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The Effect of Virtual Labs on High School Student Attitudes Towards Chemistry

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The Effect of Virtual Labs on High School Student Attitudes Towards Chemistry

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Abstract

This mixed-methods action research project evaluated high school chemistry student attitudes towards chemistry before and after the students completed a virtual laboratory. Students were surveyed by utilizing the Attitude Toward the Subject of Chemistry Inventory (Bauer, 2008) and a random sample of students were interviewed by the author. Survey scores in five subscales (emotional satisfaction, anxiety, intellectual accessibility, interest and utility, and fear) were compared through statistical analysis of mean, standard deviation, and t-test. Student attitudes were not significantly different before and after the virtual laboratory experience but did show a general decrease in perceptions of interest and utility of chemistry. Themes in the interviews showed that students enjoyed the lab experience. Students also felt that they learned a chemistry concept but did not express a change in attitude toward chemistry. The results of the action research show that the use of virtual labs in a chemistry classroom and student attitudes towards chemistry should continue to be evaluated.

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Chapter 1

Introduction

Completing laboratory experiences in a high school chemistry classroom is what many students know of chemistry before taking a chemistry course. Movies and TV shows often show a chemistry lab where there are bubbling flasks with steam pouring out and explosions that occur when two materials are incorrectly mixed. Chemistry labs are not usually like this but are still places where students can do hands-on experimentation to learn more about the ideas of chemistry. Using lab experiences in a chemistry classroom is well-documented as being necessary for a deeper understanding of chemistry ideas (National Research Council, 2005).

As technology has advanced, virtual laboratory experiences have emerged as a tool to provide a laboratory experience when a physical experience is not possible. For example, many schools do not possess the equipment necessary to carry out specific experiments. Additionally, many colleges and high schools have shifted to online instruction to reach students that are not able to attend classes or chose not to. In 2020 as the COVID-19 pandemic forced many schools to stop in-person instruction and move to an online or hybrid teaching model, chemistry teachers found that virtual labs were the only option for providing students an opportunity to see chemistry in action.

The decision to move to virtual lab experiments was not made because virtual labs are known to be a best teaching practice, but instead because of necessity. The purpose of this study was to look at one of the possible impacts of moving to virtual lab experiences, a change in student attitude towards chemistry. Typically, making a drastic change to teaching practice would happen only after spending time determining the impact the change might have on students. It is important to determine how this change impacted students and use that information to determine whether virtual labs will continue to be an appropriate and effective teaching method after in-person classes can resume.

Brief Literature Review

Virtual labs have been used for many years before distance teaching became wide-spread with the COVID-19 pandemic. Many research studies have focused on the effectiveness of virtual labs and how virtual labs can alter student attitudes towards science. Additionally, research has been on-going in determining how to measure student attitudes and the value of understanding not only what students know about a subject but how they feel about a subject.

Using virtual labs can be an effective teaching method. The effectiveness of a tool in teaching students desired learning outcomes is an important piece of knowledge for any teacher. Virtual labs have been studied as an alternative to or addition to in-person labs to determine if students will learn from the virtual lab experience (Davenport et al., 2018; Miller et al., 2018; Tatli & Ayas, 2013; Enneking et al., 2019, Pyatt & Sims, 2012). Through multiple studies, virtual labs have been shown to be as effective or possibly more effective for student learning across a variety of student populations. Therefore, it was not the objective of this study to measure the specific learning outcomes of using virtual laboratory experiences with students. Instead, the focus was specific to how students' attitudes were affected by the implementation of the virtual lab being incorporated into the teaching methods.

The evaluation of student attitude is an important step for educators to take when determining if a teaching method is valuable. Not only should educators strive to use teaching methods that provide adequate learning gains, but also educators should strive to make classes enjoyable and engaging. The American Association for the Advancement of Science (1989) included the acquisition of attitude along with knowledge and skills as tenets of a curriculum that promotes scientific literacy. By measuring student attitudes, educators can learn about their student’s responses to different effective teaching methods, to better understand which will improve not only academic understanding but also improve a student 's attitude towards a subject.

