The Effects of Project-Based Learning on High School Girls' Attitudes Towards Chemistry

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Abstract

The goal of this study was to examine the effects of project-based learning in chemistry on high school girls' perceived communal value of chemistry, personal communal values, attitudes and motivations in chemistry, and future college and career plans. The effects on male students and the whole population were also analyzed. The 22 study participants included 13 female and 9 male high school sophomores enrolled in the honors chemistry course at a Midwestern suburban high school. These students engaged in a project-based learning unit on the chemistry of air, adapted from The American Chemical Society's *Chemistry in the Community* textbook, over the course of 3 months. In this unit of study, students learned about the chemistry and behavior of gases and the chemistry of the environment, including carbon emissions, global climate change, and ocean acidification. Upon completion of the unit, students designed scientific investigations to address air quality issues of their choice.

Participants completed a pre-unit and post-unit survey regarding their perceptions, attitudes, and motivations both before and after their project-based learning experiences. The survey included 17 statements of which participants responded on a 1-5 Likert scale of agreement and 2 open-ended questions regarding attitudes towards chemistry. The results were analyzed using a paired t-test, and the results and data analysis confirmed that there were statistically significant changes in both student personal communal values and college and career plans. The results showed and mean score increase in personal communal values of 1.22. The results also showed that 33% of participants indicated an increase in their desire to pursue chemistry in the future. Therefore, it can be concluded that project-based learning in chemistry can increase personal communal values and desire to pursue chemistry in the future. However, score differences in perceived communal value of chemistry, attitudes, and motivations were not found to be statistically significant.

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I would like to thank Dr. Patty Rieman for her guidance and expertise during this process. I would also like to thank her for encouraging me to pursue my interests instead of taking the easy way out.

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Chapter 1

Introduction

Background of the Problem:

Historically, males performed better than females in secondary and post-secondary science courses. In their study of science achievement, Kost, Pollock, and Finklestein (2009) found that there was a significant gap in the conceptual understanding of science between boys and girls. In recent years, the gender achievement gap in STEM education has been reduced. According to the Wisconsin Department of Public Instruction (DPI), there was no difference between the 2017 male and female average ACT science scores. In the 2017-2018 school year, male and female high school students in Wisconsin scored an average of 21.2 and 21.1 on the ACT science assessment respectively (DPI, 2017).

While males and females are equal in science achievement, there still remains a gender gap in science, technology, engineering, and mathematics (STEM) fields in higher education and the workforce. Women are vastly underrepresented in post-secondary STEM education and even more underrepresented in STEM careers. According to the National Science Foundation (NSF), women earned 57% of all bachelor's degrees earned in 2014. However, women earned only 32% of chemistry and physics bachelor's degrees in that time. The already evident gender gap in physical science in college continues to widen as women move into the workforce. Women comprise only 27.8% of workers in physical science and engineering occupations (National Science Foundation, 2017).

Gender stereotypes of female scientists have had a significant societal impact on women pursuing science degrees and careers. Carol Robinson, the first female chemistry professor at the University of Cambridge and the University of Oxford, explained that many female scientists often adopt more aggressive personalities and communication styles, as well as more masculine wardrobe choices in order to fit into the male-dominated field (Robinson, 2011).

Popular culture and the media perpetuate these gender stereotypes by underrepresenting females as scientists in film and television shows. Furthermore, when female scientists are represented in film or television, their intelligence is downplayed, and their professional ineptitude and emotional problems are highlighted (Flicker, 2003). Even *The Big Bang Theory*, a situational comedy about a group of (male and female) scientists, emphasizes the overly-emotional situations of the female scientists, in addition to other female scientist stereotypes. In addition, the scientists on *The Big Bang Theory* are seemingly segregated by gender, with males dominating the physical sciences and females dominating the life sciences (McIntosh, 2014).

Gender roles in society may also be to blame for the underrepresentation of females in STEM fields. Role congruity theory explains that people tend to align their behavior with the demands of social roles (Eagly and Diekman, 2004). In alignment with this theory, women tend to pursue careers that will help them achieve communal goals; women more often choose careers in which they feel they can make a difference in the world or the life of others (Stout, Grunberg, & Ito, 2016). The physical sciences are not typically viewed as a path to achieving communal goals, which may be why women shy away from them.

Project-based learning could offer a solution to this problem. Project-based learning allows students to apply new knowledge and skills to solve real-world problems (Nation, 2008). Teachers have reported that project-based learning improved communication skills among students and ignited their curiosity (MacMath, Sivia, & Britton, 2017). Collaboration among students and solving real-world problems could help students see the communal values in the physical sciences.

Project-based learning also offers a bridge between the sciences in that biology or environmental science concepts can be intertwined with the physical sciences (MacMath, Sivia, & Britton, 2017). Women are well-represented in the biological sciences in higher education and the workforce (National Science Foundation, 2017), so the cross-cutting concepts of the biological and physical sciences could also allow females to see the communal value of the physical sciences.

