within the domain of study, will not yield in a predictive relation. One can argue that the general SE scales and academic SE scales are missing key information that about a student’s confidence in specific areas of study. Efficacy beliefs may vastly vary from task to task. For instance, individuals may excel in certain areas of their academics but not other areas. Results from an academic self-efficacy scale may not be an appropriate tool used to predict how an individual believes they would perform in ideal gas laws of chemistry. Or, even more specifically, a student may feel confident in their ability to learn chemistry in lecture but not in chemistry lab. Using these general scales could introduce a great deal of statistical noise and will not be useful in telling us about how one feels about their ability to complete a specific task in chemistry. Thus, it is important to use task-specific SE measures rather than general SE instruments to evaluate the predictive nature of the construct.

General SE is valuable tool that could be used in conjunction with task specific scales since it serves more as a trait-like belief in one’s global competence (Scherbaum, Cohen-Charash, & Kern, 2006). It is likely that a person’s perseverance in academics could be linked to their ability to perform a task successfully, but not always probable.

A paucity of chemistry SE scales exist and of the studies that have been published, most of the items constructed in the surveys included general chemistry questions such as, “How well can you choose an appropriate formula to solve a chemistry
problem” or “How well can you collect data during the chemistry lab” (Uzeuntiryaki & Aydn, 2009). There is a need to develop SE surveys to measure a specific topic in chemistry SE such as the research of Merchant et al (2012) “I can characterize a molecule or ion as obeying or disobeying the octet rule” OR “I can explain the differences in physical properties between iconic and covalent substances. To date, no such ideal gas laws SE scales exist in the literature. Therefore, we need better ways of measuring ideal gas laws SE. Introducing and validating a new scale for the purpose of the current study could contribute to the literature on SE in Chemistry.

The Development of Self-Efficacy

Age related changes. A person’s self-perception shifts throughout development based on different experiences and reactions to those experiences. Young individuals are able to see themselves through a more abstract lens (Harter, 1998) and develop a more complex understanding of their own identity. As a result, feelings of competency and SE often decline as children move from elementary to middle school- especially in mathematics [Jacobs, Lanza, Osgood, Eccles, & Wigfield, (2002); Schunk & Meece, (2006)]. One reason posited for this change is that elementary and middle school children have learning environments that lead to different goals. In middle school, competition and ability differences are more emphasized and as a result, normative evaluations are valued more than individual mastery (Schunk & Meece, 2006) often leading to feelings of low SE. Environments that emphasize collaboration, effort and self-improvement typically lead to feelings of higher SE (Anderman & Midley, 1997; Anderman & Young, 1994; Greene, Miler, Crowson, Duke & Akey, 2004, Meece, 1991; Meece, Herman, & McCombs, 2003; Urdan & Midgley, 2003 as cited in Schunk & Meece, 2006).
**Home Influence.** SE is strongly influenced by how children are raised at home. Parental expectations about their children’s ability to complete tasks/goals are predictive of their children’s SE (Vekiri & Cronaki, 2008). Parents who provide a challenging environment with obstacles are enhancing and stimulating their children’s cognitive development and self-esteem. Providing such an environment fosters children’s ability to achieve small goals and persist even in the presence of hurdles. Some research has shown that parents who are involved with their children’s schooling have kids with higher scores in math (Sheldon & Epstein, 2005), better GPAs (Lee & Bowen, 2006), higher scores on standardized tests (Jeynes, 2005), and positive attitudes about school. However, the research on parent involvement seems to be complex. Two separate meta-analyses (Jeynes 2003; Jeynes, 2007) revealed that parental involvement was positively related to academic achievement for African American students, and for urban secondary students, respectively. Parents who involve their children in parent-child discussions (i.e., talking regularly about the importance of school) have more of a direct impact on their children’s achievement (McNeal, 2014). Similarly, parents who actively monitor their children’s academic progress (homework; helping plan their curriculum) are also influential in their children’s academic success, regardless of SES, gender and ethnicity.

Parents’ beliefs also directly and indirectly influence their children’s choice in their career. For instance, mothers who believe that their children will be successful in math will impact the choices their children make in choosing careers related to that field (Bleeker & Jacobs, 2004).

**School Influence.** Friends/Peers play a large role in shaping students’ SE in middle school and high school because they become more influenced by their peer
groups during this phase (Schunk & Miller, 2006). They have larger peer networks and tend to choose friends who are similar in regard to learning (Schunk & Meece, 2006). When students observe similar role models completing a task successfully, they feel that they can achieve the same task or goal.

Students are also receptive to the performance feedback they receive from their teachers and peer group. Instructional feedback is useful in helping shape students SE (Pintrich, 2003). Schunk and Lilly (1984) found that when students were provided with performance feedback, there were no gender differences with their SE or the task outcome. Another method that fosters students SE in middle school is the introduction of self-regulatory strategies (i.e., setting proximal goals vs. end goals) (Zimmerman & Kitsantas, 1996). Self-regulatory strategies are useful because they guide students to take ownership over the tasks by providing them with setting specific goals and strategies (Schunk & Meece, 2006). These strategies will hone students’ ability to achieve mastery over the material particularly in a way that could help them achieve short-term goals.

Schunk and Meece (2006) also argued that the type of instruction can impact children’s development of SE. This includes an emphasis on competition or cooperation, the type of assessment used and the manner in which they attend to the students. Computer-based simulations could serve as potentially valuable resource for students tapping into their SE beliefs. Students could better gage their performance due to the nature of the feedback such programs provide. Therefore, this study could address the extent to which simulations play a role in student’s ideal gas laws SE.

**Self-efficacy in science**
The amount of students who are enrolling in Science, Technology, Engineering, and Math (STEM) disciplines is declining according to the United States Government Accountability Office (2006). The US Education Departments National Center for Education Statistics (2014), reports that about half of the candidates in STEM leave this field before they complete a degree. Ost (2010) found that STEM students are often drawn towards non-science majors where they are more likely to receive better grades. They feel discouraged from completing these degrees when they fail introductory courses in STEM. Ninety eight percent students who leave science and engineering majors say that they decide to drop out because of “poor teaching by faculty”, and 86% of those who stay also agree with that statement (Seymour & Hewitt, 1997). Combined with low scores and poor teaching, students often experience a loss of self-confidence and drop out of the programs (Brainard & Carlin, 1998)

A central thesis in the proposed research study is improving students’ SE in STEM with a particular emphasis on using a chemistry-based simulation. There is a paucity of research that investigates chemistry SE. Chemistry is a required course in STEM track degree programs and could potentially impact a person’s decision to persist in this area. General chemistry, a course usually taken in the first year, is often viewed as a difficult “weed out” course (Porter & Fuller, 1997). Chemistry is important because the concepts learned from this area are essential for advanced STEM courses. Chemistry requires skills that draw from verbal, quantitative and spatial reasoning (Halpern, 2007). Research has found that chemistry SE was the best predictor of course performance in chemistry (Zusho, Pintrinch & Coppolla, 2003). Having high academic SE relates to academic success in school and this could lead to future success and interest in STEM
EFFECT OF INTERVENTION ON SELF-EFFICACY

(O'Brien, Martinez-Pons, & Kopala, 1999). High math or science SE also mediates choice and commitment to pursue a STEM major in the presence of challenges (Lent, Brown, Brenner, Chopra, Davis, Talleyrand, & Suthakaran, 2001). Therefore, we need more research studies that address students SE in Chemistry to learn more about how student’s feel about their capability to perform in this domain.

Females and minority students are an underrepresented population particularly in STEM and these groups will be of particular focus in this proposed research study. It is possible that the reason behind this underrepresentation in science is that these two groups do not believe they are skilled enough to pursue STEM careers. As summarized above, many factors contribute to the development of SE. If an individual believes that they are not skilled in a task or content area, they will not continue to pursue the necessary steps to completing that task (Zimmerman, 1995). Some research has investigated how females and underrepresented minorities self-perceptions and/or SE could potentially impact their decision to choose STEM as a career. This area of research will be reviewed below.

Female self-perception in STEM. The Organization of Economic Corporation and Development administered a science test to 15 year old girls and boys in 65 developed nations (Fleischman, Hopstock, Pelczar, & Shelley, 2010). They found that on average, girls outperformed boys in this test, but in the United States, Canada and England, the reverse was true. It is no surprise that females do not have as much confidence in their ability to do well in math and science in the United States (Meece & Jones, 1996).
There is a large gender gap in the United States with regard to women entering STEM track degree programs. Somewhere between elementary school and adulthood, females are choosing to opt out of these career paths. There are no universally recognized biological differences between males and females in their ability to perform well in math and sciences (Hyde, Lindenberg, Linn Ellis, & Williams, 2008; Nosek et al., 2009). However, boys consistently perform better on tasks that require spatial reasoning while girls perform better on tasks that require writing skills (Halpern, 2007). According to a meta-analysis, although females are just as talented in math as males, they are less confident and motivated in their ability to pursue these areas in the US (Else-Quest, Hyde, Linn, 2010). Spelke and Ellison (2009) argue that the main reason for the gender gap in science and math is social and historical. Males have traditionally been encouraged more than females to participate in science and math related fields (Fox, Tobin & Brody, 1979). Society has demonstrated an overall male perception of science and math being “an inherent masculine worldview in scientific epistemology” and this may deter females from moving further along in their career in science (Blinckenstaff, 2005). This overall perception starts with child rearing. Parents have been shown to have lower expectations of their daughters over sons in math and science and attribute their daughters’ successes to effort and their sons’ successes to innate ability (Furnham, Reeves, & Budhani, 2002).

In the US, data has shown that girls believe that they are less academically skilled at science and math than males (Stout, Dasgupta, Hunsinger, & McManus, 2011). Since 1972, boys have been scoring higher on the SATs than girls. The College Board released their 2013 results that high school boys outperform girls with a 32 point advantage.
Basic math and science knowledge is needed in order to continue on the STEM career path. As women enter college, they observe fewer females taking advanced math and science courses. This could influence their sense of belonging in those fields (Stout, Dasgupta, Hunsinger, & McManus, 2011). As a result, females who do not have confidence in their skills in math or science because of cultural stereotypes are much less likely to pursue classes/degrees in STEM (AAUW, 2010).

Social support systems seem to be a critical element needed for females to get through STEM degree programs. Some research argues that females are more driven to continue pursuing STEM through vicarious learning experiences and the social persuasion of others (Zeldin & Pajares, 2000). Zeldin and Pajares found that girls who observed other females be successful in STEM, and who also received encouragement to continue on with the field were more likely to progress in that area later in life. Early learning experiences are critical for females and their development of a strong SE towards a career. When girls have encouragement in the form of female role models, it is more likely that they will feel more confident in their ability to succeed in these areas.

Although the gender gap is narrowing between males and females entering STEM disciplines there are still less females completing the degrees (NSF, 2013) and entering the STEM workforce. Research has revealed that males and females do not have equal access to courses preparing for STEM (Enman & Lupart, 2000). Women do not have equal opportunities to the same employment positions as men. Moss-Racusin, Dovidio, Brescholl, Graham, and Handlesman (2012) found when science faculty were seeking a person to fill a laboratory manager position, they rated males applicants as more competent and eligible for the position than female applicants with exactly the same
content on their CVs. They also offered males a higher starting salary and more mentoring opportunities. With the lack of social support in our culture, it is no surprise that females feel intimidated to commit to science-based careers (Sonnert, Fox, & Adkins, 2007).

Females who were successful with pursuing science in college and having a career in STEM had high math grades in high school (Camp, Gilleland, Pearson, & Putten, 2009), high college entrance exam scores (Fassinger, 1990) and high college GPAs. More importantly, these females had higher aspirations to pursue STEM prior to entering the intense course sequence that many degrees require. “Grit” research studies argue that interest, engagement and perseverance will have more to do with success than actual ability (Duckworth, 2007). Females who do not believe in their capability to achieve goals needed to be successful in STEM education, could dismiss pursing the field (Beier & Rittmayer, 2008). For instance, Clewell (2002) found that although males & females perform the same in science in middle school, females begin to lose interest in math/science as they get older. By the time they complete middle school, twice as many boys demonstrate an interest in STEM. Consequentially, this lower sense of science SE and lack of interest will prevent girls from pursuing a STEM career path down the line (Bakken, Sheridan & Carnes, 2003; Zeldin & Pajares, 2000).

According to three separate meta-analyses that looked at gender and the effect it has on SE, academic SE for males is higher than academic SE for females (Huang, 2013, Wilgenbusch & Merrell, 1999; Whiteley, 1997). Females reported higher SE than males in language arts while males reported higher math, computer and social science SE (Cassidy & Eachus, 2002). In STEM, males appear to have higher STEM SE and are
more likely to enter careers in STEM and become successful in their field (Schunk & Pajares, 2002).

Some argue that girls do not pursue majors and careers in STEM because of low SE in STEM (O’Brian, Martinez-Pons, & Kopala, 1999). Gender influences STEM SE as students progress through school - these differences intensify once they get older (Huang, 2013). Huang’s meta-analysis revealed that gender differences in academic SE were the highest when people were in high school and then again when they reached adulthood. In elementary school, there do not appear to be any gender related differences in students’ math SE (Pajares, 2000). The research seems to be less clear for students in middle school. Pajares found that gender differences begin to reveal themselves in feelings towards math, with boys having an advantage. Britner & Pajares (2001) found that girls in 7th grade have higher SE in science and self-regulation than boys. However, other researchers found that these SE differences did not yet exist in middle school (Friedel, Cortina, Turner & Midgley (2007); Kenney-Benson, Pomerantz, Ryan, Patrick, 2006).

The research paints a clearer picture for students’ SE in high school and beyond. Gender differences in traits, attitudes and achievement in math/science become more prominent as youth get older and the curricula become more challenging (AAUW, 1994; 1991 Hackett, 1985; Post-Kammer & Smith, 1986). The gender gap continues to widen and females have lower SE in classes that prepare for STEM fields. Fewer females enroll in courses that are more demanding. Males are more likely to choose advanced courses in math and sciences and by the time they enter college, gender differences become much more prominent in terms of choice in major (Nosek et al, 2009). Females who enrolled in STEM track undergraduate programs, reported feeling more intimidated by math and
science and were more willing to give up earlier when they were unhappy with the program of study (Hewlett et al., 2008, Frehill, Brandi, Di Fabio, Keegan, & Hill, 2009). O’Hare (1995) found that females reported having high self-esteem and confidence just before entering degree programs in engineering. However, during the first year of their academic career, their self-confidence and SE declined and never returned to the same beginning level. Females were more critical of themselves than males in these programs. Researchers found that they would drop out of the discipline as soon as they failed the course, yet males would opt to retake it and continue on the track (Marra & Bogue, 2006). Females are more likely to give up even when their performance is the same as their male peers (Brainard & Carlin, 1998; Jackson, Gardner, & Sullivan, 1993).

**Nuances in Gender Differences in Math and Science.** Gender differences in achievement in math and sciences in US are complex and there is not one answer that explains why boys outperform girls in math and science domains. It is important to note nuances in gender differences in these domains because population averages may lead to conclusions that are not accurate (Halpern, 2007).

Some research has shown that there are differences between male and females ranging from innate to sociocultural factors. Taking into account how genetics shape differences in academic performance, males have been shown to have an advantage with tasks that require visual-spatial skills as early as infancy (Moore & Johnson, 2008). Females on the other hand have demonstrated vast advantages with tasks that require verbal skills, specifically writing (Strand, Deary, & Smith, 2006). Gender differences in math ability are more nuanced as students move along the academic continuum. Females tend to do better during early school years in tasks that require computation problems.
For instance, females performed better on solving math problems that require using conventional computation methods (Gallagher, De Lisi, Holst, McGillicuddy-De Lisi, & Morely, 2000). Males begin to perform better in secondary school with math courses that requires spatial reasoning such as calculus and geometry (Geary, 1996; Hyde, Fennema, & Lamon, 1990). For instance, boys were better with obtaining data from vertical or horizontal graphs (Lowrie & Diezmann, 2011).

Taking into account how sociocultural factors interact with gender in math and science performance, boys seem to be more influenced by their neighborhood environment. Comparing to girls, boys will benefit more from enriched environments but will suffer more from poor neighborhoods (Entwistle, Alexander, & Olson, 1994). Historically, teachers have treated males and females differently in science and math classes— they encourage boys more than girls to ask questions and elaborate on concepts being addressed in class (AAUW, 1995). Investigating the nuances further between male and female math/science performance, it is important to note that there are less gender differences in these areas for students with mid range abilities. The largest gender differences are seen at the upper and lower tails of the distribution for quantitative and visuospatial tests (Humphreys, 1988). One example of this is that males are up to four times more likely than females to perform 700 or higher on the quantitative portion of the SAT (Halpern, 2007). Females on the other hand, perform better in math and science classes and high school entrance exams (Halpern, 2007). Therefore, this study would be valuable because it could inform us on how female’s perception about ideal gas laws aligns with their performance in this area. Further, as mentioned above, there appears to be a disconnect between how females perceive their ability to perform in STEM-based
disciplines and how they actually perform in these areas since there is no evidence that they are less skilled than their male counterparts. Administering a Sources of SE questionnaire could be valuable in that it could help us understand where are females drawing their SE beliefs. Perhaps this could help us design better interventions targeting areas that women need support in (i.e., more support in university departments). Thus, it is important to investigate these gender nuances further and see what role sources of SE plays in this disconnect.

**Underrepresented Racial and Ethnic Groups in STEM**

**Minority graduation rates in STEM.** The US Department of Education (2007) reports that the population in the United States is becoming very diverse and the minority population is growing faster than the White population- this trend is expected to rise quickly so that by 2050, 50% of the US population will be in the “minority” (Minority Access to Education) with ALANA (African American, Latino, Native American and/or Southeast Asian [Cambodian, Vietnamese Hmong, and Laotian]) groups to account for the largest growth in the workforce in the next ten years (Fullerton & Toossi, 2001).

URM students have exhibited differences in academic achievement over students who are White or Asian American starting early in school (Brooks-Gunn & Markman, 2005). Latinos for example are one of the fastest growing populations yet they face many academic barriers leading them to hold only 13% of bachelor’s degrees (Census, 2012). Since 1972, they have been the group with the highest high school dropout rate and are much more likely to live in poor areas (National Center for Education Statistics, 2013). Coming from a low SES background is a substantial risk factor for low academic achievement. URM students are much more likely to come from families of lower SES
are thus, less likely to major in STEM than students who come from higher SES backgrounds (Shaw & Barbuti, 2010). They face numerous obstacles in completing a high school degree and experience significant disparities in STEM employment (Landivar, 2013).