Research has shown that a positive attitude towards chemistry can increase student engagement, improve student interest, and increase the potential for students to study chemistry in the future (Ross et al., 2020; Kaur & Zhao, 2017). Other research has shown that by improving student attitudes towards a subject, student achievement also increases (Xu & Lewis, 2011). Measuring student attitudes towards chemistry can provide valuable insight into how a student may choose to engage with chemistry in their future.

Student attitudes towards a content or teaching method are valuable and should be considered when planning for effective instruction. While the research has shown relative agreement on the effectiveness of virtual labs for content knowledge gains and cognitive growth, and that student attitude can improve motivation and achievement, the research does not agree about the attitude students have towards the use of virtual labs. Many studies have been done that measured both cognitive growth and student attitude. Some have shown negative student attitudes towards virtual labs, others have shown no difference in student attitude between virtual and in-person labs and still others have shown a positive effect on student belief in their lab abilities (Hensen & Barbera, 2019; Enneking et al, 2019; Pyatt & Sims, 2012; Miller et al., 2018; Kolil et al. 2020). This disagreement of research led to the focus of how students feel about performing virtual labs as compared to in-person.

Statement of the Problem

Due to distance learning and teaching, hands-on chemistry laboratory experiments were not available for student learning. Instead, many chemistry educators relied on a virtual laboratory platform to provide students with lab experiences. It was important to know how these virtual laboratory experiences were perceived by students, and how they affected student attitudes towards science. The attitude of students towards the tool of virtual laboratories was used to determine if virtual labs should continue to be used after students return to in-person learning, or if virtual labs were only a tool to fill-in during the atypical distance learning situation.

Purpose of the Study

Utilizing virtual laboratory experiences was a requirement due to distance learning and distance teaching during the COVID-19 pandemic, but in the future could be an effective teaching method in place of hands-on laboratories for some experiments. Virtual labs may provide opportunities for students to experience labs that require specialized equipment a school does not own or could be used in situations where students cannot be in a class like snow days or when students are home ill. Some research has shown that students learn chemical laboratory concepts equally as well with virtual lab experiences and hands-on lab experiences. By evaluating student attitudes towards virtual lab experiences, data was used to guide the decision on whether or not to continue the use of virtual laboratory experiences once hands-on laboratories can be implemented again.

Research Question

How will the implementation of virtual laboratory experiences affect student attitudes towards science?

Definition of Variables

The following are the variables in the study:

a. Independent Variable: Virtual laboratory experiences - "Virtual laboratories simulate a real laboratory environment and processes, and are defined as learning environments in which students convert their theoretical knowledge into practical knowledge by conducting experiments" (Woodfield, 2005 as cited by Tatli, 2013)

b. Dependent Variable: Student attitudes - "A tendency to respond to a certain stimulus, where the response has both a cognitive (what do I think about studying chemistry?) and an affective (how do I feel about studying chemistry) dimension." (Rosenbeerg & Hovland, 1960 as cited by Brown, 2015)

Significance of the Study

By understanding students' attitude towards the subject of chemistry, and how it can be changed through the implementation of new teaching methods like virtual labs, improvements can be made to teaching practices to meet students' needs. Additionally, the process of this research can be repeated to determine the effect on student attitude of other teaching practices in the chemistry classroom. While virtual labs were necessary for the 2020-2021 school year, they will not always be. Once it is safe to return to in-person learning, chemistry teachers will return to physical labs. However, virtual labs may be a good alternative when equipment or supplies are not available due to space or budget or may provide a better learning opportunity for specific content ideas. The potential benefit of continuing to use virtual labs must be weighed with how the use of the virtual labs affects student attitudes towards the subject.