Statement of the Problem:

Females are underrepresented in physical science fields (physics and chemistry) in both college and career (National Science Foundation, 2017; Robinson, 2011). Research has shown the cause of this gap may stem from role congruity, that women tend to pursue careers that agree with their gender role in society. The careers most often pursued by women are those in which there is a perceived communal value (Diekman, et. al., 2010; Eagly and Diekman, 2004; Oliver, et. al., 2017; Smith, et. al., 2015; Stout, Grunberg, & Ito, 2016). Problem-based learning may increase students' perceived communal value of the physical sciences because it allows students to work collaboratively on exploring and solving community problems (Prince and Felder, 2006; Nation, 2008).

Purpose of the Study:

The purpose of this study was to examine how project-based learning affects the attitudes of high school girls toward chemistry. This study also served to examine the effects of project-based learning on the future plans of these female students, including intended college majors and careers.

Research Questions:

How does project-based learning affect high school girls' perceptions of the communal value of chemistry?

How does project-based learning affect high school girls' motivation and attitudes toward chemistry?

How does project-based learning affect high school girls' choice of college majors and careers?

Definition of Terms:

Agency/Agentic - The meta-concept associated with self-advancement in social hierarchies (Trapnell and Paulhus, 2012).

Biological/Life Sciences - Sciences relating to biology or a health-related science

Community/Communal - The meta-concept associated with maintenance of positive relationships, with others and the community (Trapnell and Paulhus, 2012).

Constructivist Theory - An instructional theory that argues that people construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences (Fensham, Gunstone, & White, 2013).

Physical Sciences - Physics and/or chemistry

Project-based learning - An approach to instruction that teaches curriculum concepts through a project. The project is guided by an inquiry question that drives the research and allows students to apply their acquired knowledge (Bell, 2010).

Role Congruity Theory - A group will be positively evaluated when its characteristics are perceived to align with the requirements of the group's typical social roles. Social roles may thus form the basis of norms that prescribe valued behavior for men and women (Diekman and Goodfriend, 2006).

Self-Efficacy - One's outlook of their ability to succeed in specific situations or accomplish a task

STEM - Science, technology, engineering, mathematics (Bandura, 1982).

Chapter Summary:

The underrepresentation of women in STEM fields needs to be addressed by encouraging more women to pursue STEM college and career plans. Some researchers believe that women shy away from physical science fields because they do not outwardly align with female social norms. A possible solution to this problem is to teach high school girls that the physical sciences have communal value by utilizing the project-based learning method of instruction. Chapter two will delve into the literature about females in STEM fields and project-based learning, as well as educational theories that support project-based learning.

Chapter 2

Literature Review

The purpose of this study is to identify the effects of problem-based learning on high school girls' attitudes and motivation towards chemistry, as well as their future college and career plans. The related literature discussed in this chapter will review a) background and experiences of women in STEM fields; b) role congruity theory; c) recent reform in national science standards; d) constructivism in the classroom; e) problem-based learning; f) student motivation in science.

Females in STEM Fields

Gender diversity in STEM fields is crucial in today's world. Women offer a diverse perspective that promotes innovation and creativity. However, in 2017, while women comprised over 50% of all bachelor's degrees earned, they comprised less than 35% of bachelor's degrees earned in physical science. Even fewer women enter the physical science and engineering workforce. Only 27% of physical science and engineering workers are women (National Science Foundation, 2017). Achievement in high school math and science classes fails to explain the gender gap. Girls tend to earn higher course grades in math and science, and they are equally likely to be enrolled in advanced science and math courses in high school (Riegle-Crumb, et al., 2012). Research has shown that women enter science fields less often than men because of occupational interests, lifestyle values, and gender stereotypes (Wang and Degol, 2017).

Marie Curie, the female chemist and physicist whose work led to the discovery of radioactivity, experienced high levels of stereotyping and prejudice in her lifetime as a result of the male dominance of science fields. In fact, Curie very rarely wore dresses (during a time in which dresses were the daily garment of women), except for one simple black dress. Carol Robinson, the first female chemistry professor at the University of Cambridge follows a similar rule today (Robinson, 2011).

Women also find that careers in science and engineering may not fit their lifestyle because they often require long hours, leaving less time to raise a family. Marie Curie herself experienced this conflict, as she would explain that balancing her work and home life was difficult (Robinson, 2011). Women in modern-day society still experience the same challenges in balancing scientific careers and raising families. In fact, many women in STEM end up leaving their original career path to seek out more flexible careers that allow them to raise their families (Monosson, 2008).

In addition to family life conflicts, many females in STEM fields experience stereotype threat, meaning that negative stereotypes about women in science psychologically impede performance (Canidu, et al., 2005; Smith, et al., 2015; Stout, Grunberg, & Ito, 2016; Sunny, et al., 2017). In turn, women in STEM fields often feel a lower level of self-efficacy in science and engineering subjects (Sunny, et al., 2017). Women who experience stereotype threat score lower in cognitive ability, report greater anxiety, and continued increase in negative thinking (Canidu, et al., 2005). Self-efficacy in introductory science courses is reported to be lower in female undergraduate students. Additionally, women who report lower self-efficacy in introductory science courses are less likely to take additional science courses throughout their undergraduate career (Hardin and Longhurst, 2016).