There is a paucity of research that investigates the relationship between minority students and SE, particularly in STEM education. Perry, Link, Boelter, & Leukfeld (2012) looked at middle school students’ SE in science and found that in general, White students had a stronger SE for completing the course than African American students. Upon further investigation, they found that Latino and African American females had more confidence than their male peers. Britner and Pajares (2001) assessed middle school science students’ SE and found that White students had stronger science SE than African American students.

A small number of minority students are showing interest in taking STEM related courses in high school. For instance, African American students are less likely than White students to enroll in classes in high school that calls for high level mathematics (Davenport, Davidson & Kuang, 1998). Low math scores could negatively influence college admissions (Cooper, Cooper, Azmitia, Chavira, & Gullat, 2002). Low achievement in school is detrimental for future college admission and success in the workforce. Low achievement and attendance in school could lead to early high school dropout. High school drop outs are more likely to commit crimes and end up in the juvenile or criminal justice system (American Civil Liberties Union, 2008) ALANA students have the highest rates of high school drop out and the lowest rates of college
graduation consisting mostly of people who are Latino and African American (National Center for Education Statistics, 2013).

A meta-analysis investigated whether membership in an ethnic group negatively influences career goals and vocational interest- the findings revealed that there were no statistically significant differences between racial groups and career goals (Fouad & Byars-Winston, 2005). ALANA students in their first year of college have the same intentions/interest in pursuing STEM majors (Astin, 1996; Morning & Fleming, 1994) however by the 6th year of school, only 29% of the original ALANA STEM majors end up completing their degree in that area (Hayes, 2007).

Though URM students might be interested in studying STEM in their academic career, they immediately start off with barriers/disadvantages over their non-minority peers. URM students typically have less access to resources that would help them achieve in school including less access to technology, less qualified as well as less experienced teachers, and worse programs (Meece & Kurtz-Costes, 2001). Many of these schools have a high staff turnover rate, larger class classes, less advanced classes, less educational supplies (Minority Access to Education, 2008). Additionally they attend underfunded schools, have fewer opportunities to move forward in Science class – AP classes and teachers with little to no training (Darling-Hammond & Post, 2000). About 50% of the students in these schools graduate with a HS diploma and those who do graduate are unprepared for college. Taking all of the above findings into consideration, we need to investigate more about STEM SE in minority students. This study would be valuable because we know that there is a vast underrepresentation of minorities who are leaving STEM disciplines yet there is little research on how these groups of individuals feel about
their ability to complete tasks in Chemistry. Further, there is not a clear set of research studies that investigates how minority students’ level of confidence aligns with their performance in Chemistry. There is also little research on how these groups of students draw their sources of Chemistry SE. Thus, this study could inform us on whether there are differences that should be addressed and determine whether future interventions should target areas of needed support.

**Metacognitive effects of Test Taking**

Another area of interest for this study was to investigate how taking a chemistry posttest following a lesson could influence SE responses after a test. As discussed in the literature review above, when establishing SE in a particular domain, adults typically draw from previous mastery experiences to assess their confidence on how they will perform on similar subsequent tasks. A theoretical concept called “metacognition” signifies an individual’s awareness of his or her own knowledge along with their ability to control their cognitive processes (Miechenbaum, 1985). These two important theoretical constructs seem to complement one another in educational research. One important example of mastery experiences, as defined by Bandura’s sources of SE, is engaging in quizzes and tests. Individuals will often use these specific experiences of test taking to control their metacognitions (Finn & Metcalfe, 2014). Even if individuals are not aware of scores they received during a test, they may have a mental representation on what items they answered correctly vs. incorrectly. There numerous benefits associated with taking quizzes and tests in class for students and teachers alike. Test taking is particularly important because it enhances learning, retention and helps students apply concepts to similar novel areas of study for summative assessments (Nguyen &
McDaniel, 2015). Additionally, students who frequently are assessed report a better understanding of the topics of study. As a result, their metacognition is improved and they can adjust their study habits (McDaniel).

To date, no research has investigated how test taking following a lesson could influence (positively or negatively) SE in chemistry. Given the above findings on the importance of student test taking on learning, we need to address to what extent test taking influences SE. It would be theoretically important to see whether viewing a test immediately following a lesson could change the way one perceives their ability to complete similar future tasks.

**Interventions in Improving SE**

Some research has focused on finding interventions that improve students’ science SE in various domains. Many of these studies looked to use interventions to improve student’s mastery experiences.

Bakken (et al., 2010) looked at how providing novice female biomedical scientists of diverse racial backgrounds with a SE enhancing intervention would effect their research efficacy beliefs. The intervention consisted of a workshop that worked to enhance mastery experiences, vicarious learning, social persuasions and physiological responses to research. After receiving the intervention directed at these sources, participants’ research SE significantly increased post intervention. In short, these interventions were successful at improving female scientists SE in conducting biomedical research. More SE programs should be implemented to increase students’ confidence in their ability to be successful in STEM education.
Research consistently demonstrates that providing opportunities for performance accomplishments in a task/goal is the most useful in promoting feelings of SE. This is because they provide students with proof of mastery experiences (Cheung, 2015). Luzzo, Hasper, Alber, Bibby, and Martinelli (1999) found that students’ math SE was improved after receiving positive feedback. When students received a passing score (regardless of actual performance) for a challenging number series task that was a test of their abilities in math, their SE improved. Students had more confidence in their ability to earn a B at math or science than those who did not get to see their results on a test. Additionally, they maintained this sense of SE one month later. Mastery experiences, interest and effort were most useful in improving math and science SE.

Schultz et al. (2011) conducted a longitudinal study and found that URM students who were enrolled in the Research Initiative for Science Excellence were more likely to pursue a career in STEM than their non-URM counterparts. The key finding was that improving mastery experiences through conducting undergraduate research was much more valuable than having a mentor. The more exposure students had to undergraduate research provided them with more opportunities for mastery, and sustained their interest in STEM. Student interest and intention lasted beyond the program, and they were more likely to view themselves as “scientists”. Sadler, Burgin, McKinney, and Punkuan (2010) conducted a meta-analysis from 53 studies that looked at how research apprenticeships influenced attitudes in science and SE and found that these programs were effective in enhancing students’ SE in science. Wessley et al. argue that an important factor in minority students succeeding in STEM programs is to identify themselves as scientists. This might explain why they continue to sustain interest in STEM. Mastery learning
goals that were emphasized in schools were strongly related to African Americans' feelings of belongingness, self-esteem, and academic performance (Kaplan & Maehr, 1999).

Because improving mastery experiences in STEM is essential in influencing STEM SE and ultimately STEM performance, teachers should emphasize more interactive, challenging activities in science class (Beier & Rittmayer, 2008). Taken the above findings, we need better interventions that will improve students’ mastery in science since it is agreed upon that mastery experiences can improve SE (Schultz et al., 2011). In the current study, computer-based simulations could prove to be a valuable resource for students because such programs provide a challenging yet interactive environment.

Chemistry and SE

Some research has investigated the relationship between chemistry and SE. Villafane, Garcia, and Lewis (2014) measured chemistry college preparatory students’ SE beliefs multiple times within a semester. The results indicated that at the beginning of the course, students were not confident in their ability to apply chemistry theory to a variety of tasks. By the end of the semester, they found that students’ confidence increased overall. They also found that the experience for students differed by racial/ethnic group. Prior to the course, Black and Hispanic males experienced overconfidence in chemistry SE beliefs but by the end of the semester, their SE beliefs were the lowest. Perhaps the classroom experiences these students had during the course of the semester influenced their perception on learning chemistry. Dalgety and Coll (2006) measured first year chemistry students’ SE three times throughout the semester. They found that in general, the students progressed in confidence by the end of the semester. After the course was
complete, students felt less confident about tutoring a first year in chemistry and less confident about proposing a meaningful question that could be answered experimentally. Males were more confident about theoretical knowledge and applying it to a problem. Females were less confident in the beginning of the course, but felt more confident by the end of the semester. Qualitative data also found that females had overall lower chemistry SE. The study however, did not factor students who dropped out of the course and this could have influenced the composite scores.

Zusho, Pintrich & Coppola (2003) similarly studied college students’ chemistry SE, how it varies over the course of the semester, and how SE relates to chemistry course achievement. They found that on average, SE declined throughout the semester. They also found that SE was the best predictor for final course scores even after they controlled for prior achievement. The changing nature of SE may have more to do with the teaching style, the classroom environment, the quizzes and exams. These studies show that chemistry SE is adaptable and may be influenced more by continuing personal experiences than previous experiences.

Wilson, Bates, Scott, Painter and Shaffer (2015) looked at differences in academic and general SE among over 600 underrepresented minorities, women and majority students in STEM fields. Wilson and colleagues collected data from 2nd through 4th year students enrolled in STEM fields at two universities. Women reported overall less academic SE compared to their male peers. The strongest difference between men and women was in chemistry and math. The authors found this surprising as chemistry and mathematics are more gender-equalized disciplines than other STEM disciplines such as physics. Academic SE was the lowest for both men and women in chemistry and
mathematics over other disciplines. Women also reported lower academic SE in computer science and engineering. When comparing race and ethnicity, they found that African American and Hispanic students had significantly higher general SE compared to Caucasian and Asian peers. African American, Hispanic and Caucasian males had similar academic SE across disciplines. Asians across all disciplines reported the lowest academic SE over all other ethnic groups. Though this study provides some insight on population differences in SE, it only investigates general and academic SE measures which provides less generalizability about people and their relationship to their respective STEM discipline. Taken the above findings, research on further investigating chemistry SE is needed because of the small number of research studies addressing this important topic. Further, it is important to investigate how URM groups and women are performing on these domain specific scales because of the need for more of these groups of people to join STEM based disciplines.

**Technology Intervention and Self-efficacy**

To address the problem with attrition in STEM, the Association of American Universities has announced an initiative that will encourage faculty members in these fields to use more interactive teaching methods in their classroom (Toiv, 2014). Video games, computer applications, platforms, websites and simulations could be some of many ways used to increase learning outcomes and promote interest and SE in STEM fields (Meluso et al., 2012). Some educational games and simulations enable the user to dynamically manipulate and gain control over the learning environment. A person’s perceived ability to interact with their learning environment can be a critical element in influencing SE (Merchant, 2012; Bandura, 1993). Games and simulations have been
viewed as important tools for building 21st century skills because they prepare students for real-world scenarios. Educational games in STEM could positively change the way the disciplines are being taught by improving performance on problem solving tasks and promoting stronger connections to science (Spires, Rowe, Mott, & Lester, 2011).

A computer simulation is “a program that contains a model of a natural or artificial system or process” according to de Jong and van Joolingen (1998). The authors add that simulations are divided into conceptual models (concepts underlying the simulation) and operational models (procedures that can be applied). Exploring a simulation leads to the active construction of knowledge. When using a simulation, a learner is actively developing a mental representation of the model underlying the simulation (Plass & Schwartz, 2014) - there is nothing passive about this learning approach. Simulations that are used in science classrooms could lead to greater learning outcomes by enabling students to be active agents by manipulating and interacting with simplified models of a process/system, practicing and solving problems in a safe environment (Rutten, van Joolingen, & van der Veen, 2012). Providing students with the opportunity to engage in computer based science simulations could enhance their scientific inquiry by providing opportunities for exploration rather than explanation (Plass & Schwartz, 2014). Learning through computer-based simulations enables the user to repeat certain interactions until a user understands the model (de Jong & van Joolingen, 1998; National Research Council, 2011). Empirical evidence suggests that computer based simulations have proven to be effective in promoting learning: A meta-analysis conducted by Rutten et al. (2012) found that computer based simulations enhance science instruction in many ways and could be used as a tool to enhance
laboratory exercises. The meta-analysis found that simulations used in traditional classrooms improved the learning outcome of students with an effect size of up to 1.54. These computer programs helped students’ conceptual understanding of the topic being studied (Jimoyiannis & Komis, 2001), enhanced scientific thinking (McKagan, Handley, Perkins, & Wieman, 2009), and helped teachers by conveying information in a timely manner (Gibbons, Evans, Payne, Shah, & Griffin, 2004). The students felt more positive and satisfied about the domain after using the simulation and they were more likely to participate and take on more initiative (Duran, Gallardo, Toral, Martinez-Torres, & Barrero, 2007). An analysis conducted by Wenglinskly (2005) found that 8th graders who learned through simulations instead of drill-and-practice programs performed better on science and math NAEP scores. Caution however should be used when interpreting the effect that simulations have on learning outcomes. Simulations should be used not to replace classroom instructional methods but rather to supplement them (Plass & Schwartz, 2014). Additionally, those administering the simulations in classrooms need to be trained on how to scaffold the users so the learners get the most out of them (Rutten, 2012; Smetana & Bell, 2012).

Some studies have investigated the impact that technology interventions have on promoting SE. Plass, Goldman, Flanagan and Perlin (2009) studied the effects of a game designed to teach girls how to design parts of the game and also develop computer programming skills. They found after the intervention, their general self-efficacy improved. Meluso et al. (2012) examined how playing a virtual science game (Crystal Island) influenced 5th grade students’ science SE. After having students play the game either collaboratively or individually, they found that students in both conditions had
improved in science SE and science knowledge content performance. They additionally
found that there were no significant differences between the two groups in SE and in
science content knowledge between collaborative and individual game play.

Ritzhaupt, Higgins, & Allred (2011) examined the effects of educational game
playing on 225 middle school students’ math SE, attitudes and achievement. After
students engaged in an intervention of at least 16 sessions, researchers found that there
were gains in students’ math SE and math attitudes. Although there were gains between
pre-test to post-test math achievement scores, these gains were not statistically
significant.

Potosky (2002) similarly found that after providing a computer training
intervention to new employees at a software development firm, their computer SE,
computer playfulness and computer knowledge were positively influenced. Individuals
had higher scores on the computer playfulness assessment were also more confident in
their computer SE post training.

Ketelhut (2007) studied 7th grade students’ science SE and scientific data
gathering behaviors’ in a multi-user virtual environment (MUVE) intervention that was
designed to improve students’ scientific inquiry. They found that students with initial low
SE had worse data gathering behaviors than students with initial high SE. As students
continued to play the MUVE their SE was no longer indicative of data gathering
behaviors. The author suggests that students’ SE and learning processes could be
positively influenced by science inquiry programs in MUVE.

Bergey, Ketelhut, Liang, Natarajan, and Karajus (2015) examined whether
“scientific inquiry SE” – the belief that one can engage in scientific inquiry related
behaviors such as solving problems in an immersive virtual environment was related to performance on a science assessment. The results from a path analysis found that initial scientific inquiry SE predicted performance on the science test, which also predicted a change in the scientific inquiry SE. Thus, scientific inquiry SE changed as a result of success on the science assessments. Berghey and colleagues (2015) have demonstrated that scientific SE can be improved by providing students the opportunity for mastery in a virtual world environment.

Merchant et al. (2012) used a virtual reality environment intervention to teach valence shell electron pair repulsion theory to an introductory chemistry course. They found that the intervention enhanced chemistry performance in this topic. Chemistry SE scores were related to how students interacted with the virtual reality environment such that the higher the chemistry SE, the more they interacted with the interface. SE scores also positively related to scores on the chemistry test. The few studies above confirm the positive impact that computer interventions have on students’ SE.

There are many other benefits to adding educational games and simulations into science curricula. Providing all students access to technology could remove inequalities, provide more learning opportunities for skill development, and lead to better career opportunities (Schank & Cotton, 2014). Students coming from low SES backgrounds do not have equal access to technology in and outside of school. When technology first became readily available across homes and schools in the past decade, the first level digital divide was viewed as the gap between people who do and people who do not have access to those technologies (van Dijk, 2006). There were particularly large disparities in gender, race and age with regard to access and use to these digital technologies (Gunkel,
The second level digital divide finds that though there are more consumers who have access to these technologies, there is a large gap with regard to how content is being used (Hargittai, 2002) (i.e., creating web content and understanding how to interact with technology vs. being a passive web user (Blank, 2013). In order to bridge the digital divide, all students need equal access to technology and school programs should emphasize the computer skills needed domain 21st century.

Technology interventions have been used to promote STEM interest in students of low SES backgrounds. Schank and Cotton (2014) researched how technology could empower middle school students and influence their STEM SE. They provided each student with a laptop and then assessed their SE in a variety of domains associated with academic STEM subject after a few months. They found that all the domains of SE (general, technological, math & science, academic) that they tested were associated with using technology; they posited that using technology would help children feel more empowered and have a stronger sense of confidence in abilities. They also found that when students shared a computer, it was related to having a stronger sense of SE in science and math possibly because of greater collaboration opportunities. Also, greater frequency of playing games was associated with greater general, math/science and academic SE. Greater frequency of emailing also promoted students’ SE. They concluded that technology was a medium that allowed students to use specific activities that promoted feeling empowered.

Mayo (2009) suggested that video games could potentially promote up to a 40% gain in learning over a lecture program. Since games work with players on an individual level and present information in visual and auditory ways, Mayo reiterates that games
could serve as a medium for a variety of different learners. Games provide a player with immediate feedback. This instant feedback in the form of points, badges, or promotion to the next level could enhance mastery greater than lectures do, and potentially enhance a player’s SE. They also require players to use inquiry-based learning by developing hypotheses and utilizing different problem solving different techniques that will get them to complete a quest or move them along to the next level.

If feelings of SE are improved with technology, this could open up an area of research that investigates the relationship between SE, technology and learning. It could potentially lead to the development of interventions that could promote interest, greater learning outcomes and increased participation in STEM by girls and URM. There is a need to increase women and minority group’s participation in STEM disciplines and this study may shed some light on the role that chemistry-based simulations have on improving SE. Therefore, given all the above findings, it seems necessary to research this topic more deeply for the current study.

**Research Questions and Hypotheses**

The findings in this review address the need to enhance science SE in women and minority students because of the vast underrepresentation of both groups in STEM. Given the need to increase participation in STEM, the positive role technology plays in successful learning, and the potential impact computer-based simulations may have on SE, the present study addresses the following research questions:

1) Are the self-efficacy scales used in this research study valid and can they be used for future research?

2) Can a computer-based simulation improve feelings of SE in chemistry?
3) Can SE be used to predict performance on the chemistry assessments?

The following hypotheses were investigated in this research study:

H1: The ideal gas laws self-efficacy survey will serve as a valid assessment tool for measuring ideal gas laws SE.

H2: There will be improvements in self-efficacy as a result of using a chemistry simulation. There will be gains from pre-test to post-test on the ideal gas laws self-efficacy survey. There also will be gains on the sources of chemistry SE survey specifically on questions that address mastery and physiological response.

H3: Scores on both SE surveys will predict student performance in chemistry.

H4: Gender will influence how participants respond to both SE surveys, such that males will score higher than females on the ideal gas laws SE survey and the mastery subsections of the sources of chemistry SE survey.