The research has shown mixed results when measuring how students perceive virtual labs. This may be a result of the implementation of virtual labs, the software used, or the age and demographic of the student population. By doing this study, the data and results add to the on-going research regarding how virtual labs can change student attitudes towards chemistry and provide a better understanding of the unique student perspectives of the classroom.

Research Ethics

Permission and IRB Approval

To conduct this study, the researcher obtained MSUM's Institutional Review Board (IRB) approval to ensure the ethical conduct of research involving human subjects (Mills & Gay, 2019). Likewise, authorization to conduct this study was obtained from the school district where the research project took place. A copy of the letter is found in Appendix A.

Informed Consent

Protection of human subjects participating in research was assured. Participant minors were informed of the purpose of the study via the Method of Assent (See Appendix A) that the researcher read to participants before the beginning of the study. Participants were made aware that this study was conducted as part of the researcher's Master Degree Program and that it will benefit their teaching practice. Informed consent means that the parents of participants were fully informed of the purpose and procedures of the study for which consent was sought and that parents understood and agree, in writing, to their child participating in the study (Rothstein & Johnson, 2014). Confidentiality was protected through the use of pseudonyms (e.g., Student 1) without the utilization of any identifying information. The choice to participate or withdraw at any time was outlined both verbally and in writing.

Limitations

This study surveyed all willing participants in the researcher's assigned chemistry classroom. The results were then used to inform teaching practices in the future. The results from this chemistry class may or may not reflect the attitudes of students in future chemistry classes. Additionally, this study was conducted after several virtual labs had already been completed by the chemistry class. This could affect how much of a change in student attitude was seen, as no student attitude measurement was made before implementing virtual labs with distance learning earlier in the year. The data measurement will only provide information on the implementation of the particular virtual lab done during the study. The results of the study could reflect student opinions about the virtual lab about concentration, and not about virtual labs as a teaching methodology.

Conclusions

The use of virtual labs became a requirement, as distance learning was implemented due to the COVID-19 pandemic. While research has shown that virtual labs can be as effective as physical labs for learning scientific content, the research is not as consistent when discussing how students feel about the subject of chemistry as a result of using these virtual lab experiments. This study focused on determining student attitudes towards the subject of chemistry before and after using a virtual lab activity. The study informed decisions on how virtual labs will or will not continue to be a useful tool for teaching practice after schools return to in-person learning. The next chapter gives a detailed review of the literature that has been published on the effectiveness of virtual labs, how student attitudes affect their academic achievement and future careers, and the lack of consensus about how students feel about virtual labs.

Chapter 2

Literature Review

Physically manipulating materials, mixing chemicals, and observing the results have long been an essential part of chemistry classrooms. Laboratory activities are typically done in a classroom setting, where students can explore the concepts of chemistry in a hands-on setting. Virtual labs have been used for many years as an addition or alternative to physical science labs. As distance and hybrid learning became commonplace due to the global pandemic, physical science labs became very difficult to complete. Therefore, many chemistry educators implemented the use of virtual labs or lab activities done on a computer without a physical lab component. Understanding the effectiveness of virtual labs in terms of learning the desired academic outcomes, to ensure that students are meeting academic goals became important to chemistry educators. Additionally, understanding student attitudes towards virtual labs was important before deciding the overall effectiveness of the tool for science lab instruction, due to student attitudes affecting their enjoyment, engagement, and potential future involvement with the subject area. Measuring changes in student attitudes towards the subject of chemistry based on their completion of virtual labs was the focus of the study. A review of past research showed that virtual labs can be a valuable tool for student cognitive growth, with many studies focusing on how well students learned chemistry concepts from virtual labs. However, research regarding how virtual labs can affect student attitudes towards the study of chemistry was more difficult to find. Literature on attitude in chemistry varied in results, with very little consensus throughout the studies that had been completed. The lack of consensus in past studies, and limited research on attitude in chemistry being affected by virtual labs, indicated that studying student attitudes in the high school setting was valuable research. Knowing how attitude is affected by virtual labs provided valuable information on whether virtual labs should be included in the chemistry classroom in the future.