Role Congruity Theory

Role congruity theory suggests that people tend to choose careers that align with known social roles (Diekman and Goodfriend, 2006). Society expects women to be nurturing caregivers, so they tend to pursue careers with high communal value (helping others and the community) over careers that offer high agentic value (helping oneself) (Diekman and Goofriend, 2006; Diekman, et al., 2010; Eagly and Diekman, 2004; Stout, Grunberg, & Ito, 2016; Trapnell and Paulhus, 2012) .

Smith, et al. (2015) found that women experience more stereotype threat in physical science fields as a result of the perceived communal value. In this study, "feelings of stereotype threat [of women] were relatively greater in the (male-dominated) physics lab classes versus the (female-dominated) biology lab classes" (Smith, et al., 2015, p.455-456). This suggests that there is a greater level of perceived communal value in biology than the physical sciences. In addition, a three-year study of college freshmen showed that women completed fewer physical science courses than men, except when women perceived a high opportunity for communion in physical science (Stout, Grunberg, & Ito, 2016, p.490).

It has been found effective to introduce science in a communal light, by highlighting the contributions of physical science to the community, to change the attitudes of students. Students who participated in an intervention emphasizing the communal value of biomedical research experienced an increased motivation for biomedical science (Brown, et al., 2015). This type of intervention is also effective in engineering, a male-dominated field with a highly perceived agentic value. Middle school girls who attended a hands-on civil engineering workshop, which highlighted the field's communal value, displayed an increase in their perceived communal value. In addition, the young female students were able to picture females as engineers at a higher rate after the workshop (Colvin, Lyden, & León de la Barra, 2012).

The Case for Constructivism

Constructivism in education today stems from Jean Piaget's theory of cognitive development and Lev Vygotsky's social learning theory. Piaget's work focused on the individual in learning, and Vygotsky's work explored the social aspect of learning (Pass, 2004). The theory of constructivism as we know it suggests that people construct their own meaning and guide their own learning through experiences, suggesting that students can experience learning through hands-on activities in the classroom (Fensham, Gunstone, & White, 2013).

The Next Generation Science Standards (NGSS), which have been fully or partially adopted by 29 states to date, aim to reduce the rote memorization of science facts and increase understanding and application of science phenomena (National Science Teacher Association, 2018). Schools that utilize NGSS aim to produce a greater understanding of scientific concepts by providing students opportunities for hands-on learning and exploration.

Very few studies have been completed regarding NGSS, as they are relatively new. However, hands-on, student-centered science lessons have proven to be effective in increasing understanding, attitudes, and motivation (Levine, et al., 2015; Levine and DiScenza, 2018). Middle school girls who attended an educational outreach chemistry camp (largely inclusive of hands-on instructional practices) demonstrated enhanced attitudes towards science and increased desire to pursue STEM careers (Levine, et al., 2015). The girls in the study were also given opportunities for interaction with female scientists during the science camp. Another hands-on science class relating to sugar chemistry increased girls' interest in pursuing careers in science, as well as increased their understanding of the application of chemistry, (Levine & DiScenza, 2018). Both of these programs offered girls an opportunity to "learn by doing"

Problem-Based Learning in Science

According to the National Science Teacher Association (NSTA), inquiry-based learning includes students "posing questions, planning investigations, and reviewing what is already known in light of experimental evidence—that mirror what scientists do" (National Science Teacher Association, 2002). Inquiry instruction includes open inquiry, in which students pose their own scientific question and plan an investigation to answer that question. Open inquiry is largely student-centered instruction. Guided inquiry is another form of inquiry instruction used in science classrooms. Guided inquiry happens when the *teacher* poses a scientific question or problem and students work to answer the question in order to learn. Problem-based learning (the focus of this study) is an example of guided inquiry (National Science Teacher Association, 2002).

Project-based learning has been found to be especially effective in science education seemingly because it mimics the work of real scientists and engages students in their own learning. Chang (2001) found that problem-based (inquiry) instruction in earth science had a greater positive effect on student achievement than direct instruction, a method of instruction in which the teacher lectures and students listen. Project-based learning has also been shown to engage students, foster a collaborative learning environment, and improve teacher-student relationships (Hugerat, 2016).

Teachers who utilize project-based learning in their classroom notice significant differences in their students. Using project-based learning, teachers have been able to help students gain the skills and work ethic to be successful in all subjects and in life

(MacMath, Sivia & Britton, 2017). Students themselves have reported an increase in their personal motivation, engagement, and organizational skills (Grant, 2011).

Student Motivation in Science

In order to generate more interest in STEM fields, the problem must be addressed *before* post-secondary education, when students begin considering their futures. Girls who previously express interest in science fields tend to abandon that interest in high school more often than boys (Wang & Degol, 2013). Girls in high school report more often lower psychological need satisfaction in physics, chemistry, and engineering courses, which may be to blame for the change in future goals (Patall, et al., 2018).

In a study of female high school students taking an elective physics class, it was found that supportive teachers and a positive school science culture contribute to female students' interest and success in science (Oliver, et al., 2017). In order to build a positive science culture in the school, science must be a priority. High school girls also need greater exposure to science and engineering careers through the high school STEM curriculum in order to negate common female scientist stereotypes (Legewie & DiPrete, 2012).