H5: Ethnicity will influence how participants respond to both surveys such that students who are White or East Asian will score higher on the ideal gas laws SE survey and mastery questions from the sources of SE survey than students of other ethnicities.

H6: Gender/ethnicity will influence performance in the chemistry post-test, and this relation will be mediated by SE.

H7: Of the four sources of SE, questions that address mastery will be the strongest predictor on chemistry scores.

H8: The order the chemistry post-test is administered will influence performance on both SE measures. Participants who take the chemistry post-test before
taking the SE surveys will exhibit lower ideal gas laws SE scores and lower mastery & physiological response scores on the sources of SE survey than participants who take the surveys before the chemistry post-test.
CHAPTER 3

Method

Research Design

An experiment was conducted with the random assignment of adults (age 18 and up). Participants in this study were recruited via a crowdsourcing internet marketplace, “Amazon Mechanical Turk”, as this is a more representative sample of individuals in the United States than a typical college setting (Behrend, Sharek, Meade, & Wiebe, 2011).

Amazon Mechanical Turk serves as a new platform for recruiting participants and has been shown to be useful in obtaining high-quality data for behavioral research (Mason & Suri, 2012). Most US Amazon Turk workers report that it is a “fruitful way to spend free time and get some cash” (Ipeirotis, 2010). It is convenient for both participants and researchers since it is conducted online, provides access to thousands of participants at any given moment, and hosts a diverse pool of participants. Since 2005, it has been used as a crowdsourcing platform that allows adults from all over the world to complete human intelligence tasks (HITS) such as experiments or market research online. Hundreds of research articles have been published data using MTurk workers in reputable journals (Stewart et al., 2015).

Requesters (experimenters) create a link to a task called a HIT. The HIT contains information about the study and the consent form. Requesters indicate the time limit and the payment amount for the task. MTurk workers may accept the human intelligence task (HIT), complete it and enter in a specific code given to them that is then returned to the requester. Once the requester reviews the results, payment can be either rejected or accepted for the work. If the worker does poorly, the task can be rejected and this could negatively impact the worker’s ratings. Thus, it is in both the worker’s and requester’s
best interest to complete the task well (Mason and Suri, 2012). The experimental tasks can range from a few minutes to a few hours and workers get paid based on each successful completion of a task (ranging from a few cents to a few dollars per task). Requesters have the option to select workers with positive ratings and prior experience completing other HITS. If a requester wants only workers who have completed at least 500 tasks successfully to view the HIT, this can be arranged. The requester simply indicates so in the custom-made qualifications section prior to the beginning of the experiment.

Using MTurk has yielded reliable results with many psychological experiments. Some researchers compared studies using MTurk populations to traditional populations and found that MTurk replicated the offline results (Buhrmester, Kwang, and Gosling, 2011; Horton et al 2010; Paolacci, Chandler, and Ipeirotis, 2010). MTurk workers are more likely to be younger, more liberal and more educated females (Schank, 2015) than the general population in the US. These workers also have lower incomes than the average US population (Mason and Suri, 2012). The average US MTurk worker is 30, 63% of MTurk workers are college educated, and 69% of the MTurk workers are females (Ross, Zaldivar, & Tomlinson, 2010).

The study contained the following variables:

Independent variables:

- IV1: Educational Intervention
  - Ideal Gas Laws Intervention (Simulation & Comic)- Treatment condition
  - Solids Liquids and Gases Narrative -Control Condition
- IV2: Chemistry Pre-test Score
- IV3: Sources of Chemistry Self-efficacy Subscale Score
- IV4: Sources of Chemistry Self-efficacy Pre-test Score
- IV5: Ideal Gas Laws Self-efficacy Pre-test Score
- IV6: Gender
- IV7: Race/Ethnicity
- IV8: Order of presentation of Chemistry posttest (counterbalance)

Dependent variables:

The main outcome variables will be:
- DV1: Sources of Chemistry Self-efficacy Post-test Score
- DV2: Ideal Gas Laws Self-efficacy Post-test Score
- DV3: Chemistry Post-test Score

Participants

There were 73 males and 112 females. 6.5% of participants were Hispanic or Latino, 5.4% were Black or African American, 1.1% were Asian, 78.4% were White, .5% were American Indian or Alaska Native, 7% were multiracial or multiethnic and 1.1% did not report their race/ethnicity. Inclusion criteria for the groups were that participants were at least 18 years of age at the time of testing. Additionally, only US participants took part in this study as this was verified through their IP addresses. Additionally, all participants needed to speak English in order to take part in the study.

Participants indicated how many years it has been since college, high school and their last chemistry course. Participants who took more advanced chemistry courses indicated so in the background information questionnaire and this data was controlled for in further statistical analyses. Participant age range was 19 to 72. 200 participants were recruited which was sufficient enough to run a confirmatory factor analysis (Arrindell &
van der Ende, 1985).

Twelve participants were removed from the analysis because they clicked less than 3 times during the computer-based simulation. 3 more participants were removed from the analysis because the data indicated that they were automatically clicking through the survey questions (i.e., clicking on the same answer throughout the experiment even though some items were reverse coded).

The computer program randomly assigned participants to one of the four conditions as participants clicked on the experimental link. IP addresses were verified and only United States participants were eligible. As a token of appreciation for completing the experiment, participants received $4 after successfully completing the experiment. The average wage an Amazon Turk worker will complete a task is $1.40 per hour (Chilton, Horton, Miller, & Azenkot, 2010) and the median hourly wage is $1.38 (Horton & Chilton, 2010).

**Procedure**

Participants worked individually on their own computer as they completed the experiment. Participants were randomly assigned to either a control group or an experimental group. The experimental group received an interactive computer based chemistry simulation covering ideal gas laws. This simulation has been used to facilitate the learning of chemical processes in high school students (Plass et al., 2012). The experimental group had two levels: one group of participants who took the SE scales prior to taking the chemistry post-test; a second group of participants who took the SE scales after taking the chemistry post-test. The control group received a narrative on scientific principles of the changing states of solids, liquids and gases without the
simulation. The control group had two levels: one group of participants who took the SE scale before taking the chemistry post-test; a second group of participants who took the SE scale after taking the chemistry post-test. Participants in all four groups were asked to complete the same chemistry knowledge pre-test, post-test and chemistry SE scale. The basic procedure was the same for both groups. The experiment took about 1 hour for each participant.

**Instrumentation**

**Ideal Gas Laws Self-efficacy.** (Pre-test and Post-test). A 16-item measure that utilizes a Likert scale to determine individual beliefs in ability to do well in the chemistry subtopic of ideal gas laws. The scale was developed for the purpose of the study and was validated using an exploratory factor analysis. Reliability scores were measured using cronbach’s alpha. Users were asked to respond using a Likert type scale ranging from 1 (Definitely False), 4 (Neither true nor false), 7 (Definitely true) to statements such as “I feel confident explaining what the ideal gas law is”. This scale was treated as a separate measure from the sources of chemistry self-efficacy below.

**Sources of SE measure in chemistry.** (Pre-test and Post-test). A 26-item that utilizes a Likert scale to determine individual sources of self-efficacy in chemistry. The scale was developed from Bandura’s (1977) theory using four sources of variables to predict SE (mastery, vicarious learning, social persuasion and physiological response). The validated survey was obtained from Usher & Pajares’ (2006; 2009) sources of math self-efficacy scale but questions were adapted for chemistry. Responses to statements will be assessed using a Likert-type scale ranging from 1 (definitely false) to 7 (definitely true).

**Chemistry Pre-test.** This 15-item forced response test was given to users before
the simulation intervention to assess chemistry knowledge of ideal gas laws. This test was built upon a measure that was used in previous research studies (Plass et al., 2012). Eight similar questions were added to the original test. The Chemistry Pre-test was administered to determine pre-existing understanding of concepts related to ideal gas laws. Rubrics were used to score the questions.

Chemistry Post-test. The 28-item post-test includes comprehension questions in the form of multiple choice to measure comprehension and open-ended extended response questions that measure the transfer of knowledge from the simulation. This test was built upon a measure that was used in previous research studies (Plass et al. 2012). Eight similar questions were added to the original test. The post-test was administered to users after they completed the simulation or narrative sequence in order to determine understanding of concepts related to ideal gas laws. Some question items were repeats from the knowledge pre-test. Rubrics were used to score both types of questions.

Computer Based Chemistry Simulation. This simulation was used in previous research to foster chemistry student understanding of ideal gas laws (Plass et al., 2012). Participants were prompted to read a comic called "The Everful Basketball" that introduced them to an everyday example, which could be explained through the application Gas Laws and Kinetic Molecular Theory. Users then worked through a tutorial that introduced them to the ideal gas laws model. The ideal gas laws model uses dynamic submicroscopic particles to help users understand the observed behavior of phenomena associated with a basketball that appeared as though it went "flat" in cold weather by manipulating variables of temperature, volume and pressure associated with the Gas Laws. As students interacted with these variables, the interactions were
dynamically populated on a graph, a symbolic representation. The dynamic model consists of interactive areas where temperature, pressure, and volume can be manipulated and particle behavior can be observed in a model container. After completing the simulation, users were reminded to relate what they did in the simulation to the everyday example of basketball.

**Narrative on Solids, Liquids and Gases.** Participants were prompted to read through a lesson on the scientific principles of the changing states of solids, liquids and gases.

**Background Information Questionnaire.** This 14-item questionnaire was given to users after the experiment to obtain information about the participant. It was administered to determine how familiar users were with chemistry (i.e., were any courses previously taken, how long has it been since the last chemistry course). Basic demographic information was also collected in this survey such as gender, race/ethnicity, household income, etc.
CHAPTER 4

Results

The goal of this study was to help us ascertain a deeper understanding of how computer-based simulations impact SE and how this construct varies for women and people of various racial and ethnic groups. Data analyses were organized around the follow main research questions:

1) Are the self-efficacy scales used in this research study valid and can they be used for future research?

2) Can a computer-based simulation improve feelings of SE in chemistry?

3) Can SE be used to predict performance on the chemistry assessments for the current study?

Reliability and Validity of SE measures

To assess whether both self-efficacy scales were reliable and valid, Cronbach’s alpha reliability was calculated and confirmatory/exploratory factor analyses were calculated:

Sources of Chemistry SE Scale – Reliability. Respondents were asked to provide a response to each item in the sources of SE scale using a 7-point scale ranging from “Definitely False” to “Neither true nor False” to “Definitely true”. The mean score for the sources of chemistry SE pretest scale was 124.89 with a standard deviation of 35.01. The minimum score was 33 and maximum score was 205. The mean score for the sources of Chemistry SE posttest scale was 122.69 with a standard deviation of 37.19. The sum of responses ranged from 30-208.

A reliability analysis was conducted for the Sources of Chemistry SE pretest
scale. The alpha coefficient for the 26 item scale was .96. The alpha coefficient for the Sources of Chemistry SE posttest 26 item scale was also .96. “The Cronbach’s alpha if items deleted” reliability score was higher when removing questions #10, #11 in both the pretest and posttest: “Many adults I know have jobs that involve science” & “People I admire are good at science”.

Alpha coefficients for the sources of SE were separately calculated. Mastery alpha ranged from .93-.95; vicarious learning ranged from .85-.89; social persuasion ranged from .96-.97; physiological response ranged from .94-.96. Literature that also investigated the reliability of sources of SE scales show that alpha coefficients are similarly lowest for vicarious experiences (Usher & Pajares, 2006).

**EFA- Sources of Chemistry SE**

One purpose of this investigation was to explore the factor structure underlying the sources of chemistry SE item responses. Factor analysis is used to reduce a large set of variables to a smaller set of factors, fewer in number than the original variable set and is capable of accounting for a large portion of the total variability in the items. Based on the literature review, 4 factors hypothesized to represent the four sources of SE were identified.

First, an exploratory factor analysis was conducted to identify the latent constructs underlying the sources of chemistry SE items. The factor analysis was conducted on SPSS version 21 using maximum likelihood estimation and promax rotation. Models ranging from 4-5 were fit. The four factor model was retained because of the increase in explained variance for larger models was modest.
The analysis included all the items that were used in the 26 item scale: mastery experience, vicarious learning, social persuasion and physiological response. Factor 1 comprised the 7 mastery items with communalities ranging from .532-.905. An example of an item included in this factor is, “I make excellent grades on chemistry tests.” Factor 2 comprised the 7 items with loadings ranging from .237-.776. An example of an item included in this factor is, “Seeing others do better than me in chemistry pushes me to do better.” Factor 3 comprised of 6 items with loadings ranging from .726-.878. An example of an item included in this factor is, “Other students have told me that I’m good at learning chemistry.” Factor 4 comprised of 6 items with loadings ranging from .631-.872. An example of an item included in this factor is, “Just being in chemistry class makes me feel stressed and nervous.”

In the context of this study, we may say that we have validity evidence supporting the conclusion that the scores from this instrument are a valid assessment of different sources of chemistry self-efficacy. We can feel confident when adding similar items up for total scores to represent the different dimensions of how one draws sources from chemistry self-efficacy (each factor represents a dimension). The maximum likelihood estimation procedure was used to extract the factors from the variable data. Using this procedure, details about the four factors that were extracted are included in Table 2.

Together, the 4 factors are capable of explaining roughly 75.8% of all the variable variances. A plot of the eigenvalues is provided in table 1. A review of the initial factor loadings suggests that an appropriate solution was attainable through maximum likelihood, as it was capable of converging in 6 iterations.
Table 1

*Total Variance Explained – Sources of Science Self-Efficacy Scale*

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<th>% Variance</th>
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<tr>
<td>5</td>
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*Extraction Method: Maximum Likelihood (N = 185)*

Figure 1

*Scree Plot for Sources of Science Self-Efficacy Scale*
Table 2

*Factor Matrix- Unrotated Loadings for Sources of Science Self-Efficacy Scale*

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<tr>
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<th>Factor 3</th>
<th>Factor 4</th>
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### EFFECT OF INTERVENTION ON SELF-EFFICACY

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<td>6</td>
<td>.037</td>
<td>.251</td>
<td>.672</td>
<td>.002</td>
</tr>
<tr>
<td>7</td>
<td>.028</td>
<td>.061</td>
<td>-.023</td>
<td>.695</td>
</tr>
<tr>
<td>8</td>
<td>.035</td>
<td>-.070</td>
<td>.375</td>
<td>.628</td>
</tr>
<tr>
<td>9</td>
<td>.120</td>
<td>-.188</td>
<td>.273</td>
<td>.600</td>
</tr>
<tr>
<td>10</td>
<td>-.169</td>
<td>.285</td>
<td>-.150</td>
<td>.414</td>
</tr>
<tr>
<td>11</td>
<td>-.066</td>
<td>.085</td>
<td>-.249</td>
<td>.675</td>
</tr>
<tr>
<td>12</td>
<td>.117</td>
<td>.181</td>
<td>-.335</td>
<td>.662</td>
</tr>
<tr>
<td>13</td>
<td>-.056</td>
<td>-.106</td>
<td>.407</td>
<td>.629</td>
</tr>
<tr>
<td>14</td>
<td>.026</td>
<td>.069</td>
<td>.361</td>
<td>.527</td>
</tr>
<tr>
<td>15</td>
<td>.043</td>
<td>.471</td>
<td>.402</td>
<td>.104</td>
</tr>
<tr>
<td>16</td>
<td>.049</td>
<td>.867</td>
<td>.048</td>
<td>.008</td>
</tr>
<tr>
<td>17</td>
<td>-.103</td>
<td>.813</td>
<td>-.003</td>
<td>.161</td>
</tr>
</tbody>
</table>

*4 factors extracted, 6 iterations required.*

**Table 3**

*Pattern Matrix for Sources of Science Self-Efficacy Scale*
### Table 4

**Factor Correlation Matrix for Sources of Science Self-Efficacy Scale**

<table>
<thead>
<tr>
<th>Factor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>.407</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>.628</td>
<td>.679</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>.321</td>
<td>.505</td>
<td>.606</td>
<td></td>
</tr>
</tbody>
</table>

*Extraction Method: Maximum Likelihood; Rotation Method: Promax with Kaiser Normalization*

1 = Physiological Response; 2 = Social Persuasion; 3 = Mastery; 4 = Vicarious Learning
### Table 5

**Factor Matrix - Goodness of fit Test – Sources of Science Self-Efficacy**

<table>
<thead>
<tr>
<th>Chi-Square</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>558.97</td>
<td>227</td>
<td>.000</td>
</tr>
</tbody>
</table>

*Note: 4 factors extracted. 5 iterations required.*

**CFA- Sources of Chemistry SE.** A confirmatory factor analysis was conducted to verify that items on the sources of SE survey reflected the characteristics that we wish to measure. To assess the hypothesized mapping of items to the 4 factors, a sequence of CFA models was fit in R to validate the 26-item sources of chemistry SE scale. The chi-square goodness of fit test rejected the null hypothesis that the model implied covariance matrix is the same as the empirical covariance matrix $\chi^2 (269)= 878.13$ with $p=0$, which indicated a poor model fit. The Root Mean Square Error of Approximation value of .111 indicated a poor model fit. The CFI (comparative fit index) value of .869 was very close to the recommended threshold of .90 (Hu and Bentler, 1999). We then tested our mappings of items with the 4 factor model with the residual for items 10, 11, & 12 correlated. We then dropped on of the residual items correlations at a time. Finally we ran a 5-Factor solution with items 10, 11, and 12 on a separate factor which led to the best model fit. The summary of the factor models is listed in the table below:
### Table 6

**Comparison of Factor Models for Sources of Science Self-Efficacy Scale**

<table>
<thead>
<tr>
<th>Model</th>
<th>LL</th>
<th>DF</th>
<th>BIC</th>
<th>CFI</th>
<th>RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted</td>
<td>-4077.24</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Factor</td>
<td>-4442.63</td>
<td>265</td>
<td>9198.485</td>
<td>.9</td>
<td>.097</td>
</tr>
<tr>
<td>4 Factor</td>
<td>-4516.3</td>
<td>269</td>
<td>9324.942</td>
<td>.869</td>
<td>.111</td>
</tr>
<tr>
<td>4 Factor CR 10,11,12</td>
<td>-4447.921</td>
<td>266</td>
<td>9203.843</td>
<td>0.898</td>
<td>0.098</td>
</tr>
<tr>
<td>4 Factor CR 10</td>
<td>-4499.764</td>
<td>267</td>
<td>9302.308</td>
<td>0.876</td>
<td>0.108</td>
</tr>
<tr>
<td>4 Factor CR 11</td>
<td>-4463.962</td>
<td>267</td>
<td>9230.704</td>
<td>0.891</td>
<td>0.101</td>
</tr>
<tr>
<td>4 Factor CR 12</td>
<td>-4462.758</td>
<td>267</td>
<td>9228.296</td>
<td>0.892</td>
<td>0.101</td>
</tr>
</tbody>
</table>

*Note: LL= Loglikelihood User Model; BIC= Bayesian; CFI= Comparative Fit Index; RMSEA= Root Mean Square Error of Approximation*

**Correlations**

The sources of chemistry SE scale was adapted from a SE scale developed by Usher & Pajares’ (2006; 2009) that asked middle school students to rate their sources of SE in math. The scale asks participants to rate personal experiences related to chemistry such as: previous mastery experiences, vicarious experiences from others successful in science and chemistry, social persuasions and how participants respond physiologically to thinking about or learning about chemistry. This scale was given to participants prior
to and after the intervention. A Cronbach's alpha reliability analysis was calculated on both the pretest and posttest survey (.96) yet the factor analysis confirmed that the items measure more than one factor.