Body of the Review

Virtual Labs Academic Effectiveness

Knowing if a tool is effective in teaching students desired learning outcomes is an important piece of knowledge for any teacher. Therefore, before implementing virtual labs, even in a distance teaching model, it should be clear that the virtual labs will provide students with learning potential and cognitive growth. Virtual labs have been studied as an alternative to or addition to in-person labs to determine if students will learn from the virtual lab experience (Davenport et al., 2018; Miller et al., 2018; Tatli & Ayas, 2013; Enneking et al., 2019; Pyatt & Sims, 2012). Through these studies, virtual labs have been shown to be as effective or possibly more effective for student learning across a variety of student populations.

Studies have compared in-person and virtual labs through measuring pre-and post-test results and have shown that the overall knowledge acquired from the virtual labs was similar to the in-person labs. In 2018, Miller et al. studied a group of undergraduate students that were not science majors enrolled in an introductory physical science class. A pre-test and post-test of ten content questions were given to the students for each lab. The group of students doing labs in-person without the use of a virtual component had overall higher scores on the posttest than the students in the virtual lab group. However, the comparison of knowledge before and after the lab showed that the two groups had comparable gains.

Pyatt & Sims (2012) saw comparable outcomes in a study of high school chemistry students. The students were exposed to both virtual and in-person labs in an alternating format. One group performed the first lab in-person and the second lab virtually and the other group did the reverse of that. The lab performance of the students - including data collection and interpretation, ability to formulate hypotheses and conceptual models, and making predictions - was measured for both types of labs. The research found that there was no significant difference in these measured outcomes between the virtual labs and in-person labs in one trial, and an increase in mean assessment scores for the virtual group in a second trial lab, suggesting that for conceptual knowledge, virtual labs could be a valuable substitute to in-person labs. Farrokhina & Esmailpour (2010) found comparable results with research in an electricity laboratory at the undergrad level. Virtual labs can be a useful tool in a variety of classroom settings.

Additional researchers have shown that virtual labs are effective in teaching conceptual ideas and have presented their ideas on why virtual labs are effective. By using the Chemical Changes Unit Achievement Test (CCUA), the laboratory equipment test, interviews, and observations, the researchers evaluated student achievement comparisons when virtual labs were used in place of traditional labs. Results on the CCUA showed that the experimental group, completing virtual labs only, had the largest increase in content knowledge (Tatli & Ayas, 2013). Students performed equally as well on the laboratory equipment test if they were exposed to the same labs virtually or in-person. Faour & Ayoubi (2018) found that the same is true for physics concepts learned through virtual labs. Tatli & Ayas (2013) proposed that an increase in content knowledge could be related to students' ability to see macro, micro, and symbolic dimensions of experiments as well as have more choice in their exploration of the laboratory, where Faour & Ayoubi (2018) believed that the ability to see microscopic aspects of the physical principles was key to improving student understanding. Sengal & Ozden (2010) suggested that learner control and immediate feedback were also important to the virtual lab's success in improving student understanding.

Virtual labs have also been shown to be a good teaching tool in addition to in-person, as a way for students to review what they have previously learned, and to add to the learning that occurred in classroom instruction. Davenport et al. (2018) utilized virtual labs in different contexts to measure the effectiveness of the virtual labs. In a study of high school students, teachers were asked to use the virtual labs in their classrooms in a variety of ways. Some teachers used virtual labs in place of in-person, some used them in addition to in-person, and others used them as a review. Additionally, virtual labs were used as homework, in the classroom, and individually or in pairs. Pre-test and post-test scores show that students did learn from all applications of the virtual labs, but the largest gains in test scores were found when the labs were used as review and individually.

While many studies found that students performed equally as well between the in-person and hybrid lab groups for cognitive and psychomotor growth, the same was not found for affective measures. Affective measures include attitude, feelings of usefulness, and overall satisfaction with the content. Enneking et al. (2019) created a hybrid lab environment for undergraduate chemistry students, where the experimental group completed alternating in-person and virtual labs, and the control group used only in-person lab. As seen in other research, students in the virtual setting had similar cognitive growth to the students in face-to-face labs.