Chapter Summary

As discussed in the literature, there is a shortage of females currently active in or pursuing physical science and engineering fields. This may be due in part to the perceived communal value of physical sciences and engineering, as women tend to prefer careers that allow them to make a difference and work with others. Previous research has shown that interventions of science communal value have been successful. Problem-based learning, which has been found to increase motivation, collaboration, and engagement, may offer an opportunity to present high school girls with the communal value of science. The next chapter will discuss how the motivations and attitudes of high school girls will be measured and analyzed in this study.

Chapter 3

Methods

The purpose of the study was to examine how project-based learning affects the attitudes of high school girls toward chemistry. The study also served to examine the effects of project-based learning on the future plans of these female students, including intended college majors and careers.

Setting

This study was conducted in an honors chemistry class at a Midwestern public high school. The school has 1200 students, of which 32% are eligible for free or reduced lunch. This high school is one of four high schools in the district, including an alternative high school. Students are required to take chemistry their sophomore year to graduate, and they have an option of regular or honors chemistry.

Project-Based Learning

The project-based learning curriculum in honors chemistry was adapted from the American Chemical Society's *Chemistry in the Community*. This curriculum and textbook was in its pilot phase in the district during the time of this study. Only honors chemistry students participated in the project-based learning curriculum.

The textbook begins each unit by describing a community problem that the students will be able to solve by the end of the unit. In this study, participants engaged in *Unit 2: Air - Designing Scientific Investigations*. Participants had to design a scientific investigation to solve an environmental problem for this unit's project. Throughout the unit, participants learned and applied knowledge of gases and atmospheric chemistry to their culminating project.

Subjects

Subjects included 41 high school sophomores enrolled in one of three honors chemistry sections taught by the same teacher. There were 13 female students and 9 male students between the ages of 15 and 16 years old who responded to both the pre-unit survey and the post-unit survey.

Research Design

This study investigated high school girls' motivation and attitudes toward chemistry, as well as their future college and career plans. The researcher used a digital survey in which participants responded to 16 statements on a 1-5 Likert scale and 2 free-response questions. Refer to Appendix A for the survey questions. This survey was distributed once before the start of the unit of study, and once upon the completion of the unit project.

Each survey statement/question fell into one of five categories:

- Perceived communal value of chemistry.
- Communal/agentic values
- Motivation in chemistry
- Attitude toward chemistry
- College and career plans

Procedure

The researcher sought out her school's principal for consent to perform the research study on students Refer to Appendix B for the principal consent form. Then, she asked her each of her honors chemistry students if they would be willing to participate in the research study. Before surveying the students, the researcher sent home a parent and student consent form to education both the student and the parent(s). Refer to Appendix A for the student and parent consent form.

After the consent forms were returned to the researcher, the pre-unit survey was conducted. An adult in the school who was not involved in the research proctored the participants' completion of the survey. Participants used identification numbers, so as to not identify themselves to the researcher.

After the completion of the pre-unit survey, participants engaged in a three month project-based learning unit on gases and atmospheric chemistry. The unit was culminated upon the completion of the unit project in which participants designed hypothetical scientific investigations to solve air quality issues of their choice.

Upon completion of the unit project, participants took the survey again, using their same identification numbers. Again, the survey was proctored by an uninvolved adult. Each survey took about 10 minutes to complete.

Data Analysis

The data for the pre-unit survey and post-unit survey were statistically analyzed via paired t-test to determine the statistical difference between the two surveys. The t-tests were performed for the whole sample and separately for males and females for each of the research questions.

The free-response survey questions were analyzed for recurring themes regarding attitudes towards chemistry and the communal value of chemistry.

Chapter Summary

Participants responded to several statements and questions about their attitudes and motivation in chemistry, their perceived communal value of chemistry, their personal communal and agentic values, and their future college and career plans before engaging in a three-month long project-based learning unit on gases and atmospheric chemistry. The unit was culminated upon completion of the unit project in which participants had to design investigations about air quality issues. After completion of the unit and the project, participants again responded to the same statements and questions as the pre-unit survey. Statistical significance was determined via paired t-test.

Chapter 4

Results

Quantitative results from each category of the 16 statements on the pre-unit were compared to that of the post-unit survey. This data is presented in Table 1.

Table 1
Comparison of Pre-unit and Post-unit Surveys by Category

	Pre-unit					Post-unit		
	N	Mean	STD	S.D.O.M		Mean	STD	S.D.O.M
Communal Value of Chem	22	11.86	2.55	0.54		12.14	2.12	0.45
Personal Communal Value	22	16.14	2.46	0.52		17.36	2.15	0.46
Motivation	22	9.50	2.97	0.63		8.82	2.92	0.62
Attitude	22	9.23	1.48	0.32		9.32	1.32	0.28
College/Career Plans	22	7.14	2.80	0.60		8.32	3.05	0.65

Perceived Communal Value of Chemistry

Hypothesis 1:

H_0 : Project-based learning will have no effect on high school girls' perceived communal values of chemistry.