Table 7

*Subscale Intercorrelations*

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Mastery</th>
<th>VL</th>
<th>SP</th>
<th>PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL</td>
<td>.589**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP</td>
<td>.806**</td>
<td>.584**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR</td>
<td>.623**</td>
<td>.328**</td>
<td>.462**</td>
<td></td>
</tr>
</tbody>
</table>

*NOTE.**p<.001; VL= Vicarious learning; SP=Social Persuasion; PR=Physiological Response.*

**Ideal Gas Laws SE scale – Reliability.** Respondents were asked to provide a response to each item in the Ideal Gas Laws SE scale using a 7-point scale ranging from “Definitely False” to “Neither true nor False” to “Definitely true”. The mean score for the Ideal Gas Laws SE pretest scale was 59.64 with a standard deviation of 25.59. The minimum score was 16 and maximum score was 112. The mean score for the ideal gas laws *posttest* scale was 69.03 with a standard deviation of 24.88. The sum of responses ranged from 16-112.

A reliability analysis was conducted for the Ideal Gas Laws SE *pretest* scale. The alpha coefficient for the 16 item scale was .97. A reliability analysis was conducted for the Ideal Gas Laws SE *posttest* scale was also .97. “The Cronbach’s alpha if items deleted” reliability score was higher when removing the last two questions in both the pretest and posttest: “I feel anxious taking a chemistry knowledge test” & “I feel anxious
at the thought of learning about ideal gas laws.”

**EFA- Ideal Gas Laws.** It was hypothesized that the ideal gas laws self-efficacy survey will serve as a valid assessment tool for measuring ideal gas laws SE. An exploratory factor analysis was conducted to identify the latent constructs underlying the ideal gas laws SE items. The analysis included all the items that were used in the scale. The maximum likelihood method of extraction was used on SPSS. Two factors were identified that could assess ideal gas laws SE. The results suggested a two factor solution in which factor 1 comprised the 14 items with communalities ranging from .616-.961. An example of an item included in this factor is “I feel confident explaining what the ideal gas law is.” Factor 2 comprised the 2 items with communalities ranging from .667-.670. An example of an item included in this factor is “In a basketball, as the air inside the ball gets colder, I feel confident drawing a line on a graph representing the volume.”

The maximum likelihood estimation procedure was used to extract the factors from the variable data. Using this procedure, the two factors that were extracted are included in Table 7. Together, the 2 factors are capable of explaining roughly 80% of all the variable variances. A plot of the eigenvalues is provided in table 8. A review of the initial factor loadings suggests that an appropriate solution was attainable through maximum likelihood, as it was capable of converging in 6 iterations.
Table 8

*Total Variance Explained – Ideal Gas Laws Self-Efficacy Survey*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Total Eigenvalues</th>
<th>% Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.664</td>
<td>72.899</td>
</tr>
<tr>
<td>2</td>
<td>1.190</td>
<td>7.436</td>
</tr>
<tr>
<td>3</td>
<td>.834</td>
<td>5.213</td>
</tr>
</tbody>
</table>

*Extraction Method: Maximum Likelihood*

Figure 2

*Scree Plot – Ideal Gas Laws Self-Efficacy Scale*
### Table 9

*Factor Matrix (Unrotated Loadings) - Ideal Gas Laws Self-Efficacy Scale*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.679</td>
<td>.047</td>
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<tr>
<td>2</td>
<td>.800</td>
<td>.112</td>
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<td>3</td>
<td>.795</td>
<td>.175</td>
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<tr>
<td>4</td>
<td>.924</td>
<td>.150</td>
</tr>
<tr>
<td>5</td>
<td>.942</td>
<td>.232</td>
</tr>
<tr>
<td>6</td>
<td>.931</td>
<td>.214</td>
</tr>
<tr>
<td>7</td>
<td>.954</td>
<td>.193</td>
</tr>
<tr>
<td>8</td>
<td>.928</td>
<td>.098</td>
</tr>
<tr>
<td>9</td>
<td>.935</td>
<td>.148</td>
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<tr>
<td>10</td>
<td>.872</td>
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<td>11</td>
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<td>12</td>
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<td>.035</td>
</tr>
<tr>
<td>13</td>
<td>.801</td>
<td>-.563</td>
</tr>
<tr>
<td>14</td>
<td>.806</td>
<td>-.504</td>
</tr>
<tr>
<td>15</td>
<td>.560</td>
<td>.129</td>
</tr>
<tr>
<td>16</td>
<td>.507</td>
<td>.124</td>
</tr>
</tbody>
</table>

*Extraction Method: Maximum Likelihood
2 Factors Extracted, 6 iterations required.*
Table 10

*Pattern Matrix- Ideal Gas Laws Self-Efficacy Scale*

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.587</td>
<td>.129</td>
</tr>
<tr>
<td>2</td>
<td>.761</td>
<td>.066</td>
</tr>
<tr>
<td>3</td>
<td>.831</td>
<td>-.021</td>
</tr>
<tr>
<td>4</td>
<td>.900</td>
<td>.052</td>
</tr>
<tr>
<td>5</td>
<td>1.009</td>
<td>-.057</td>
</tr>
<tr>
<td>6</td>
<td>.979</td>
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<tr>
<td>7</td>
<td>.974</td>
<td>-2.026E-5</td>
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<tr>
<td>8</td>
<td>.843</td>
<td>.122</td>
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<tr>
<td>9</td>
<td>.907</td>
<td>.056</td>
</tr>
<tr>
<td>10</td>
<td>.859</td>
<td>.038</td>
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<td>11</td>
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<td>.124</td>
</tr>
<tr>
<td>12</td>
<td>.771</td>
<td>.211</td>
</tr>
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<td>-.033</td>
<td>1.003</td>
</tr>
<tr>
<td>14</td>
<td>.039</td>
<td>.923</td>
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<tr>
<td>15</td>
<td>.584</td>
<td>-.011</td>
</tr>
<tr>
<td>16</td>
<td>.529</td>
<td>-.019</td>
</tr>
</tbody>
</table>

*Extraction Method: Maximum Likelihood*

*Rotation Method: Promax with Kaiser Normalization, Rotation Converged in 3 iterations*
Table 11

*Factor Correlation Matrix for Ideal Gas Laws SE Survey*

<table>
<thead>
<tr>
<th>Factor</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>.706</td>
</tr>
<tr>
<td>2</td>
<td>.706</td>
<td></td>
</tr>
</tbody>
</table>

*Extraction Method: Maximum Likelihood; Rotation Method: Promax with Kaiser Normalization*

Table 12

*Factor Matrix Goodness of fit Test – Ideal Gas Laws Self-Efficacy Scale*

<table>
<thead>
<tr>
<th>Chi-Square</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>733.656</td>
<td>89</td>
<td>.000</td>
</tr>
</tbody>
</table>

*2 factors extracted. 6 iterations required*
To assess the strength of the relationship between all the main factors of the study, a correlation analysis was computed. Results can be found in the table below:

Table 13

_Bivariate Correlations among Pretest SE subscale Measures, Ideal Gas Laws SE & Chemistry Scores_

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mastery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. VL</td>
<td>.589**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. SP</td>
<td>.806**</td>
<td>.584**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. PR</td>
<td>.623**</td>
<td>.328**</td>
<td>.462**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. SE1</td>
<td>.926**</td>
<td>.739**</td>
<td>.874**</td>
<td>.743**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. SE2</td>
<td>.713**</td>
<td>.558**</td>
<td>.649**</td>
<td>.537**</td>
<td>.749**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. C-Score</td>
<td>.344**</td>
<td>.302**</td>
<td>.276**</td>
<td>.210**</td>
<td>.343**</td>
<td>.450**</td>
<td></td>
</tr>
</tbody>
</table>

**p < 0.01; *p<.05

Note. VL= Vicarious Learning Pretest; SP= Social Persuasion Pretest; VL= Vicarious Learning Pretest; SE1= Sources of Self Efficacy Pretest; SE2= Ideal Gas Laws Self-efficacy Pretest; C-Score= Chemistry Pretest

How a Computer-Based Simulation Influences Feelings of SE

To assess whether a computer-based simulation improves feelings of SE in chemistry, several analyses were conducted. A one-way repeated measured analysis of variance (ANOVA) was conducted to evaluate the hypothesis that there would be a significant increase in participants’ ideal gas laws scores when measured before and after participation in a science-based intervention. The results of the ANOVA indicated a significant time effect, Wilks’ Lambda = .76, $F(1,183) = 58.43, p < .01, n^2 = .24$.

Follow up comparisons indicated that each pairwise difference evaluating the simulation treatment condition vs. control condition, was significant, $p < .01$. There was a
significant increase in scores over time in both treatment and control conditions. In the control condition, participants’ ideal gas laws self-efficacy mean pretest score was 60.76 and mean posttest ideal gas laws SE score was 65. In the simulation condition, participants’ ideal gas laws SE mean pretest scores was 58 and posttest ideal gas laws SE mean posttest score was 74, suggesting that participation in the study led to increased self-efficacy scores regardless of condition.

To further assess these findings, a two way, repeated measures analysis of variance (ANOVA) was conducted to assess whether any change in self-efficacy ideal gas laws scores is the result of the interaction between the type of treatment and gender with gender and type of treatment being the independent variables and change in ideal gas laws SE scores being the dependent variable. There was a significant main effect for change in ideal gas laws scores from pretest to posttest, \( F(1, 181) = 54.99, p < .001, n^2 = .23 \) There was a significant interaction between type of treatment condition and the change in scores on the ideal gas laws SE test, \( F(1, 181) = 16.71, p < .001, n^2 = .08 \), indicating that the change in scores participants had on the ideal gas laws self-efficacy test was different for the treatment groups. There was no significant interaction between gender and the change in scores on the ideal gas laws SE scale, \( F (1, 180)=0, p>.05, n^2 = 0 \). An independent \( t \) test was calculated using pretest ideal gas laws survey scores as the dependent variable and gender as the independent variable. There was a significant difference in the pretest ideal gas laws survey scores for males \( (M=65.37, SD= 23.64) \) and females \( (M=55.91, SD= 26.22) \); \( t(183)=2.49, p=.01 \). There was also a significant difference in the posttest ideal gas laws survey scores for males \( (M=74.67, SD= 22.32) \) and females \( (M=65.36, SD= 25.85) \); \( t(183)=2.52 , p=.01 \). Independent t-test analyses
were conducted using gender as the independent variable and chemistry pretest and posttest scores as dependent variables. There were no significant differences in the chemistry pretest scores for males ($M = 10.22, SD = 3.26$) and females ($M = 9.21, SD = 3.75$); $t(183) = 1.87, p > .05$. There were also no significant differences in the posttest chemistry scores for males ($M=29.23, SD= 8.49$) and females ($M=28.46, SD= 7.53$); $t(183)=.65, p>05$.

**Sources of Self-Efficacy - Mastery**

A one-way repeated measured analysis of variance (ANOVA) was conducted to evaluate the hypothesis that there is significant change in participants’ mastery scores when measured before and after participation in a science-based intervention. The results of the ANOVA indicated a significant time effect, Wilks’ Lambda = .95, $F(1,183) = 58.43, p < .05, n^2 = .05$.

Follow up comparisons indicated that the pairwise difference evaluating the simulation treatment condition vs. control condition was significant, $p < .01$. There was a significant change in scores over time for both treatment and control conditions. For the treatment condition, mean mastery scores significantly increased from pretest to posttest, [GIVE MEANS], indicating that mastery increased for participants who used the science simulation. In contrast, mean mastery scores for participants in the control condition significantly decreased from pretest ($M = 33.62$) to posttest ($M = 32.17$), indicating that participation in the study decreased mastery scores participants in the control condition.
Using SE scales as prediction tools

It was hypothesized that both SE measures would predict chemistry performance. To assess if SE measures can be used to predict performance on a chemistry assessment, several regressions analyses were computed.

Pretest Sources of Chemistry SE. A simple linear regression was calculated using the sources of Chemistry SE pretest scores as the independent variable and chemistry pretest as the outcome variable. The results of the simple linear regression suggest that a significant proportion of the total variation in chemistry pretest scores was predicted by pretest sources of chemistry self-efficacy scores. The unstandardized slope (.235) and standardized slope (.344) are statistically different from 0 ($t = 4.952$, $df = 184$, $p = .000$); The regression equation for this model is:

$$\text{Chemistry pretest score} = 34.71 + .235(\text{Pretest Sources of SE score}).$$

The confidence around the unstandardized slope does not include 0 (95% CI [.141, .329]), further confirming that sources of chemistry SE is a statistically significant predictor of chemistry pretest scores. Multiple $R^2$ indicates that approximately 11.3% of variation in the chemistry pretest scores was predicted by the sources of SE pretest scale. ($R^2 = .113$, $F(1,184) = 24.52, p = .000$).

Further regressions were calculated to test if the Sources of Chemistry SE influenced the chemistry pretest. A multiple regression analysis was calculated regressing Sources of Chemistry SE (IV) on the Chemistry Pretest (DV) using the following predictors: age, annual income, education level, whether previous chemistry courses were taken, gender and race/ethnicity. It was found that the Sources of Chemistry SE pretest was still significant in predicting variation in chemistry pretest performance ($\beta = .029$,}
EFFECT OF INTERVENTION ON SELF-EFFICACY

Multiple $R^2$ indicates that approximately 22.7% of variation in the chemistry pretest scores was predicted by the model ($R^2 = .227, F(1, 173) = 17.06, p = .000$).

**Pretest Ideal Gas Laws SE.** A simple linear regression was run using ideal gas laws pretest SE scores as the independent variable and chemistry pretest as the dependent variable. The results of the simple linear regression suggest that a significant proportion of the total variation in chemistry pretest scores was predicted by pretest ideal gas laws self-efficacy scores. The unstandardized slope (.422) and standardized slope (.451) are statistically different from 0 ($t = 6.83, df = 184, p = .000$); The regression equation for this model is:

Chemistry pretest score = 38.91 + .422(Pretest Ideal Gas laws SE score).

The confidence around the unstandardized slope does not include 0 (95% CI [.300, .544]), further confirming that ideal gas laws SE is a statistically significant predictor of chemistry pretest scores. Multiple $R^2$ indicates that approximately 19.9% of variation in the chemistry pretest scores was predicted by ideal gas laws SE scale ($R^2 = .199, F(1, 183) = 46.67, p = .000$).

Further regressions were calculated to test if ideal gas laws SE influenced the chemistry pretest. A multiple regression analysis was calculated regressing ideal gas laws (IV) on Chemistry Pretest (DV) using the following predictors: age, annual income, education level, whether previous chemistry courses were taken, gender and race/ethnicity. It was found that the ideal gas laws pretest was still significant in explaining variation in chemistry pretest performance ($\beta = .055, SE = .009, p = .000$, $\text{partial eta sq} = .175; 95\% \text{ CI} [.073, .175]$). Multiple $R^2$ indicates that approximately 30%
of variation in the chemistry pretest scores was predicted by the model. \( R^2 = .300, F(1,173) = 36.73, p = .000 \).

**Simulation Group - Sources of SE.** To assess how SE posttest surveys were related to the simulation-only groups, follow-up simple linear regressions were calculated. A simple linear regression was run analyzing the simulation-only groups: the sources of Chemistry SE posttest scores served as the independent variable and chemistry posttest was the dependent variable. A large proportion of the total variation in chemistry posttest scores was predicted by posttest sources of SE scores. The unstandardized slope (.097) and standardized slope (.482) are statistically different from 0 \( (t = 5.04, df = 85, p = .000) \); The regression equation for this model is:

\[
\text{Chemistry posttest score} = 18.88+.097(\text{Posttest sources of SE score})
\]

The confidence around the unstandardized slope does not include 0 (95% CI [.059, .135]) further confirming that sources of SE is a statistically significant predictor of chemistry posttest scores. Multiple \( R^2 \) indicates that approximately 22.4% of variation in the chemistry posttest scores was predicted by sources of SE scale \( R^2 = .224, F(1,84) = 25.47, p = .000 \).

**Simulation Group - Ideal Gas Laws.** A simple linear regression was run using the ideal gas laws posttest scores as the independent variable and chemistry posttest as the dependent variable. A large proportion of the total variation in chemistry posttest scores was predicted by ideal gas laws SE posttest scores in the simulation-only group. The unstandardized slope (.097) and standardized slope (.482) are statistically different from 0 \( (t = 7.81 df = 85, p = .000) \); The regression equation for this model is:

\[
\text{Chemistry score}=16.07+.20(\text{Posttest ideal gas laws score})
\]
The confidence around the unstandardized slope does not include 0 (95% CI \([.151, .254]\)), further confirming that ideal gas laws SE is a statistically significant predictor of chemistry posttest scores. Multiple \(R^2\) indicates that approximately 41.4% of variation in the chemistry scores was predicted by posttest ideal gas laws SE scale \((R^2 = .414, F(1,84) = 61.02, p = .000)\).

**Do Sources of SE Predict Chemistry Scores?**

It was hypothesized that of the four sources of SE, mastery scores would be the strongest predictor of chemistry scores, but that the other sources of SE would also significantly predict chemistry scores.

Several simple linear regressions were calculated separately to assess which source would best predict chemistry test performance. A linear regression was calculated separately regressing each source of SE (IV) on chemistry pretest scores (DV).

**Mastery.** The proportion of total variation in chemistry pretest scores was moderately predicted by mastery scores. The unstandardized slope (.110) and standardized slope (.344) are statistically significant from 0 \((t = 4.96, df = 184, p = .000)\). The model accounted for 11.9% of variance in the dependent variable.

**Vicarious Learning.** The proportion of total variation in chemistry pretest scores was mildly predicted by vicarious learning scores. The unstandardized slope (.110) and standardized slope (.302) are statistically significant from 0 \((t = 4.29, df = 184, p = .000)\). The model accounted for 9.1% of variance in the dependent variable.