H_1: Project-based learning will improve high school girls' perceived communal values of chemistry.

Hypothesis 2:

H_0 : Project-based learning will have no effect on students' perceived communal values of chemistry.

H_1: Project-based learning will improve students' perceived communal values of chemistry.

The results of the statements regarding the subjects' perceived communal value of chemistry can be seen in Table 2. The total possible score in this category was 15. The mean score for all participants increased by 0.28 between the pre-unit and post-unit survey. A paired t-test was used to determine statistical significance between the pre-unit and post-unit survey for the whole population and for each gender. The female group had a critical t-value of 2.179 for $p = 0.05$ and $df = 12$ and an observed t-value of 0.174. The whole population had a critical t-value of 2.080 and an observed t-value of -0.478. Therefore, one cannot reject the null hypotheses.

Table 2
Perceived Communal Value of Chemistry

Communal Value of Chemistry - All			**Communal Value of Chemistry - Females**			**Communal Value of Chemistry - Males**	
Difference	-0.273		Difference	0.154		Difference	-0.889
t (Observed value)	-0.478		t (Observed value)	0.174		t (Observed value)	-1.577
|t| (Critical value)	2.080		|t| (Critical value)	2.179		|t| (Critical value)	2.306
DF	21		DF	12		DF	8
p-value (Two-tailed)	0.638		p-value (Two-tailed)	0.865		p-value (Two-tailed)	0.154
alpha	0.05		alpha	0.05		alpha	0.05

Personal Communal Values

Hypothesis 3:

H_0 : Project-based learning will have no effect on high school girls' personal communal values.

H_1: Project-based learning will increase high school girls' personal communal values

Hypothesis 4:

H_0 : Project-based learning will have no effect on students' personal communal values.

H_1: Project-based learning will improve students' personal communal values.

The results of the statements regarding the subjects' personal communal values can be seen in Table 3. The total possible score in this category was 20. The mean score for all participants in this category increased the most out of all five categories. A paired t-test was used to determine statistical significance between the pre-unit and post-unit survey for the whole population and for each gender. The female group showed an observed t-value below that of the critical t-value. However. the combined population had a critical t-value of 2.080 and an observed t-value of -2.952, leading to the rejection of null hypothesis 4 only.

Table 3
Personal Communal Values

Personal Communal Values - Combined			**Personal Communal Values - Females**			**Personal Communal Values - Males**	
Difference	-1.227		Difference	-1.154		Difference	-1.333
t (Observed value)	-2.952		t (Observed value)	-2.004		t (Observed value)	-2.138
|t| (Critical value)	2.080		|t| (Critical value)	2.179		|t| (Critical value)	2.306
DF	21		DF	13		DF	8
p-value (Two-tailed)	0.008		p-value (Two-tailed)	0.068		p-value (Two-tailed)	0.065
alpha	0.05		alpha	0.05		alpha	0.05

The second free-response question asked students to describe how they believe chemistry impacts the world. In the pre-unit survey, many of the responses to this question were vague, such as "Everything we do involves chemistry. Chemistry can relate to everything". However, in the post-unit survey, more student responses were specific and included examples like "Medically, environmentally, throughout space, molecularly and atomically, and biologically".

Motivation in Chemistry

Hypothesis 5:

H_0 : Project-based learning will have no effect on high school girls' motivation in chemistry.

H_1: Project-based learning will increase high school girls' motivation in chemistry.

Hypothesis 6:

H_0 : Project-based learning will have no effect on students' motivation in chemistry.

H_1: Project-based learning will improve students' motivation in chemistry.

The results of the statements regarding the subjects' motivation in chemistry can be seen in Table 4. The total possible score in this category was 15. The mean score for all participants in this category experienced a decrease between pre-unit and post-unit surveys. A paired t-test was used to determine statistical significance between the pre-unit and post-unit survey for the whole population and for each gender. The female group showed an observed t-value of 0.876, which is below that of the critical t-value. The combined population also showed an observed t-value below the critical value. Therefore, null hypotheses 5 and 6 cannot be rejected.

Table 4
Motivation in Chemistry

Motivation in Chemistry - Combined		**Motivation in Chemistry - Females**		**Motivation in Chemistry - Males**	
Difference	0.682	Difference	0.769	Difference	0.556
t (Observed value)	1.115	t (Observed value)	0.876	t (Observed value)	0.652
|t| (Critical value)	2.080	|t| (Critical value)	2.179	|t| (Critical value)	2.306
DF	21	DF	13	DF	8
p-value (Two-tailed)	0.277	p-value (Two-tailed)	0.398	p-value (Two-tailed)	0.532
alpha	0.05	alpha	0.05	alpha	0.05

Participants described their motivations and interests in the free-response questions at the end of the survey. 8 students indicated that their lack of motivation in chemistry stems from a high degree of difficulty or an inability to gain understanding. Participant 6617 stated "It is very confusing and it's hard to fully understand something if it doesn't seem interesting. Some parts of chemistry are fun but a lot aren't because they don't make sense". This participant showed a similar viewpoint upon completion of the project-based learning unit.