**Social Persuasion.** The proportion of total variation in chemistry pretest scores was mildly predicted by social persuasion learning scores. The unstandardized slope (.089) and standardized slope (.276) are statistically significant from 0 \((t = 3.89, df = 184, p = .000)\).
EFFECT OF INTERVENTION ON SELF-EFFICACY

$p = .000$). The model accounted for 7.6% of variance in the dependent variable.

**Physiological Response.** The proportion of total variation in chemistry pretest scores was slightly predicted by physiological response scores. The unstandardized slope (.070) and standardized slope (.210) are statistically significant from 0 ($t = 2.91, df = 184, p = .004$). The model accounted for 3.9% of variance in the dependent variable.

**Gender, SE and Chemistry Performance**

To assess to the extent to which gender influences participant response on both SE surveys, several statistical analyses were computed. It was hypothesized that males would score higher than females on the ideal gas laws survey and mastery subsections of the sources of chemistry SE survey.

**Gender & Ideal Gas Las SE**

A multiple linear regression was calculated regressing counterbalanced posttest, gender, age, annual income, education level, sources of SE chemistry pretest, chemistry pretest, race/ethnicity, chemistry course, on ideal gas laws SE posttest scores (the dependent variable). The treatment and control condition differed on two levels (participants who received the chemistry posttest immediately following the intervention and participants who received the self efficacy surveys immediately following the intervention) so calculations were made separately for each condition. This model accounted for 64% of variance in ideal gases posttest survey scores. Females performed significantly worse on the ideal gas laws posttest when they received the SE survey first, $\beta = -8.00, SE = .3.24, p = .01; 95\% CI[-14.45, -1.55]$. To assess whether there were any gender differences in the chemistry posttest first group, a multiple regression analysis was used to test if gender responses significantly predicted participant responses on the
posttest ideal gas laws survey using the same covariates as above. It was found that the model accounted for 54% of variance in ideal gases posttest survey scores. There were no statistically significant differences on the ideal gas laws posttest for males and females in this condition, $\beta = -3.66$, $SE = .3.96$, $p > .05$; 95% CI[-11.55, 4.22].

**Gender & Mastery**

To assess the extent that gender varied on performance on the sources of SE subscales, correlations were computed. Below, correlations between males, sources of self-efficacy (pretest), ideal gas laws (pretest) and chemistry scores (pretest) are reported:

Table 14

*Bivariate Correlations among Males, SE subscale Measures, Ideal Gas Laws SE & Chemistry Pretest*

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<tbody>
<tr>
<td>1. Mastery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. VL</td>
<td>.664**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. SP</td>
<td>.849**</td>
<td>.638**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. PR</td>
<td>.601**</td>
<td>.295*</td>
<td>.392*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. SE #2</td>
<td>.758**</td>
<td>.707**</td>
<td>.684**</td>
<td>.436**</td>
<td></td>
</tr>
<tr>
<td>6. C-Pretest</td>
<td>.289*</td>
<td>.237*</td>
<td>.294*</td>
<td>.129</td>
<td>.381**</td>
</tr>
</tbody>
</table>

**p < 0.01; *p<.05
Note. VL= Vicarious Learning; SP= Social Persuasion; VL= Vicarious Learning; SE #2= Ideal Gas Laws Self-efficacy Pretest; C-Pretest= Chemistry Pretest

In the table below, correlations between females, sources of self-efficacy (pretest), ideal gas laws (pretest) and chemistry scores (pretest) are reported:
Table 15

_Bivariate Correlations among Females, SE subscale Measures, Ideal Gas Laws SE; Chemistry Pretest_  

<table>
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<tr>
<td>2. VL</td>
<td>.544**</td>
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<td></td>
</tr>
<tr>
<td>3. SP</td>
<td>.763**</td>
<td>.553**</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>4. PR</td>
<td>.643**</td>
<td>.348**</td>
<td>.506**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. SE #2</td>
<td>.703**</td>
<td>.479**</td>
<td>.640**</td>
<td>.582**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. C-Pretest</td>
<td>.375**</td>
<td>.338**</td>
<td>.266**</td>
<td>.236*</td>
<td>.465**</td>
<td></td>
</tr>
</tbody>
</table>

**p < 0.01; *p<.05  
Note. VL= Vicarious Learning; SP= Social Persuasion; VL= Vicarious Learning; SE #2= Ideal Gas Laws Self-efficacy Pretest; C-Pretest= Chemistry Pretest

_Gender & Chemistry Performance_

To explore this further, a multiple regression analysis was calculated that regressed gender (IV) on chemistry posttest scores (DV) using the following predictors: counterbalanced posttest, age, annual income, level of education, whether previous chemistry courses were taken, sources of chemistry SE score, pretest chemistry performance and race/ethnicity. It was found that gender was still not significant in influencing performance on the chemistry posttest in the self-efficacy first condition ($\beta = .58, SE=1.13, p>.05$; 95% CI [-1.683, 2.847]), and the chemistry posttest first condition ($\beta = .74, SE=1.12, p>.05$; 95% CI [-1.814, 3.295]). To further test whether females confidence aligned with chemistry posttest performance, another analysis was run and found that males and females did not perform any differently on the chemistry knowledge test, $F(1,171) = 124,12, p >.05$.

_Race/Ethnicity, SE and Chemistry Performance_
To assess how race/ethnicity influences participant response on both SE surveys, several statistical analyses were computed. It was hypothesized that participants who identify as White or East Asian would score higher on SE surveys than participants who identify as other race/ethnicities. Since there was a vast underrepresentation of certain racial or ethnic groups, participants were grouped into: White, African American, Hispanic/Latino and Other categories.

Several correlations were computed to assess the extent that each major racial/ethnic group of respondents in this study completed the pretest surveys. For Black or African American respondents, the following correlation table represents how they responded:

Table 16

<table>
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<tbody>
<tr>
<td>Mastery</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>VL</td>
<td>.650*</td>
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<td>SP</td>
<td>.941*</td>
<td>.653*</td>
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</tr>
<tr>
<td>PR</td>
<td>.262</td>
<td>-.227</td>
<td>.056</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE #2</td>
<td>.806**</td>
<td>.420</td>
<td>.844**</td>
<td>-.108</td>
<td></td>
</tr>
<tr>
<td>C-Pretest</td>
<td>.046</td>
<td>-.051</td>
<td>.029</td>
<td>-.259</td>
<td>.406</td>
</tr>
</tbody>
</table>

**p < 0.01; *p < .05
Note. VL = Vicarious Learning; SP = Social Persuasion; VL = Vicarious Learning; SE #2 = Ideal Gas Laws Self-efficacy Pretest; C-Pretest = Chemistry Pretest

Table 17

For Hispanic or Latino respondents, the following correlation table represents the relationship that they responded:
**EFFECT OF INTERVENTION ON SELF-EFFICACY**

### Bivariate Correlations among Hispanic or Latino Respondents, SE subscale Measures, Ideal gas laws SE scale, Chemistry Pretest

<table>
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<tr>
<td>2. VL</td>
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<tr>
<td>3. SP</td>
<td>.904**</td>
<td>.567</td>
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<td></td>
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<tr>
<td>4. PR</td>
<td>.560</td>
<td>.134</td>
<td>.436</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. SE #2</td>
<td>.685*</td>
<td>.589*</td>
<td>.848**</td>
<td>.364</td>
<td></td>
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</tr>
<tr>
<td>6. C- Pretest</td>
<td>.305</td>
<td>.646*</td>
<td>.219</td>
<td>.103</td>
<td>.391</td>
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</tr>
</tbody>
</table>

**p < 0.01; *p<.05**

**Note.** VL= Vicarious Learning; SP= Social Persuasion; VL= Vicarious Learning; SE #2= Ideal Gas Laws Self-efficacy Pretest; C-Pretest= Chemistry Pretest

### Table 18

For White respondents, the following correlation table represents the relationship that they responded:

### Bivariate Correlations among White Respondents, SE subscale Measures, Ideal gas laws SE scale, Chemistry Pretest

<table>
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<tbody>
<tr>
<td>1. Mastery</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2. VL</td>
<td>.587**</td>
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<tr>
<td>3. SP</td>
<td>.784**</td>
<td>.580**</td>
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<tr>
<td>4. PR</td>
<td>.703**</td>
<td>.441**</td>
<td>.543**</td>
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<td></td>
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</tr>
<tr>
<td>5. SE #2</td>
<td>.760**</td>
<td>.615**</td>
<td>.642**</td>
<td>.631**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. C- Pretest</td>
<td>.392**</td>
<td>.304**</td>
<td>.284**</td>
<td>.322**</td>
<td>.444**</td>
<td></td>
</tr>
</tbody>
</table>

**p < 0.01; *p<.05; Note.** VL= Vicarious Learning; SP= Social Persuasion; VL= Vicarious Learning; SE #2= Ideal Gas Laws Self-efficacy Pretest; C-Pretest= Chemistry Pretest

For multiracial and/or multiethnic respondents, the following correlation table represents
the relationship that they responded:

Table 19

*Bivariate Correlations among Multiracial or Multiethnic, SE subscale Measures, Chemistry Pretest*

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1. Mastery</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2. VL</td>
<td>.449</td>
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</tr>
<tr>
<td>3. SP</td>
<td>.819**</td>
<td>.428</td>
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<td></td>
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<td></td>
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<tr>
<td>4. PR</td>
<td>.524</td>
<td>.342</td>
<td>.264</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. SE #2</td>
<td>.413</td>
<td>.179</td>
<td>.415</td>
<td>.295</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. C-Pretest</td>
<td>.480</td>
<td>.212</td>
<td>.582*</td>
<td>-.026</td>
<td>.784**</td>
<td></td>
</tr>
</tbody>
</table>

**p < 0.01; *p < .05**

Note. VL = Vicarious Learning; SP = Social Persuasion; VL = Vicarious Learning; SE #2 = Ideal Gas Laws Self-efficacy Pretest; C-Pretest = Chemistry Pretest

**Race/Ethnicity & Ideal Gas Laws**

To address the hypothesis that race/ethnicity may influence self-efficacy scores in chemistry, a multiple regression was calculated that regressed race/ethnicity (Independent variable) on pretest ideal gas laws SE survey performance (dependent variable) in the test conditions with the following predictors: age, education level, chemistry pretest score, experience with chemistry courses, SES and gender. There was no significant main effect of race/ethnicity on the pretest ideal gas laws surveys $F(1,171) = .828, p > .05$, partial eta $sq = .364$.

**Race/Ethnicity & Ideal Gas Laws Posttest.** A multiple regression analysis was calculated that regressed race/ethnicity (IV) on posttest ideal gas laws posttest (DV) using
the following predictors: counterbalanced posttest, age, annual income, education level, whether previous chemistry courses were taken, sources of SE pretest, chemistry pretest and gender. There was a significant main effect for race/ethnicity in the group that received the SE surveys first – only Black or African American participants in this group responded differently on the ideal gas laws posttest, $\beta = 19.54, SE = 7.93, p = .01; 95\% CI[3.759, 35.325]$. The model explained 64% variation in the ideal gas laws posttest. In sum, participants who identified as Black or African American responded statistically better than other racial/ethnic groups on the ideal gas laws posttest when they did not have access to the chemistry posttest.

The same model was used to analyze the group that received the chemistry posttest first. There was no significant main effect for race/ethnicity, and Black or African American responses did not predict variation in performance on the ideal gas laws posttest scale, $\beta = 1.89, SE = 6.98, p > .05$.

**Race/Ethnicity & Mastery.** A multiple regression analysis was calculated that regressed race/ethnicity (independent variable) on pretest mastery scores (dependent variable) using the following predictors: age, education level, chemistry pretest score, experience with chemistry courses, SES and gender. There was no significant main effect of race/ethnicity on the pretest mastery survey scores, $F(1,171) = .104, p > .05$, partial $\eta^2 = .748$.

**Sources of SE Posttest.** A multiple regression analysis was calculated that regressed race/ethnicity (IV) on the posttest sources of SE posttest (DV) using the following the following predictors: counterbalanced posttest, age, annual income, education level, whether previous chemistry courses were taken, ideal gas laws pretest,
chemistry pretest and gender. There was a significant main effect for race/ethnicity in the group that received the SE surveys first - only Black or African American participants in this group responded differently on the sources of SE posttest, $\beta = -45.30, SE = 13.19, p = .0001; 95\% \text{ CI} [-71.559, -19.047]$. The model explained 62% variation in the sources of chemistry SE posttest. In sum, participants who identified as Black or African American responded statistically worse than other racial/ethnic groups on the sources of SE posttest when they did not have access to the chemistry posttest.

The same model was used to analyze the group that received the chemistry posttest first. There was no significant main effect for race/ethnicity, and Black or African American responses did not predict variation in performance on the sources of chemistry SE posttest scale, $\beta = -7.12, SE = 10.15, p > .05; 95\% \text{ CI} [-27.336, 13.0884]$.

**Race/Ethnicity & Chemistry Performance**

It was hypothesized that race/ethnicity would influence performance on the chemistry assessments. To assess whether individuals who identify as a specific race/ethnicity respond differently on the chemistry assessment, a one-way ANOVA was calculated using race/ethnicity as the independent variable and chemistry performance as the dependent variable. There was no significant effect of ethnicity on the chemistry performance at the $p < .05$ level in the treatment conditions, $F(6,181) = 1.34, p > .05$.

To explore this further, a multiple regression analysis was calculated that regressed ethnicity (IV), by creating dummy variables for the various categories, on chemistry posttest scores (DV) using the following predictors: age, annual income, level of education, whether previous chemistry courses were taken, sources of chemistry SE, pretest chemistry performance and gender. It was found that race/ethnicity was not
significant in influencing performance on the chemistry posttest in the self efficacy first condition for: Black or African Americans ($\beta = -3.37, SE = 2.78, p > .05; \text{ 95\% CI [-9.118, 1.962]}$), Hispanic or Latinos ($\beta = -1.96, SE = 3.19, p > .05; \text{ 95\% CI [-8.307, 4.385]}$), or Other participants ($\beta = -2.725, SE = 2.12, p > .05; \text{ 95\% CI [-6.955, 1.505]}$).

There were also no differences in how racial or ethnic groups performed on the scale in the group that received the chemistry posttest first for: Black or African Americans ($\beta = -.82, SE = 2.26, p > .05; \text{ 95\% CI [-5.321, 3.677]}$), Hispanic or Latinos ($\beta = -5.96, SE = 1.69, p > .05; \text{ 95\% CI [-3.965, 2.772]}$), or Other participants ($\beta = -.802, SE = 2.43, p > .05; \text{ 95\% CI [-4.052, 5.658]}$).

**Counterbalancing the posttest**

Finally, to assess whether counterbalancing the chemistry posttest with the SE measures influenced performance on SE, multiple regression analyses were calculated. It was hypothesized that participants who took the chemistry posttest prior to taking the SE surveys would have lower ideal gas laws scores and lower mastery/physiological response scores on the sources of SE assessment than participants who viewed the SE surveys first.

**Ideal Gas Laws SE.** A multiple regression analysis was calculated that regressed the counterbalanced posttest (IV) on the ideal gas laws SE posttest (DV) using the following predictors: age, annual income, level of education, chemistry course taken, sources of SE pretest score, chemistry pretest score, gender, race/ethnicity. The treatment group (simulation vs. non simulation group) was found to be significant in predicting variance in the ideal gas laws posttest for participants in the chemistry posttest first group ($\beta = 15.58, SE = 3.45, p = 0; \text{ 95\% CI [8.706, 22.470]}$). The results of the regression
indicated that the predictors above explained 62.5% of the variance ($R^2 = .625$, $F(11,79) = 14.64$, $p = 0$.)

For the group that received the SE surveys first, treatment group (simulation vs. non-simulation) was not found to significantly predict variance in the ideal gas laws posttest, ($\beta = 3.21$, $SE = 3.22$, $p > .05$; 95% CI [-3.204, 9.636]. The results of the regression indicated that the predictors listed above explained a combined 64.8% of the variance, $R^2 = .648$, $F(11,82) = 16.59$, $p = 0$.

In sum, there was a main effect for increased ideal gas laws performance in the treatment group that received the chemistry posttest first. There was no main effect for ideal gas laws performance in the group that received the SE surveys first.

**Sources of Chemistry Self-Efficacy.** A multiple regression analysis was calculated to assess whether groups who had the chemistry posttest first differed from groups who had the SE surveys first. The analysis was calculated regressing the counterbalanced posttest (IV) on the sources of Chemistry SE posttest (DV) using the following predictors: age, annual income, level of education, chemistry course taken, ideal gas laws pretest score, chemistry pretest score, gender, race/ethnicity. The treatment (simulation vs. non simulation group) was found to be significant in predicting variance in the sources of SE posttest for participants in the chemistry posttest first group, $\beta = 9.69$, $SE = 3.65$, $p = .01$; 95% CI [2.423, 16.975]. The results of the regression indicated that the predictors above explained a combined 77% of the variance, $R^2 = .77$, $F(11,90) = 29.33$, $p = 0$.

For participants who received the self-efficacy survey first, the treatment group (whether or not they received the simulation) was not found to be significant in predicting
variance in the sources of SE posttest, $\beta = 1.11, SE = 2.15, p > .05; 95\% CI [-3.181, 5.406]$. The results of the regression indicated that the predictors above explained a combined 93.8% of the variance, $R^2 = .938, F(11,93) = 130.11, p = 0$.

In summary, there was a main effect for increased sources of SE performance in the treatment group that received the chemistry posttest first. There was no main effect for increased sources of SE performance in the group that received the SE surveys first.
CHAPTER 5

Discussion

Summary of Results

The purpose of this research was to assess how using a computer-based simulation can influence self-efficacy in chemistry. The validity of the SE measures were also investigated using factor analyses. The current research study also investigated to what extent the measures predict performance in chemistry. Factors such as race/ethnicity and gender were explored, more specifically on how sources of SE and ideal gas laws differ as a function of group membership. This study also investigated how changing the order of presenting a chemistry posttest could influence feelings about the content being assessed.

In the treatment condition, participants were prompted to read a comic about “The Everful Basketball” that introduced them to an everyday example of Gas laws and Kinetic Molecular Theory. Users then worked through a tutorial that introduced them to the ideal gas laws model. As students interacted with these variables, the interactions were dynamically populated on a graph, consisting of areas where temperature, pressure, and volume can be manipulated. The treatment group was separated into two levels: participants who received the chemistry posttest immediately following the simulation; participants who received the SE surveys immediately following the simulation. Aside from the different sequence of events, both groups received exactly the same measures.

In the control condition, the intervention differed from the simulation. Participants received a narrative on the scientific principles of the changing states solids, liquids and gases. The control group was also separated into two levels: those who received the
chemistry posttest immediately following the narrative; those who received the SE surveys immediately following the narrative. Aside from the different sequence of events, both groups received exactly the same measures.