Many students also explained that chemistry was not interesting to them. Participant 7422 said "I honestly don't like chemistry because I just don't find it interesting" and 3 female students indicated that they found the biological sciences to be more interesting than chemistry.

Attitude Towards Chemistry

Hypothesis 7:

H_0 : Project-based learning will have no effect on high school girls' attitudes towards chemistry.

H_1: Project-based learning will increase high school girls' attitudes towards chemistry.

Hypothesis 8:

H_0 : Project-based learning will have no effect on students' attitudes towards chemistry.

H_1: Project-based learning will improve students' attitudes towards chemistry.

The results of the statements regarding the subjects' attitudes towards chemistry can be seen in Table 5. The total possible score in this category was 15. A paired t-test was used to determine statistical significance between the pre-unit and post-unit survey for the whole population and for each gender. The female group showed an observed t-value of -0.485, which is below the critical value of 2.179. The combined population showed an observed t-value of -0.346, which is below the critical value of 2.080. Therefore, null hypotheses 7 and 8 cannot be rejected.

Table 5
Attitudes Towards Chemistry

Attitude Towards Chemistry - Combined			**Attitude Towards Chemistry - Females**			**Attitude Towards Chemistry - Males**	
Difference	-0.091		Difference	-0.154		Difference	-8.7E-17
t (Observed value)	-0.346		t (Observed value)	-0.485		t (Observed value)	0.000
|t| (Critical value)	2.080		|t| (Critical value)	2.179		|t| (Critical value)	2.306
DF	21		DF	13		DF	8
p-value (Two-tailed)	0.732		p-value (Two-tailed)	0.636		p-value (Two-tailed)	1.000
alpha	0.05		alpha	0.05		alpha	0.05

Some participants expressed their attitudes towards chemistry in general, as well as their attitudes towards the project-based learning unit. In the post-unit survey, participant 9370 said "Labs and hand on activities are fun, [but] I don't enjoy taking lots of notes and doing some projects". In addition, multiple students described chemistry as "boring" in the pre-unit survey, with no distinguishable change in the post-unit survey.

College and Career Plans in Chemistry

Hypothesis 9:

H_0 : Project-based learning will have no effect on high school girls' desire to pursue college majors or careers in chemistry.

H_1: Project-based learning will increase high school girls' desire to pursue college majors or careers in chemistry.

Hypothesis 10:

H_0 : Project-based learning will have no effect on students' desire to pursue college majors or careers in chemistry.

H_1: Project-based learning will improve students' desire to pursue college majors or careers in chemistry.

The results of the statements regarding the subjects' desire to pursue college majors or careers in chemistry can be seen in Table 6. The total possible score in this category was 10. The total population's mean scores increased from 7.14 to 8.32 between the pre-unit and post-unit survey. A paired t-test was used to determine statistical significance between the pre-unit and post-unit survey for the whole population and for each gender. The female group showed an observed t-value of -1.749, which is below the critical value of 2.179. However, the combined population showed an observed t-value of -2.108, which is above the critical t-value. Therefore, only null hypothesis 10 can be rejected.

Table 6
College and Career Plans

College/Career Plans - Combined			**College/Career Plans - Females**			**College/Career Plans - Males**	
Difference	-1.182		Difference	-1.143		Difference	-1.250
t (Observed value)	-2.108		t (Observed value)	-1.749		t (Observed value)	-1.139
|t| (Critical value)	2.080		|t| (Critical value)	2.160		|t| (Critical value)	2.365
DF	21		DF	13		DF	8
p-value (Two-tailed)	0.047		p-value (Two-tailed)	0.104		p-value (Two-tailed)	0.292
alpha	0.05		alpha	0.05		alpha	0.05

Chapter Summary

The total scores of the statements in each of the five categories on the survey were analyzed via paired t-test for the whole population, female participants, and male participants. The results showed that null hypotheses 4 and 10 could be rejected based on an observed t-value lower than that of the critical value. Hypotheses 1-3 and 5-9 could not be rejected, as the t-tests showed no statistical significance.

Chapter 5

Discussion

The purpose of the study was to examine how project-based learning affects the attitudes of high school girls toward chemistry. The study also served to examine the effects of project-based learning on the future plans of these female students, including intended college majors and careers.

Conclusions

How does project-based learning affect high school girls' perceptions of the communal value of chemistry?

Based on the pre-unit and post-unit survey results, the project-based learning unit did not change students' (male or female) perceptions of the communal value of chemistry. However, results showed that, as a whole, the population did experience an increase in their personal communal values over the course of the project-based learning unit. The participants were exposed to environmental and atmospheric chemistry, including ocean acidification, coral bleaching, climate change, and air pollution. Some of the issues discussed in class were new information to many of the students, possibly attributing to the increase in their concern for the world and their community.

How does project-based learning affect high school girls' motivation and attitudes toward chemistry?

This study found no significant change in pre-unit and post-unit survey scores in the areas of motivation and attitude. In fact, some participants noted a decrease in their attitudes and motivation after the project-based learning unit, citing the subject's difficulty and their greater level of misunderstanding. The selection of the honors chemistry course over the general chemistry course may have contributed to this result.

Honors students typically have higher rates of autonomy and tend to be less socially oriented than non-honors students (Clark, 2000). The project-based learning curriculum requires collaborative work and discussion among groups, which may not be strengths of honors students.

How does project-based learning affect high school girls' choice of college majors and careers?

Between the beginning and end of the project-based learning unit, the female population alone and the male population alone did not experience a considerable increase in their desires to pursue chemistry in the future, either in college or career. However, the total population did show a significant increase in this area, with a mean score increase of 1.18. 33% of participants indicated an increase in their desire to pursue chemistry in the future.

Recommendations and Limitations

Population size was a major limitation of this research. With only 21 participants in the study, the results may be unreliable. While the number of returned permission slips was over twice as many, student absences on survey days and voluntary participant drop out may have been responsible for the lower number of participants. If this study is duplicated in the future, it would be recommended to begin with a larger population of students from a variety of classrooms, backgrounds, and levels. In addition, some participants mentioned that they could not remember which phone number they used for their participant code. It is also recommended that the survey proctor keep records of participant codes and absences.

At the time of this study, the project-based learning curriculum and textbook was only approved for honors-level chemistry as a pilot curriculum. The difficulty with this is that honors students often prefer the "sit and get" style of learning, as some participants had noted, even though honors students have greater higher-level thinking abilities and more self-efficacy (Moore, 1994). The project-based learning curriculum required students to learn information through exploration, and that can be difficult or frustrating for students who would prefer to be given the necessary information. Some participants even expressed a dislike for projects by the end of the unit, implying that they would prefer a written exam. For future studies, it would be beneficial to include a mix of abilities, including honors, general, and even special education chemistry courses.

The "Air" unit was specifically chosen for this research because it was believed that it would offer and introduce students to the most communal value. This, however, was an issue because the "Air" unit did not begin until second semester, and the participants had already experienced a project-based learning unit: "Materials". In this previous unit, the culminating project required students to make an educated decision about the future of the dollar bill and dollar coin, giving them early access to the environmental implications of chemistry. In addition, this research was completed over the course of only 3 months. For future studies, an entire school year should be utilized to give students the most exposure to the communal values of chemistry and allow students to become more accustomed to the project-based learning style.

Implications

Oftentimes, school districts and the teachers within them become so focused on standardized test scores and student academic achievement that they neglect the development of the whole child. This research shows that pedagogy can help to shape the values of students and their opinions of the world around them which, in turn, can help to guide students on the path to becoming productive members of society. Students completed their air-quality investigations with a new sense of appreciation and concern for the world around them.

In addition, the outcomes of this research will help high school teachers and counselors understand how to better expose students to the possibilities of new careers, especially in STEM subjects. The participants' new awareness of chemistry and experience applying chemistry to the world around them opened their eyes to new career possibilities in chemistry and related sciences. Project-based learning allows students to essentially immerse themselves in possible careers, which may lead to new opportunities for their futures.

Chapter Summary

Project-based learning in chemistry showed an increase in students' personal communal values and their desire to pursue chemistry in the future. However, it did not have an effect on student attitudes towards or motivation in chemistry. Possible limitations of this study were small population size, lack of diversity in academic achievement levels, and time. If this study were to be performed again in the future, the researcher should use a larger, more diverse population and increase the time frame of the study. A major implication of this study is that project-based learning may have an effect on the development of future members of society.

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Appendix A

Chemistry Attitude Survey

What is your gender?

What is your 4 digit participant code?

	1 - Strongly Disagree	**2 - Disagree**	**3 - Neither agree nor disagree**	**4 - Agree**	**5 - Strongly Agree**
The state of the environment matters.	**1**	**2**	**3**	**4**	**5**
The state of the community matters.	**1**	**2**	**3**	**4**	**5**
Chemistry is of great importance to the world.	**1**	**2**	**3**	**4**	**5**
Chemistry is boring.	**1**	**2**	**3**	**4**	**5**
The only reason I am taking chemistry is because I have to; I would not take chemistry otherwise.	**1**	**2**	**3**	**4**	**5**
During chemistry class, I am usually interested.	**1**	**2**	**3**	**4**	**5**
Chemistry is fascinating and fun.	**1**	**2**	**3**	**4**	**5**
I have a real desire to learn chemistry.	**1**	**2**	**3**	**4**	**5**
I would like to learn more about chemistry.	**1**	**2**	**3**	**4**	**5**
I would be most happy in a career in which I can help people.	**1**	**2**	**3**	**4**	**5**
I would be most happy in a career in which I have personal and financial success.	**1**	**2**	**3**	**4**	**5**
A career in chemistry would give me an opportunity to make a difference in the world.	**1**	**2**	**3**	**4**	**5**
Chemistry can solve real-world problems.	**1**	**2**	**3**	**4**	**5**
Chemistry makes a substantial difference in how we live.	**1**	**2**	**3**	**4**	**5**
I am interested in pursuing a career in chemistry in the future.	**1**	**2**	**3**	**4**	**5**
I am interested in studying chemistry further in college.	**1**	**2**	**3**	**4**	**5**
I am excited to take chemistry courses in college.	**1**	**2**	**3**	**4**	**5**

How would you describe your current feelings towards chemistry?