Participants in all groups scored higher on the ideal gas laws survey after the intervention. The ideal gas laws SE scores were more predictive of student performance in chemistry than the sources of SE chemistry scores. Additionally, gender influenced how participants responded to the ideal gas laws SE pretest and posttest. Race/ethnicity significantly predicted performance on the both surveys, but did not predict differences in chemistry performance. There were also main effects for the order that the posttests were administered. There were statistically significant different SE scores between the simulation group vs. control group for participants who viewed the chemistry posttest prior to viewing the surveys.

It was hypothesized that the ideal gas laws self-efficacy survey will serve as a valid assessment tool for measuring ideal gas laws SE. The survey was developed for this study and asked participants to rate their confidence in their ability to answer questions about ideal gas laws such as “I feel confident explaining what the ideal gas law is”. This scale was given to participants prior to the intervention and after the intervention. To measure the internal consistency of this item, a Cronbachs alpha reliability analysis was calculated on both the pretest and posttest survey. The alpha coefficient for the items in both pretest and posttest ideal gas laws scales was .97. Since the reliability was tested before and after and had the same high score, this suggests that the items on the scale have a high internal consistency. To date, this is the only ideal gas laws SE scale that exists.
The alpha coefficient for the sources of SE scale for both pretest and posttest was .96. However, this does not suggest that the items measure one factor, as evidenced by the factor analysis. Usher and Pajares similarly found that the internal consistency for the sources of SE scale was .95 when assessing middle school students. All sources of SE were significantly correlated with one another, ranging from .33-.81. The strongest relationship was between mastery responses and social persuasion responses. This could suggest that individuals who do well in chemistry at school also receive encouragement from others that they are doing well. The weakest statistically significant association was between physiological response and vicarious learning. This was no surprise since those two constructs should not be nearly as related.

The ideal gas laws SE scale was developed for the purpose of this study because to date, such a scale does not exist and integrating more task-specific SE scales are useful in predicting student SE, and student performance rather than general SE measures (Bandura, 2006). Thus if SE is going to be used in a practical sense, it is useful to develop task-specific SE scales to estimate how students feel they grasp the lesson. The results from the exploratory factor analysis found that the ideal gas laws scale had two factors. This is was surprising since the scale asked participants to rate their confidence in answering specific questions about ideal gas laws. Two questions appeared to belong to a second factor. Both questions asked students to answer how they felt about drawing a line on a graph representing pressure or volume. These two questions may tap more in their confidence in mathematical skills than in ideal gas laws skills. Perhaps if this scale was used again in future research, these two questions should be removed since they do not seem to fit well into the ideal gas laws SE construct.
The results from the exploratory factor analysis found that the sources of science SE scale had four factors which was no surprise since the structure of the survey contained four general themes: mastery, vicarious learning, social persuasion and physiological response. Two variables however did not seem to load as strongly onto any of the four factors: “Many of the adults I know have jobs that involve science” & “My chemistry teachers/professors have told me that I am good at learning chemistry”. These item were originally categorized as vicarious learning and social persuasion factors respectively. The confirmatory factor analysis revealed that the five-factor model fit best, which differed from the findings from Usher & Pajares, 2009 who found a 4 factor solution in their sources of math SE scale. The fifth factor included the following questions:

“Many adults I know have jobs that involve science”

“People I admire are good at science”

“The people I want to be like are mostly people who are involved in science”

The analysis of both surveys provided us with some evidence that these scales have strong internal consistency, and to some extent, have content validity, and therefore can be used to measure sources of self-efficacy in chemistry and ideal gas laws self-efficacy for future research using adults on Amazon Mechanical Turk. The exploratory factor analysis and the confirmatory factor analysis both found similar results with the following question: “Many adults I know have jobs that involve science”. The EFA found that it did not load strongly with the other four factors and the CFA found that this question along with two others belong with a 5th factor. It may be necessary to remove the question all together when studying similar participants again in this context or
organize it its own factor.

The unanticipated fifth factor that was found after running the CFA wasn’t surprising since we tested adults who were using MTurk. This was because the items that were originally designed to access vicarious experience for middle school students would differ for an older population that is more likely to be out of school. It is possible that this specific group responded uniquely to their relationship with individuals who have careers in science not only because they are adults but because of the nature of MTurk workers. Perhaps, if we surveyed middle school or high school students including the same questions, the items would load together with our proposed vicarious learning factor. In the future, when measuring sources of science self-efficacy beliefs in school aged participants, it might be worth it to keep these factors together similarly to the current study and see whether our proposed four-factor solution would be validated. If the study were to be duplicated using adult participants again, it may be necessary to either refine our fifth factor and define it as a separate sub-source of vicarious learning or remove the three questions all together.

**Does the intervention improve SE?**

The following findings from this study are important as they support the value of assessing students on their knowledge following a chemistry lesson. It was hypothesized that there will be a) improvements in ideal gas laws self-efficacy as a result of using a chemistry simulation; b) gains on select questions of the sources of chemistry SE survey. To summarize, the results obtained from the measures ANOVA that measured differences from ideal gas laws SE pretest to posttest performance found that there was a statistically significant increase for participants in both groups: the simulation group and
the control group. In other words, participants felt more confident about the topic being assessed after having a lesson about it. This result implies that participants in the treatment group felt more confident in their ability to answer questions about ideal gas laws after receiving the chemistry based simulation. This is no surprise since the treatment condition consisted entirely of topics related to ideal gas laws. The narrative explained real world examples of how ideal gas laws can be applied in a situation where pressure and volume and temperature are interrelated. The treatment group also received the simulation that allowed participants to manipulate this information in a model container and see how these changes can be applied to a graph. Interestingly, the treatment group that received the chemistry posttest immediately following the simulation had more confidence in their ability to learn about/apply the ideal gas law than participants in the treatment group that received the ideal gas laws posttest SE survey following the treatment. This can be interpreted as participants who took the posttest first thought they understood the material and did well on the posttest so they felt even more confident in their ideal gas laws SE.

Surprisingly there was a slight gain in ideal gas laws SE among participants in the control group who received no information about ideal gas laws in their training. This suggests that participants who receive inaccurate teaching may have a misconception about their own ability in the topic at hand. This finding is concerning for educators that are invested in increasing self-efficacy in students but would like for these beliefs to align with performance. If students are feeling better about their ability to complete a task with little to no proper training, this speaks to the notion that self-efficacy scores should always be taken with caution and are not always reflective of ability. An interaction was
found between type of treatment group and change in participants’ scores on the ideal gas laws SE scales. This suggests that the way material that participants received from the conditions interacted with the way that they felt about their ability to complete that specific task they did or did not master.

Taken together, the main findings are consistent with current SE research in technology-based interventions and SE. Similar SE research has found that using a virtual intervention can enhance student science SE. Meluso et al. (2012) found that students who played a virtual science game (Crystal Island) had an increase in science SE and an increase in science knowledge performance in both collaborate and competitive groups. More online simulations and games should be used in chemistry education to get students more interested and engaged in these topics.

In addition to the ideal gas laws survey, the Sources of Chemistry SE survey was administered to participants before and after the intervention. This was necessary because participants may have changed their outlook on how they feel about chemistry after the intervention (i.e., they may feel more or less of a sense of mastery after engaging in the simulation itself and experiential learning may improve feelings of mastery). Participants in the control condition felt less mastery in chemistry after completing the solids, liquids and gases narrative task. Participants in the treatment condition felt about the same after competing the computer-based simulation. It was not surprising that participants felt worse about their mastery after completing the control task perhaps because the information portrayed in this narrative was not related to the types of questions that they were receiving about ideal gas laws. Hence, this may have led to more confusion among the participants and decreased their sense of mastery in chemistry.
Together, these findings imply that testing is an important indicator for participants to understand whether they believe they grasp the material being assessed. Low-stakes testing (quizzing immediately after a lesson), has been studied to assess whether it fosters long term learning. Research has shown that final test performance is always better when quizzes are administered after a lesson (McDaniel, Agarwal, Huelser, McDermitt, & Roediger, 2011). Quizzing helps students activate and retrieve information acquired during the lesson and this has been shown to improve overall memory about the content (Carpenter & DeLosh, 2006). In addition to influencing memory, testing also enable learners to assess what they do know versus what they do not know. Judgments of Learning (JOL) are important in fostering one’s performance diagnoses. This will impact future self-regulatory actions about further studying and improving metacognitive awareness about knowledge on the lesson material (Kornell & Son, 2009). Adults are able to discriminate between correct and incorrect item responses they took on a test (Finn & Metcalfe, 2014; Gardiner & Klee, 1976). It would however be useful to see whether judgments of learning are accurately assessed in this simulation for younger students who have less accurate judgments of learning (Finn & Metcalfe, 2014). Hence, not only is testing important for teachers to gage their students understanding level, it is also essential for students. Assessments can be a great way for students to more accurately evaluate what they do know, how confident they feel about it, and whether they need to continue studying to acquire more information.

**SE as Prediction Tools**

The following findings from the current study are viewed as important because Chemistry SE measurement tools have previously been found to predict Chemistry grade
performance (Zusho, Pintrinch & Coppolla, 2003). It was important to assess to what extent the SE measurements used in this study predict success in our chemistry assessments. It was hypothesized that scores on both SE surveys would predict student performance in chemistry. The results verified that scores on both surveys somewhat predicted student performance on the chemistry pretest and chemistry posttest. To summarize, the magnitude of variance the sources of chemistry SE pretest had on the chemistry pretest was 11.3%. The magnitude of variance the ideal gas laws had on the chemistry pretest was higher (19.9%). The increased predictive value of ideal gas laws SE was no surprise since the survey asked questions specific to the topic being assessed. Thus, it should have been a more predictive assessment of performance. It was no surprise that the general sources of Chemistry SE scale was not as predictive because it includes items about where one draws their SE from (family, friends, experiences and feelings).

These results align with the current literature on the usefulness of SE as a predictor to performance. Pajares and Kranzler (1995) found that SE beliefs may be more predictive in their academic performance than their intelligence or ability. The control group had increases in ideal gas laws but did not have increases in chemistry performance. This overconfidence is not unusual - high performance in SE measures do not always guarantee high performance in the domain being assessed (Champion, 2009). This sense of overconfidence is known as the “illusion of knowing” effect: when young adults have an overconfidence in an area but had inadequate learning because of “premature termination of cognitive processing” (Lin and Zabrucky, p. 384, 1998). Perhaps poor/inaccurate teaching could negatively impact student’s calibration judgments
about their performance. This field of study in particularly in STEM SE would be interesting and should warrant further investigation.

To assess which “source” of SE was more useful in predicting chemistry performance, it was found that mastery in the pretest was the strongest predictor on chemistry scores. Most literature in this field investigates how previous mastery experiences influence SE, however less research investigates how previous mastery scores on a sources of SE assessment influences grades on a chemistry test. It was no surprise that mastery was found to be the strongest predictor in grade performance in the chemistry since previous mastery experiences are the most useful in guiding future grades (Sawtelle et al., 2012). Mastery scores in sources of SE measurement scales have been historically viewed as the most useful and powerful source of self-efficacy building information (Bandura, 1997). Perhaps, rather than concerning ourselves with how strong the relationship between mastery scores and task-specific self-efficacy scales are, the sources of SE scale might be more useful as a separate diagnostic tool. It is possible that such assessments can help us see get a sense of how groups of people differ in how they develop their self-efficacy beliefs in a particular area. For instance, if we know that men vs. women differ in how they feel during high stakes taking environments, we can find ways for certain groups to cope with these anxieties that would typically impede their ability to be successful with these tests. It might also be useful in such scales to assess other mental experiences associated with a particular task such as transformative experiences (e.g., how a person imagines themselves completing a task successfully) (Maddux, 2009). Additionally, the literature on decreasing attrition for traditionally underrepresented groups in STEM programs addresses the importance of students’ sense
of belongingness. Studies have found that when students feel a greater sense of belongingness, they are more likely to be successful in completing the program (i.e., women in engineering). Addressing belongingness measures in social persuasion or vicarious learning subscales of sources of self-efficacy, could help us gain a deeper understanding of how at-risk populations could benefit from having a greater social community or network (Stout, Dasgupta, Husinger, & McManus, 2011). Taken together, individuals may weigh various sources of self-efficacy differently from one another, and also throughout their life. Although, taken separately, each of these constructs may not directly correlate with how a person performs on a specific task or how they believe they perform in a particular area, these sources are useful in helping us access the larger picture of the complexity of how success is achieved. The development of mastery, along with having a strong sense of self-efficacy on a particular task, appears to be multidimensional.

In many research studies, the sources of SE scales aren’t typically measured as a diagnostic tool in predicting performance on a particular task. These scales are typically used to compare how experiences with “sources” relate to beliefs of self-efficacy. Often, such tools are used to assess group differences, particularly in areas where there are often gaps in academic performance (i.e., writing or math).

When self-efficacy is measured in other research studies, it is often used as a tool to correlate the extent that scores relate to other measures such as self-esteem, academic self-concept, optimism, GPA, SAT or GRE scores. Most often, rather than task-specific scales, general and academic self-efficacy scales are more frequently used to compare performance with other academic constructs. As mentioned in the literature review,
research findings varies with how task-specific SE scales compare to performances on a task because of the nature of how tasks vastly differ from one another (ex. Exercising vs. conducting a science experiment).

The purpose both scales of SE were measured in this study was because they were necessary in helping reveal how feelings of a task and sources of self-efficacy are both related to how people perform on that task. Since one of the primary research questions was to see whether men and women differ in how they felt in their ability to perform the chemistry tasks, it was important to use both self-efficacy measures to see if there were task-related differences and also, experience related differences in chemistry. It was essential to look beyond the task of the study to see whether there were any different experiences that participants reported with the topic of chemistry (e.g., did women or men receive more or less encouragement; did women or men feel different levels of anxiety when they thought about with chemistry). If differences emerged, it was important to understand whether it was exclusively a task that groups felt differently about, or was it previous experiences related to chemistry. Since the task was presented online, individuals may have not felt as strongly about the task because of the nature of the low-stakes environment of MTurk. Thus, it was important to use both measures to see if they compliment or differ widely from one another.

Although it may not be practical to assess self-efficacy for each individual on each task at school, perhaps it would be useful in future research to study how academic self-efficacy tasks relate to a variety of unrelated task-specific scales. If a diverse number of self-efficacy tasks all strongly correlate with academic self-efficacy, it may be more time efficient to assess academic self-efficacy for students at the beginning of the school
year. This could help educators find out where students lie in the spectrum of confidence in academics and work with students who need more in-class support.

**Gender, SE and Chemistry Performance**

It was also hypothesized that gender will influence how participants respond to both SE surveys, such that males will score higher than females on the ideal gas laws SE survey and the sources of chemistry SE survey. The extent to which gender plays a role in chemistry SE was deemed an important area of investigation because of the countless research studies that demonstrates the vast underrepresentation of females in STEM fields. To summarize the findings, males outperformed females on the pretest and posttest ideal gas laws SE survey. Upon further investigation, it was found that these gender differences were changed once the chemistry posttest was broken into two groups—participants who received the chemistry posttest and participants who did not yet receive the posttest. The females who first viewed the chemistry posttest did not feel any differently from males about ideal gas laws SE. The females who did not view the chemistry posttest first felt worse about ideal gas laws than their male counterparts.

The main finding above was not surprising as extensive literature finds that females feel less confident about science subjects, particularly adult females. Schunk and Pajares (2002) similarly found that males have higher STEM SE and are much more likely to follow career paths in STEM and become more successful than females. Huang’s (2013) meta-analysis also found that the gender effect for STEM SE gets stronger for people in high school and beyond. This aligns with the current research study as the sample being tested had individuals ranging from age 18-72. According to Hewlett (2008), females who enroll in STEM courses begin to feel more intimidated by the
content and are more likely to give up earlier. Perhaps the females in this sample felt intimidated by the content and as a result, felt less confident than males.

Additionally, males have been shown to have more of an advantage for tasks that require visual-spatial skills (Moore & Johnson, 2008). The computer-based simulation specifically taps into visual spatial skills by having participants work through a tutorial that introduces the gas laws model. Then the model uses the dynamic submicroscopic particles to help users understand the observed behavior of the “Everful Basketball phenomena”. Participants interact with the variables in the model container than each of these interactions gets recorded on a graph. Other studies found that males are better at obtaining data from vertical or horizontal graphs than females (Lowrie & Diezmann, 2011). Males may have felt that they simply got more out of the chemistry-based simulation than their female counterparts. Perhaps males may have benefitted more from the graph data interactions than females. Additionally, visual treatment interventions may work better for male self-efficacy then female self-efficacy. Some greater implications from this result is that females may need more verbal teaching interventions in science classrooms. In addition to tapping into visual spatial skills for learning, having more in depth classroom discussions about science concepts might benefit females even more.

It was interesting that gender differences were removed once females saw the chemistry test and felt just as competent as males in answering questions about ideal gas laws. Regularly providing students with assessments can improve their confidence and skill level -this could be an important development in the field of SE as it relates to gender.
The fact that females demonstrated that they were just at competent at understanding and applying the ideal gas law was not surprising since it is evident that males and females possess equal ability in science (Spelke).

In regard to whether males and females draw from sources of SE in different way, the current study found no statistically significant differences between how males and females responded to each of the subscales. This misaligns with the current literature on gender differences in responses to sources of self-efficacy. Zeldin and Pajares (2000) found in their qualitative analysis that female SE stems more from social experiences such as receiving encouragement of others and experiencing vicarious learning while male SE stems more from mastery experiences. The current study found no differences in how gender influences how individuals draw from sources of SE. It is possible that the way that males and females develop their self efficacy about chemistry is not necessarily different - perhaps previous mastery experiences are the most influential in shaping SE in all individuals.

Yet, rather than overgeneralizing our findings to the broad population, it is important to acknowledge that gender differences and self-efficacy are context dependent. We may view gender differences for men and women in one situation yet those differences would disappear in a separate context. Men and women who opt to use MTurk as a tool for earning an income may share more similarities to each another in this context. They are using technology in a novel sense and this interface is not readily accessible or knowledgeable by all. Based on studies that examined the demographics of MTurk workers, they are more likely to have a college education (Behrend, 2011), and it is possible that they are in a similar life situation (using MTurk as a part time gig, in their
30s, etc.). As mentioned, gender differences in self-efficacy vary in different circumstances. Researchers reported that gender differences were the greatest later in life and the least in elementary school (Huang, 2013), particularly when it came to STEM focused subjects. It might be interesting to see how these findings could transfer to a college setting since gaps in self-efficacy beliefs seem to be largest for these groups of individuals.