Describe the ways, if any, that you believe chemistry impacts the world.

Appendix B

Principal Consent Form

Project Title: The Effect of Project-Based Learning on High School Girls' Attitudes Towards Chemistry

Advisor: Patricia Rieman, Education **Co-Investigator(s):** Christina Schaefer

WHAT IS THE PURPOSE OF THIS STUDY?

Your school is being invited to take part in a research study designed to determine if Project-Based Learning has an effect on student attitudes towards chemistry, perceived communal value of chemistry, and future college and career plans. Data of male and female students will be necessary for comparison. Project-Based Learning is a classroom method in which students are presented with a problem or question at the beginning of a unit of study. Then, students learn the content required to solve the problem, as they work on it along the way. Each unit is culminated with the completion of a project that solves the problem or answers the question. This study will be used to complete the requirements of the Master of Education program at Carthage College with the possibility of utilizing the anonymous results for publication and presentation. We have selected this area of study to address the gender gap in STEM fields beyond high school.

WHAT WILL HAPPEN DURING THIS STUDY AND HOW LONG WILL IT TAKE?

Students will be asked to anonymously complete a digital pre and post survey to determine their attitudes towards chemistry before and after a classroom unit of study. Students will not be asked questions by or influenced in any way by the researchers. The observation and surveys will take place in the classroom under the supervision of an uninvolved teacher. This study will last approximately eight weeks (the length of the unit).

CONFIDENTIALITY/ANONYMITY

The information provided during this research study will be kept anonymous to the extent permitted by law. To help protect anonymity, student participants will be using a code in lieu of their name on all surveys. Names will not be associated with the coded numbers, so the researchers will not be able to identify participants. All surveys and data collected from the surveys will be stored in a password-protected document. Only the researchers will have access to this document.

DO PARTICIPANTS HAVE A CHOICE TO BE IN THE STUDY?

Students will not lose any benefits or rights they would normally have if they choose not to volunteer. They can stop at any time during the study and still keep the benefits and rights they had before volunteering. They will not be treated differently if they decide to stop taking part in the study. They are free to skip any questions that they would prefer not to answer.

Principal/Administrator's Approval:

The project described above is within the usual educational procedures of this school district.

I give my approval to the Student Investigators listed above to conduct this project.

____

Principal/Administrator's Signature Date

____

School School District

Appendix C

Parent/Student Informed Consent

Project Title: The Effect of Project-Based Learning on High School Girls' Attitudes Towards Chemistry

Dear Participant:

You are being asked to participate in a research study through the Department of Education at Carthage College by Patricia Rieman, PhD. The researchers are required to receive your informed consent before you participate in this project.

Your participation in research is voluntary. If you choose not to participate, there are no penalties or loss of benefits or services to which you are otherwise entitled. You may withdraw or be withdrawn from the study at any time without penalty and without loss of benefits.

A basic description of the project is written below. Please read the explanation below and discuss it with the researchers. We encourage you to ask questions to help you understand the project at any time during the experiment. After any questions you may have are answered and you decide to participate in the research, please sign on the last page of this form in the presence of the person who explained the project to you. A copy of this form will be given to you to keep.

1. PROJECT PURPOSE:
The purpose of this research study is to determine the effect that project-based learning has on student attitudes towards chemistry, perceived communal value of chemistry, and future college and career plans. This study will be used to complete the requirements of the Master of Education program at Carthage College with the possibility of utilizing the anonymous results for publication and presentation.

2. EXPLANATION OF PROCEDURES:
As a participant in this study, you will be asked to anonymously complete a pre and post survey to determine your attitudes, motivations, and future plans in chemistry before and after a classroom unit of study. The survey will be distributed in electronic form. You will not be asked questions that may reveal your identity or influence you in any. The completion of the surveys will take place in the classroom under the supervision of an adult who is not involved in the research study. If you agree to take part in this study, your involvement will last approximately eight weeks (the length of the unit), and you can expect to spend about 20 minutes on active participation (survey completion).

3. CONFIDENTIALITY:

Participation in research entails a potential loss of privacy. The information you provide during this research study will be kept anonymous. To help protect anonymity, student participants will be using a code on all surveys. Names will not be associated with the coded numbers so the researchers will not be able to identify any participant. An uninvolved adult will distribute and collect all consent forms and surveys to protect your anonymity. All surveys and data collected from the surveys will be stored in a password-protected document. The digital data will be destroyed three months after the completion of the study.

4. COMPENSATION:

You will not be compensated for taking part in this research study.

5. BENEFITS:

We do not know if you will benefit from participating in this study. However, we believe that in the future, other teachers and students may benefit from the results of this study by learning about new instructional strategies.

6. RISKS:

There are no foreseeable risks to participating in this study

7. CONSENT:

☐ I have read the above information about *The Effect of Project-Based Learning on High School Girls' Attitudes Towards Chemistry* and have been given an opportunity to ask questions. I agree to participate in this project.

____ **Date:** ____________________

Signature of Participant

____

Printed Name of Participant

____ **Date:** ____________________

Signature of Parent/Guardian

____

Printed Name of Parent/Guardian