It was also hypothesized that race/ethnicity would influence how participants respond to both surveys such that students who are White or East Asian will score higher on the ideal gas laws SE survey and mastery questions from the sources of SE survey than students of other ethnicities. The extent to which race and ethnicity plays a role in chemistry SE was deemed an important area of investigation. A vast underrepresentation of minorities (Black or African American, Hispanic or Latino, SE Asian, Native American participants) occurs in STEM fields, and understanding SE may reveal more on why disproportionately less students of various racial or ethnic groups pursue these careers. To summarize the findings from the current study, a multiple regression analysis revealed that race was a significant factor in predicting variance in the ideal gas laws posttest and the sources of SE posttest only for participants who received the SE surveys prior to the chemistry posttest. Participants who received the chemistry posttest first had no differences in survey performance. This could be interpreted as participants who did not see the posttest had different levels of self-efficacy than other racial or ethnic groups. Black or African American participants felt more confident than other racial or ethnic groups about ideal gas laws when they did not view the chemistry posttest. On the other hand, Black or African American participants felt worse about how they drew sources of
chemistry SE when they did not view the chemistry knowledge posttest. This was not the case for participants who saw the chemistry posttest since no differences were found between groups. Participants in this group may have had a better understanding of what they do/do not know once they access the posttest.

This finding supports the general theme of this study: assessing individuals immediately following a lesson seems to provide a more accurate portrayal of how individuals view their ability on a task. This is one of the first studies that investigates race/ethnicity and its relationship to Chemistry SE in adults using an online simulation, and how having access to a knowledge posttest influences SE. Test taking serves as a valuable tool for individuals to have a more accurate representation of what they do know/do not know. The current findings can also be taken with literature on how race and ethnicity influences participants science SE. Perry, Link, Boeler, & Leukfelt (2012) found that white students have higher SE for completing a science course than African American students. Britner and Pajares (2001) also found that middle school students science SE was greater for White students than African American students. Perhaps if these students in the above studies were tested immediately following a lesson, differences in SE may disappear.

These results add to the current literature on race/ethnicity and SE, however these results should be taken with caution. First, there was not enough representation of all racial and ethnic groups to make true claims about the general population. Although the demographic group included in this study was slightly more representative of the US population than a typical college setting, it still wasn’t diverse enough to make true claims about the general population. The main racial group being studied was White
Further testing is recommended in future research to assess whether any true differences in SE occur among different ethnic or racial groups in the general population. The MTurk subject pool has limitations of its own – people with access to an online crowdsourcing marketplace, people of higher education levels, a greater proportion of women & adults. Thus generalizations about the US population should be taken with caution when using the MTurk subject pool. Individuals who participated in this study most likely had internet access at home and may have been in more of an economically advantaged position. The outcome of this research study may not necessarily transfer to those in environments where this type of technology/internet access isn’t as readily accessible.

Another research question tested for this study was that gender/ethnicity will influence performance in the chemistry post-test. This question warranted investigation because of the enormous underrepresentation of females and URM in STEM track degree programs. It was important to investigate whether self-efficacy beliefs have anything to do with having mastery in chemistry. However, this hypothesis was not supported by the findings. The results from the current study found that there were no differences in the chemistry posttest for males and females, and for various racial/ethnic groups. The fact that gender did not influence performance on the chemistry measure was not surprising given the literature that males and females are equally skilled in science (Spelke, 2005). Additionally, it wasn’t surprising that ethnicity or race had nothing to do with performance on the chemistry posttest. Since over 84% of the participants in the study (~84%) while the rest of the participants fell into Hispanic/Latino, Black or African American, Native American, Asian and Mixed ethnic or racial group.
were Caucasian, the sample didn’t have enough variability to make any true claims about the general population. Additionally, if there are racial or ethnic differences in chemistry performance, it would have more to do with individuals coming from families of low SES with less academic resources rather than having any inherent differences in ability. The MTurk population represents adults who have regular access to internet who may not necessarily come from places of low SES with less academic resources.

The final hypothesis tested for this study was that the order the chemistry post-test is administered will influence performance on both SE measures. It was hypothesized that participants who take the chemistry post-test prior to taking the SE surveys will exhibit lower ideal gas laws SE scores and lower scores on the sources of SE survey than participants who take the surveys before the chemistry post-test. The justification for this research question was that this may give us further insight on how taking knowledge tests can have an immediate impact on confidence levels. If SE differs as a result of taking the posttest, this could help us understand the malleability of SE. The results from the present study found a main effect for order of test administration.

**Ideal Gas Laws SE**

Viewing the chemistry posttest first improved scores in ideal gas laws SE. The results from this analysis found statistically significant differences between the simulation and control group that received the chemistry posttest prior to the SE surveys. There were no differences between the simulation and control group that received the SE surveys before chemistry posttest. Another words, the treatment condition influenced participant response on the ideal gas laws SE for those who received the chemistry posttest. The treatment group did not influence participant response on the ideal gas laws
SE for those who did not yet receive the chemistry posttest. This could be interpreted as participants who took a test had a greater understanding of what they do/do not feel confident in. Participants who did not take a test believed they were equally capable at answering questions about ideal gas laws regardless of what intervention they received.

Sources of SE

There were also statistically significant differences between the simulation group and control group that received the chemistry posttest before the SE surveys. There were no differences between the simulation group and control group that received the SE surveys before chemistry posttest. Another words, the treatment condition influenced participant response on the sources of SE for those who received the chemistry posttest. The treatment group did not influence participant response on the sources of SE for those who did not yet receive the chemistry posttest. It was surprising that participant responses differed between the simulation vs. non simulation group in the sources of SE survey. It seems that taking a difficult posttest with little to no prior knowledge on the topic may decrease individual perception on the overall topic being tested on.

Interestingly, in addition to questions on previous mastery and physiological response, the sources of SE scale assessed feelings on social persuasions and vicarious learning which should not change over the course of the experiment.

Implications for these findings are that it may be best to assess SE immediately after someone completes an assessment rather than after a lesson. When students receive an assessment, they can have a better handle on how they feel about the content. This way, more accurate measures of individual perception on the task can be found. It would be interesting to see whether participants that scored high on SE measures in the
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treatment posttest first group would also perform just as well, and feel just as confident after even further delays (one week or one month).

**Strengths and Limitations**

The present study examined how a computer-based simulation can influence chemistry SE in adults through an online crowdsourcing marketplace. Participants were randomly assigned to treatment and control conditions and this allows for the differences to be attributed to the treatment variables rather than external factors not related to the study. Out of the 200 MTurk workers that participated in this study, 186 were used in the analysis. To date, this is the first research study that examined chemistry self-efficacy in adults through MTurk. MTurk workers are more diverse than a typical college setting (Behrend, Sharek Mease, & Wiebe, 2011), younger and more educated females (Schank, 2015). Because this is a particular group being studied, external validity issues are threatened and this study should be replicated among students in school.

Threats to internal validity were addressed in this study. Pretest chemistry scores were used as covariates in most of the analyses, since prior chemistry knowledge could influence confidence levels in chemistry as well as chemistry performance. Additionally, since this study was completed entirely online, there were no experimenter bias issues. Both treatment groups were engaged in the activities for about the same amount of time so time on task was addressed.

Many limitations of this study should be addressed. In the present study, it was not a requirement for participants to be enrolled in school. The results from the study may not necessarily generalize to younger school age populations and this may pose threats to external validity. To address this issue, participants indicated their age, whether they
enrolled in chemistry courses and how long it has been since their last chemistry course. Though the current study examined adult chemistry SE, it informed us on how SE changes throughout adulthood with regard to courses taken earlier in life.

Further limitations with this study include the nature of conducting research online. Participants using MTurk are likely participating in the experiment in the comfort of their home. The home environment has more distractions and there is less accountability than there would be in an experimental setting such as a school or laboratory. During the experiment, participants could be clicking on other websites, watching television, interacting with other individuals in the home and not placing their full attention/effort on the task. In turn, this experiment may have replicated more of a homework setting than a lab research setting. Further, participants in the present study may not have been exploring the simulation thoroughly. If participants do not explore the simulation, they may not benefit from the intervention. To address this, participants who clicked less than 3 times during the simulation were removed from the analysis.

There was no way to guarantee that participants were responding to the questions honestly and to the best of their ability. Participants could have clicked through the questionnaires and knowledge tests without reading them through. To address this, some reverse coded items were added into the surveys and participants that answered the same way throughout all the survey (including the reverse coded items) were removed from the analysis. Additionally, time spent on the assessments were recorded, and participants that spent less than three minutes on the knowledge pre-test and post-test were removed from the analysis. Participants that spent less than 15 seconds on the SE surveys were removed from the analysis.
The sources of Chemistry SE scale was originally developed for middle school math students to rate where they draw sources of math SE. For instance, in the vicarious and social persuasion portions of the scale, participants are asked to rate the degree to which professionals and classroom peers expose them or encourage them in chemistry and science. MTurk participants may not currently have such influences but rather may recall back to when they were students in school—this may not be as accurate due to the time lapse. Since most participants are in the workforce and have less vicarious experiences and social encouragement to do chemistry, they may be responding according to their current situation.

Another limitation was that participants may have felt fatigued by the end of the experiment since it was over an hour long. Perhaps they may not have performed as well on the last few tasks as a result of being fatigued and less motivated. This threat to internal validity was addressed as the last few tasks were counterbalanced. Future research should consider running these studies in a school setting over an extended period of time to see to what extent SE changes throughout many training opportunities and greater lapses of time.

Further research should consider to what extent race/ethnicity plays a role in SE in chemistry since the present study did not have enough representation of participants from all groups. There is still a need to better understand how race/ethnicity influences SE in STEM fields. Other fields in STEM that are even more unbalanced (physics, engineering, computer science) should be similarly researched to better understand why such a vast underrepresentation exists.
Future research should also explore grit and perseverance since these are characteristics that successful people hold, even more so than talent. It would be interesting to see how grit relates to SE and how it influences academic performance in chemistry. Since grit seems to be a personality trait, researchers are currently investigating concrete interventions that could be applied to individuals who may not have those characteristics (Duckworth, 2007).

In subsequent studies, it would also be worth exploring how females perform on the chemistry SE scale in other countries with less gender differences in math and science. According to the PISA (2009) of the 65 countries tested worldwide, 15 year old boys and girls typically perform about the same in science (with the exception of the US and a few other countries). In Albania, Dubai, Qatar, Jordan, Finland, Slovenia, & Turkey, girls outperform boys in science by at least 10 points. It would be interesting to assess the girls’ chemistry SE in countries where there is no gender gap in science performance, or countries where girls outperform boys in the science. Since MTurk is used internationally, it can be used as a great tool to investigate SE among citizens of other countries.

The development of more domain specific SE scales in STEM fields can be considered a useful step in identifying SE and its relationship to the topic being assessed. Based on the findings from the present study, it might be more useful for educators to assess student SE soon after receiving an assessment on a topic rather than at other points during a lesson. This may be more beneficial with regard to the predictive value that SE has on academics. The ideal gas laws survey and sources of chemistry SE scale may be used both by schools and universities to collect information about student feelings in
chemistry. The sources of SE scale may be useful in understanding where SE beliefs stem from on an individual level. Looking at this might be especially useful for women and minority students in the STEM field and can at least bring more awareness to these targeted groups about the existing underrepresentation.

In summary, for the current study, we developed a task specific SE scale to assess individual SE in ideal gas laws in the field of chemistry. We validated the scale using the exploratory factor analysis and found this scale measured two separate factors. We also measured sources of SE beliefs, which informed us on how participants draw their science SE beliefs. We validated the scale using confirmatory and exploratory factor analysis and found that this scale measures four factors. Data from these surveys were analyzed based around gender and underrepresented minority status. Females were less confident in their ability to complete tasks in ideal gas laws. Ethnic or Racial status did not influence response on the scales. To assess the extent to which SE can be influenced by a computer-based intervention, we measured SE beliefs prior and after the treatment. We found that SE beliefs in ideal gas laws improved and the groups that received the ideal gas laws simulation felt more confident in their ability to complete tasks in this subject. To assess whether receiving a test prior to completing a SE survey influences responses on the SE scales, we altered the order of presentation of assessments for four groups. We found that ideal gas laws SE was worse for females who did not have access to the chemistry posttest. We found that sources of SE was worse for African or Black participants if they did not see the test. We found that ideal gas laws SE was better for African or Black participants that did not see the test. These differences were removed for participants who first had access to the chemistry posttest.
APPENDIX A

Sources of Chemistry Self-efficacy

Please rate your degree of confidence by recording a number from 1 to 7 using the scale given below:
1…………………………………………4……………………………………………………………………..7
definitely false neither true nor false definitely true

Mastery:
1) “I make excellent grades on chemistry tests”
2) “I have always been successful with chemistry”
3) “Even when I study very hard, I do poorly in chemistry”
4) “I got good grades in chemistry class”
5) “I do well on chemistry assignments”
6) “I do well on even the most difficult chemistry assignments”
14) “I imagine myself working through challenging chemistry problems successfully”

Vicarious Learning:
7) “Seeing professionals do well in chemistry pushes me to do better”
8) When I see how my chemistry teacher/professor solves a problem, I can picture myself solving the problem in the same way”
9) “Seeing others do better than me in chemistry pushes me to do better”
10) “Many of the adults I know have jobs that involve science”
11) “People I admire are good at science”
12) “The people I want to be like are mostly people who are involved in science”
13) “When I see another classmate solve a chemistry problem, I can see myself solving the problem in the same way”

Social Persuasion:
15) “My chemistry teachers/professors have told ME that I am good at learning chemistry”
16) “People have told me that I have a talent for chemistry”
17) “Adults in my family have told me what a good chemistry student I am”
18) “I have been praised for my ability in chemistry”
19) “Other students have told me that I’m good at learning chemistry”
20) “My classmates like to work with me in chemistry because they think I am good at it”

Physiological Response:
21) “Just being in chemistry class makes me feel stressed and nervous”
22) “Doing chemistry work takes all of my energy”
23) “I start to feel stressed-out as soon as I begin my chemistry HW”
24) “My mind goes blank and I am unable to think clearly when doing chemistry work”
25) “I get depressed when I think about learning chemistry”
26) “My whole body becomes tense when I have to do chemistry”
APPENDIX B

IDEAL GAS LAWS SELF-EFFICACY SURVEY

Rate your degree of confidence by recording a number from 1 to 7 using the scale given below:

1……………………………………………..4……………………………………………..7
definitely false……………………………………………..neither true nor false……………………………………………..definitely true

1) “I feel confident using a chemistry-based simulation to learn about ideal gas laws”
2) “I feel confident explaining what the ideal gas law is”
3) “I feel confident that I am able to apply the ideal gas law”
4) “I feel confident answering questions about temperature affecting pressure”
5) “I feel confident answering questions about pressure affecting volume”
6) “I feel confident answering questions about pressure affecting temperature”
7) “I feel confident answering questions about temperature affecting volume”
8) “I feel confident answering questions about volume affecting temperature”
9) “I feel confident answering questions about volume affecting pressure”
10) “I feel confident answering a question about what happens to gas particles when you raise or lower the temperature”
11) “I feel confident answering a question about what happens to gas particles when you increase or decrease the pressure”
12) “I feel confident answering a question about what happens to gas particles when you increase or decrease the volume”
13) “In a basketball, as the air inside the ball gets colder, I feel confident drawing a line on a graph representing the volume”
14) “In a basketball, as the air inside the ball gets warmer, I feel confident drawing a line on a graph representing the pressure”
15) “I feel anxious taking a chemistry knowledge test”
16) “I feel anxious at the thought of learning about ideal gas laws.”
APPENDIX C

CONTROL CONDITION

The Changing States of Solids, Liquids, and Gases
Series: The Essentials of Chemistry Basics

When a substance goes from one state of matter — solid, liquid, or gas — to another state of matter, the process is a change of state. Some rather interesting things occur during this process.

Melting point as a chemistry concept

If you measure the temperature of a chunk of ice, you may find it to be –5° Celsius or so. If you take temperature readings while heating the ice in a pot on your stove, you find that the temperature of the ice begins to rise as the heat from the stove causes the ice particles to begin vibrating faster and faster.

After a while, some of the particles move so fast that they break free of the crystal lattice (which keeps a solid solid), and the lattice eventually breaks apart. The solid begins to go from a solid state to a liquid state — a process called melting. The temperature at which melting occurs is the melting point (mp) of the substance. The melting point for ice is 32° Fahrenheit, or 0° Celsius.

If you watch the temperature of ice as it melts, you see that the temperature remains steady at 0°C until all the ice has melted. During changes of state (phase changes), the temperature remains constant even though the liquid contains more energy than the ice (because the particles in liquids move faster than the particles in solids).

Boiling point of water

If you heat a pot of cool water, the temperature of the water rises and the particles move faster and faster as they absorb the heat. The temperature rises until the water reaches the next change of state — boiling. As the particles move faster and faster, they begin to break the attractive forces between each other and move freely as steam — a gas.

The process by which a substance moves from the liquid state to the gaseous state is called boiling. The temperature at which a liquid begins to boil is called the boiling point (bp). The bp is dependent on atmospheric pressure, but for water at sea level, it’s 212°F, or 100°C. The temperature of the boiling water will remain constant until all the water has been converted to steam.

You can summarize the process of water changing from a solid to a liquid to a gas in this way:

ice → water → steam
Because the basic particle in ice, water, and steam is the water molecule, the same process can also be shown as:

\[ H_2O(s) \rightarrow H_2O(l) \rightarrow H_2O(g) \]

Here the (s) stands for solid, the (l) stands for liquid, and the (g) stands for gas. Unlike water, most chemical substances don’t have different names for the solid, liquid, and gas forms.

**Freezing point of a substance**

If you cool a gaseous substance, you can watch the phase changes that occur. The phase changes are:

- **Condensation** — going from a gas to a liquid
- **Freezing** — going from a liquid to a solid

The gas particles have a high amount of energy, but as they’re cooled, that energy is reduced. The attractive forces now have a chance to draw the particles closer together, forming a liquid. This process is called condensation. The particles are now in clumps, but as more energy is removed by cooling, the particles start to align themselves, and a solid is formed. This is known as freezing. The temperature at which this occurs is called the freezing point (fp) of the substance.

You can represent water changing states from a gas to a solid like this:

\[ H_2O(g) \rightarrow H_2O(l) \rightarrow H_2O(s) \]

**Sublimation**

Most substances go through the logical progression from solid to liquid to gas as they’re heated — or vice versa as they’re cooled. But a few substances go directly from the solid to the gaseous state without ever becoming a liquid. Scientists call this process sublimation. Dry ice — solid carbon dioxide — is the classic example of sublimation.

You can see dry ice particles becoming smaller as the solid begins to turn into a gas, but no liquid is formed during this phase change.

The process of sublimation is represented as:

\[ CO_2(s) \rightarrow CO_2(g) \]

In addition to dry ice, mothballs and certain solid air fresheners also go through the process of sublimation. The reverse of sublimation is deposition — going directly from a gaseous state to a solid state.
APPENDIX D

BACKGROUND INFORMATION QUESTIONNAIRE

1. Age: _____

2. Gender: female  male

3. Annual Household Income: _____________________

4. Ethnicity (Mark one or more to best indicate what you consider yourself to be).
   - American Indian/Alaska Native
   - Asian
   - Black or African American
   - Hispanic or Latino
   - Native Hawaiian or Other Pacific Islander
   - White
   - Other (specify ____________)

5. Language(s) spoken at home
   - We speak mostly: ________________
   - We also speak: ________________

6. Are you currently enrolled in a College or University?
   - Yes
   - No

7. Level of education
   - no HS diploma
   - high school graduate
   - some college
   - college graduate
   - graduate or professional degree

8. Have you ever taken a chemistry course (Y/N) _______

9. What (if any) chemistry courses have you taken?
Please also indicate if you are currently enrolled in one.

10. Number of years since last Chemistry course (if applicable) ______

11. Number of years since high school ______

12. Number of years since college (indicate N/A if this question doesn’t apply to you) ______

13. Have you ever used computers to learn about science? (Check all that apply).
   - Yes, I have used the Internet to do research on a science topic.
   - Yes, I have used computers to get materials that a teacher assigned or suggested.
   - Yes, I have taken science tests on a computer.
   - Yes, I have looked at or used science demonstrations or simulations on the computer.
   - Yes, a teacher has shown my class some stuff about science on the computer.
   - No, I have never used computers to learn about science before.

14. Have you used simulations to learn about chemistry before?
   - Yes
   - No
   - I don’t know
APPENDIX E

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Title of Research Study: Effect of Intervention on Self-Efficacy

Principal Investigator: Yolanta Kornak-Bozza, M.A., M.Phil.  
Graduate Student

Faculty Advisor: Dr. Bruce Homer, Ph.D.  
Associate Professor

Research Sponsor: Doctoral Student Research Grant

You are being asked to participate in a research study because we want to learn more about how self-efficacy plays a role in chemistry content knowledge. Your participation in the study will contribute to a better understanding of chemistry self-efficacy for students. We are asking a total of 200 individuals to participate in our study.

Purpose:
The purpose of this research study is to find out how chemistry self-efficacy contributes to performance on chemistry knowledge tests.

Procedures:
If you volunteer to participate in this research study, we will ask you to do the following:

- Complete 2 surveys about chemistry self-efficacy. These surveys ask questions about your feelings towards chemistry. Each survey should take about 2-3 minutes
- Take 2 chemistry knowledge tests. These tests include some multiple-choice and short answer questions about ideal gas laws. Each should take about 10-15 minutes.
- Participate in a chemistry lesson which should take about 20 minutes
- Complete a survey that asks questions about your age, gender, how long it’s been since you last took chemistry, etc. This should take about two minutes.

Time Commitment:
Your participation in this research study is expected to last for a total of 1 hour.
**Potential Risks or Discomforts:**

- Participating in the experiment may place you at risk of experiencing fatigue since the experiment lasts for up to one hour. You may withdraw at any time, if you choose to discontinue for any (or no) reason.

**Potential Benefits:**

You will not directly benefit from your participation in this research study. The potential benefits that society may receive from this research is that the educational research community may learn more about how self-efficacy (and how the sources that are drawn from self-efficacy) can influence chemistry learning.

**Payment for Participation:**

You will receive $1.41 for participating and completing this research study in full. The money will be debited directly to your Amazon Mechanical Turk account.

**Confidentiality:**

We will make our best efforts to maintain confidentiality of any information that is collected during this research study, and that can identify your worker ID #. We will disclose this information only with your permission or as required by law. Your Amazon account information will be kept while we collect data for tracking purposes only. This information will be stripped from the final dataset.

We will protect your confidentiality through the following methods:
- Each participant worker ID # will be assigned a random identifier in the form of a four digit number.
- Codes linking worker ID numbers will be stored in a password protected computer file.

The research team, authorized CUNY staff, and government agencies that oversee this type of research may have access to research data and records in order to monitor the research. Research records provided to authorized, non-CUNY individuals will not contain identifiable information about you. Publications and/or presentations that result from this study will not identify you by your worker ID#.

**Participants' Rights:**

- Your participation in this research study is entirely voluntary. If you decide not to participate, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled.
You can decide to withdraw your consent and stop participating in the research at any time, without any penalty.

Questions, Comments or Concerns:
If you have any questions, comments or concerns about the research, you can talk to one of the following researchers: Yolanta Kornak-Bozza, MA., M.Phil., at ykornak@gc.cuny.edu.
If you have questions about your rights as a research participant, or you have comments or concerns that you would like to discuss with someone other than the researchers, please call the CUNY Research Compliance Administrator at 646-664-8918. Alternately, you can write to:

CUNY Office of the Vice Chancellor for Research
Attn: Research Compliance Administrator
205 East 42nd Street
New York, NY 10017

If you understand and want to participate in this study, please click "continue".
DATE: January 12, 2015
TO: Yolanta Komak-Bozza
FROM: Graduate School & University Center (CUNY) HRPP Office
PROJECT TITLE: [896498-1] Effects of a Computer-based Simulation on Chemistry Self-Efficacy
SUBMISSION TYPE: New Project
ACTION: APPROVED
APPROVAL DATE: January 12, 2015
EXPIRATION DATE: January 11, 2016
RISK LEVEL: Minimal Risk
REVIEW TYPE: Expedited Review
REVIEW CATEGORY: Expedited review category # 6 & 7

Thank you for your submission of New Project materials for this project. The University Integrated IRB has APPROVED your research. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

Please remember that informed consent is a process beginning with a description of the project and assurance of the participant’s understanding, followed by a signed consent form(s). Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

The University Integrated IRB has determined that a waiver of documentation of consent has been approved for this research, under 45 CFR 46.117.

Please note that any modifications/changes to the approved materials must be approved by this IRB prior to implementation. Please use the appropriate modification submission form for this request.

All UNANTICIPATED PROBLEMS (UPS) involving risks to subjects or others, NON-COMPLIANCE issues, and SUBJECT COMPLAINTS must be reported promptly to this office. All sponsor reporting requirements must also be followed. Please use the appropriate submission form for this report.

This research must receive continuing review and final IRB approval before the expiration date of January 11, 2016. Your documentation for continuing review must be received with sufficient time for the IRB to conduct its review and obtain final IRB approval by that expiration date. Please use the appropriate continuation submission forms for this procedure. PLEASE NOTE: The regulations do not allow for any grace period or extension of approvals.

If you have any questions, please contact Claire Panetta at (212) 817-7527 or cpanetta@gc.cuny.edu. Please include your project title and reference number in all correspondence with this committee.
CHEMISTRY KNOWLEDGE PRETEST

1. When the temperature of a gas is increased, what happens to the gas particles?
   - The size of the particles expands
   - The speed of the particles decreases
   - The number of particles increases
   - The speed of the particles increases
   - Don't know

2. If the pressure is held constant and temperature is decreased, what happens to the volume of a gas sample?
   - The gas volume increases
   - The gas volume decreases first, but then returns to the previous level
   - The gas volume does not change
   - The gas volume decreases
   - Don't know

3. If the temperature is held constant and the pressure on its container is increased, what happens to the volume of a gas sample?
   - The gas volume increases
   - The gas volume decreases
   - The gas volume does not change
   - The gas volume increases and then decreases
   - Don't know

4. If the gas is in a container with its volume held constant, how could you decrease the gas pressure?
   - Decrease the gas temperature
   - Increase the gas temperature
   - Do not change the temperature
   - The gas pressure cannot be changed
   - Don't know
5. The diagram below shows three containers with the same number of gas particles. However, each container has a different volume.

If all three containers are at the same temperature, which container has the highest pressure?

- Container A
- Container B
- Container C
- All containers have the same pressure
- Don't know

6. Suppose you inflate your car tires to a recommended pressure. What happens to the tire pressure if the temperature becomes much hotter the next day?

- The pressure increases
- The pressure decreases
- The pressure stays the same
- The pressure in each tire could go either up or down
- Don't know
7. The picture below shows a balloon filled with helium gas.

If you suddenly decrease the temperature of the gas in the balloon, which of the following diagrams best represents the effect of this temperature change on the balloon?

- Smaller balloon
- Larger balloon
- Same size
- Same size, more particles
- Don't know
8. Which of the graphs below shows a linear increase in the volume of a gas when the temperature is increased?

- [ ]

- [ ]

- [ ]

- [ ]

- [ ]

9. When the temperature of a gas is decreased, what happens to the gas particles?

- [ ] The size of the particles expands
- [ ] The speed of the particles decreases
- [ ] The number of particles increases
- [ ] The speed of the particles increases
- [ ] Don’t know

10. If the gas is in a container with its volume held constant, how could you increase the gas pressure?

- [ ] Decrease the gas temperature
- [ ] Increase the gas temperature
- [ ] Do not change the temperature
- [ ] The gas pressure cannot be changed
- [ ] Don’t know
11. The diagram below shows three containers with the same number of gas particles. However, each container has a different volume.

![Diagram of three containers with gas particles]

In all three containers are at the same temperature, which container has the lowest pressure?
- Container A
- Container B
- Container C
- All containers have the same pressure
- Don’t know

12. Suppose you leave a basketball outside overnight. What happens to the pressure if the temperature becomes much colder the next day?

- The pressure increases
- The pressure decreases
- The pressure stays the same
- The pressure in the ball could go either up or down
- Don’t know

13. If the pressure in a container is held constant and the temperature is increased, what happens to the volume of the gas sample?
- The gas volume increases
- The gas volume decreases first, but then returns to the previous level
- The gas volume does not change
- The gas volume decreases
- Don’t know
14. If the temperature is held constant and the pressure on its container is decreased, what happens to the volume of a gas sample?
   - The gas volume increases
   - The gas volume decreases
   - The gas volume does not change
   - The gas volume increases and then decreases
   - Don’t know

15. The picture below shows a balloon filled with helium gas.

If you suddenly increase the temperature of the gas in the balloon, which of the following diagrams best represents the effect of this temperature change on this balloon?
1. Identify three variables that were included in the simulation of the gas laws. Select the correct variable for each of the three drop-down menus below:

2. Which of the variables shown in this picture is being held at a constant value?

   - Volume
   - Pressure
   - Size of container
   - Temperature
   - Don't know
3. In the simulation, which of the following gas properties can be affected by changing the temperature? Click "Affected" or "Not affected" for each gas property.

<table>
<thead>
<tr>
<th>Property</th>
<th>Affected</th>
<th>Not affected</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>internal pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>number of particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>speed of particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>color of particles</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. In the simulation, which of the following gas properties can be affected by changing the pressure? Click "Affected" or "Not affected" for each gas property.

<table>
<thead>
<tr>
<th>Property</th>
<th>Affected</th>
<th>Not affected</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>volume</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>number of particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>color of particles</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. If the temperature is constant, which of the following graphs represents the relationship between pressure and volume of a gas sample?

A

B
6. If the pressure is constant, which of the following graphs represents the relationship between temperature and volume of a gas sample?

A

B
7. Which graph represents the relationship between pressure and volume for a sample of gas at a constant temperature?

- [ ] Pressure
- [ ] Pressure
- [ ] Pressure
- [ ] Pressure
- [ ] Don't know

8. When the temperature of a gas is increased, what happens to the gas particles?

- [ ] The size of the particles expands
- [ ] The speed of the particles decreases
- [ ] The number of particles increases
- [ ] The speed of the particles increases
- [ ] Don't know

10a. If the temperature is held constant and the pressure on its container is increased, what happens to the volume of a gas sample?

- [ ] The gas volume increases
- [ ] The gas volume decreases
- [ ] The gas volume does not change
- [ ] The gas volume increases and then decreases
- [ ] Don't know

10b. Why does this happen? The reason for my answer is:

- [ ] Gas particles have no effect on volume
- [ ] Gas particles move faster to take up more volume
- [ ] The space between gas particles is reduced
- [ ] Gas particles have less energy to take up volume
- [ ] Don't know
9a. If the pressure is held constant and temperature is decreased, what happens to the volume of a gas sample?

- The gas volume increases
- The gas volume decreases first but then returns to the previous level
- The gas volume does not change
- The gas volume decreases
- Don't know

9b. Why does this happen? The reason for my answer is:

- Gas particles move more slowly
- Gas particles move faster
- Gas particles have no effect on volume
- Gas particles are also affected by pressure
- Don't know

Questions 11 and 12 refer to the graph below.

11. Jo was working with the Gas Law simulation. She held volume constant so she could explore the relationship between temperature and pressure. She had already plotted four points (see graph above) but wanted to make a claim for a pattern in the data. Which temperature below would be the best one for her to choose to be able to make that claim?

- 400 K
- 320 K
- 475 K
- 455 K
- Don't know

12. Based on Jo’s data, what do you predict as the value for pressure if the temperature of the gas is 550 K?

- About 2.5 atm
- About 0.6 atm
- About 3.5 atm
- About 1.6 atm
- Don't know
Questions 13 and 14 refer to the graph below.

13. Sam was working with the Gas Law simulation. He held temperature constant so he could explore the relationship between pressure and volume. He had already plotted five points (see graph above) and wanted to make a claim for a pattern in the data but felt he needed to plot at least one more point. Which pressure below would be the best one for him to choose to be able to make that claim?

- 4.0 atm
- 1.5 atm
- 12.0 atm
- 5.1 atm
- Don't know

14. Based on Sam’s data, what do you predict as the value for volume if the pressure of the gas is 7 atm?

- About 22 L
- About 5 L
- About 12 L
- About 40 L
- Don't know
15. If the temperature is held constant, what change in the volume of a gas container will decrease the gas pressure from 10 atm to 5 atm?
   - Double the volume of the container
   - Reduce the volume by half
   - Make the container three times larger
   - Decrease the volume of the container by a quarter
   - Don't know

16. A gas sample at constant pressure occupies a volume of 10 liters at a temperature of 300 K. What change would increase the gas volume to 15 liters?
   - Increase the temperature to 600 K
   - Increase the temperature to 450 K
   - Decrease the temperature to 150 K
   - Increase the temperature to 400 K
   - Don't know

17. A gas sample at a constant temperature has a volume of 12 liters and a pressure of 0.5 atmospheres. If you increased the pressure to 2 atmospheres, how would that affect the volume?
   - Decrease the volume to 2 liters
   - Decrease the volume to 6 liters
   - Decrease the volume to 4 liters
   - Decrease the volume to 3 liters
   - Don't know
18. Remember when Gaby and Tac left Gaby's 'Everfull' basketball outside in the cold night air?

**Wow, I just got an EVERFULL basketball.**
It's SEALED so it NEVER GOES FLAT!

**This ball is busted, Gaby!**
It's not supposed to lose any air, but it sure feels FLAT this morning!

**What if the ball DIDN'T lose air? Is there ANY OTHER EXPLANATION?**

Use the Gas Laws and the particle theory to explain to Gaby and Tac what happened to Gaby's basketball?

20. On a very hot summer day, your friend realizes that he has left a can of air freshener in the back of his car. It was exposed to the sun and it is now is very hot.

**Warning note on the back of the can**

WARNING! Contents under pressure. Avoid prolonged exposure to sunlight or heat from radiator, stoves, hot water and other heat sources that may cause bursting. Do not puncture, incinerate or store above 120°F.

a. What would you do to prevent the aerosol from bursting?

b. Explain using the Gas Laws and particle theory why you expect this to work.
19. In this simulation, you were able to change three variables of a container: volume, pressure, and temperature.

Although the balloon (A) and the gas container (B) have different shapes, they have the same volume and temperature.

a. What can you say about the pressure in each container?


b. Explain your answer using the Gas Laws and the particle theory of matter (KMT).
21. As you dive from the water surface to deep under water the water pressure increases significantly.

Explain, using the Gas Laws and particle theory, why air bubbles from a scuba diver's tank get bigger as they travel from deep water to the surface.
22. When the temperature of a gas is decreased, what happens to the gas particles?
   - The size of the particles expands
   - The speed of the particles decreases
   - The number of particles increases
   - The speed of the particles increases
   - Don’t know

23. If the gas is in a container with its volume held constant, how could you increase the gas pressure?
   - Decrease the gas temperature
   - Increase the gas temperature
   - Do not change the temperature
   - The gas pressure cannot be changed
   - Don’t know

24. The diagram below shows three containers with the same number of gas particles. However, each container has a different volume.

![Diagram of three containers with different volumes](image)

In all three containers are at the same temperature, which container has the lowest pressure?
   - Container A
   - Container B
   - Container C
   - All containers have the same pressure
   - Don’t know

25. Suppose you leave a basketball outside overnight. What happens to the pressure if the temperature becomes much colder the next day?
26. If the pressure in a container is held constant and the temperature is increased, what happens to the volume of the gas sample?
   - The gas volume increases
   - The gas volume decreases first, but then returns to the previous level
   - The gas volume does not change
   - The gas volume decreases
   - Don’t know

27. If the temperature is held constant and the pressure on its container is decreased, what happens to the volume of a gas sample?
   - The gas volume increases
   - The gas volume decreases
   - The gas volume does not change
   - The gas volume increases and then decreases
   - Don’t know

28. The picture below shows a balloon filled with helium gas.

If you suddenly increase the temperature of the gas in the balloon, which of the following diagrams best represents the effect of this temperature change on this balloon?
EFFECT OF INTERVENTION ON SELF-EFFICACY

- Smaller balloon
- Larger balloon
- Same size
- Same size, more particles
- Don’t know
What can a BASKETBALL teach us about the GAS LAWS?

Can a BASKETBALL teach us ANYTHING about how gases behave? Take a careful look at...

The Case Of The BUSTED BASKETBALL

Wow, I just got an EVERFULL basketball. It's SEALED so it NEVER GOES FLAT!

I'll never have to pump it up!

Everyone will be soooo jealous!

It's getting really hot! I need some water!

Let's catch the game on tv.
EFFECT OF INTERVENTION ON SELF-EFFICACY

It sure is cold this morning!
Look, Gaby, your water froze!

This ball is busted, Gaby! It's not supposed to lose any air, but it sure feels FLAT this morning!

Did the ball lose air? Well, it felt flat, so it must have, right?

It MUST have lost AIR!

HOLD IT RIGHT THERE!
EFFECT OF INTERVENTION ON SELF-EFFICACY

What if the ball DIDN'T lose air? Is there ANY OTHER EXPLANATION?

What's inside that ball, anyway? Do you know there are lots of gas particles in there? Do you know they are moving all the time?

On the next screen you can use a computer program that will help you find the answers in the case of The Busted Basketball.

So that program showed us something about the Gas Laws. How do you think it connects to Gaby and Tac and that BUSTED BASKETBALL?
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