Research showed that teaching via virtual labs is a viable technique for student growth. Although virtual labs are at least as reliable in teaching chemistry concepts as physical labs, teachers also want students to have a positive attitude towards the subject they are teaching. The effect of virtual lab experiments on student attitudes and affective measures is another side of research that must be explored before virtual labs can be thoroughly vetted as a sound teaching tool. However, research has not been as clear on the changes that can occur in student attitude when utilizing virtual labs in place of physical labs.

Attitude Towards Chemistry

The evaluation of student attitude is an important step for educators to take when determining if a teaching method is valuable. Not only should educators strive to use teaching methods that provide adequate learning gains, but also educators should strive to make classes enjoyable and engaging. The American Association for the Advancement of Science (1989) includes the acquisition of attitude along with knowledge and skills as tenets of a curriculum that promotes scientific literacy. By measuring student attitude, educators can learn about their student's responses to different effective teaching methods, to better understand which will improve not only academic understanding but also improve on student attitude towards a subject.

The definition of attitude utilized is "a tendency to respond to a certain stimulus, where the response has both a cognitive (what do I think about studying chemistry?) and an affective (how do I feel about studying chemistry) dimension." (Rosenbeerg & Hovland, 1960 as cited by Brown, 2015) Attitude was measured through the use of the Attitude toward the Subject of Chemistry Inventory (ASCI) as developed by Bauer (2008) which has been shown to provide information about student perceptions of interest and usefulness, intellectual accessibility, feelings of anxiety, and emotional satisfaction associated with chemistry.

A positive attitude towards chemistry can increase student engagement (Ross et al., 2020). Also, a positive attitude can improve students' interest in the subject and their potential to study the subject in the future (Kaur & Zhao, 2017). Akkus (2019) found that students who have high positive attitudes toward science are open to new ideas, which is important for students to carry into their futures, even if they are not studying chemistry.

Additionally, research has shown that attitude can, but does not always, correlate with an increase in academic achievement in regards to science courses (Brown et al., 2015). Student attitude has sometimes been linked to student achievement. Many teachers will report that students tend to perform better in class when they have a positive outlook towards the content. Brown et al. (2015) studied a group of undergraduate chemistry students to determine if their attitude towards chemistry was correlated with their achievement in an undergraduate chemistry course. Students were asked to complete the Attitude to the Study of Chemistry Inventory to determine their feelings towards the content. The results showed no significant correlation between student attitude and achievement in the course. Xu & Lewis (2011) found that attitude and achievement were shown to be significantly related if initial ability scores were considered. In similar studies, research has shown a correlation between attitude and achievement (Xu & Lewis, 2011; Afari, 2015; Ali & Awan, 2013, Veloo et al., 2014).

As the research has shown, student attitude is an important aspect of education. In addition to knowing that attitude affects student motivation and achievement, students must enjoy chemistry, and ensuring that a teaching method is not only effective in teaching content but also in improving or maintaining student attitude is paramount to holistic education. By evaluating the attitude changes of students, educators understand how the implementation of virtual labs changes student views on chemistry as a subject. Although there is sufficient research showing the academic effectiveness of virtual labs, and evidence that attitude is an important part of a student’s education, there is not a consensus on how student attitude is impacted by the use of virtual labs in a chemistry classroom.

Studying Student Attitudes Towards Virtual Labs

While the research has shown relative agreement on the effectiveness of virtual labs for content knowledge gains and cognitive growth, and that student attitude can improve motivation and achievement, the research is not as consistent in terms of student attitudes towards the use of virtual labs. Several studies have been done that measured both cognitive growth and student attitude. Some have shown negative student attitudes towards virtual labs, others have shown no difference in student attitude between virtual and in-person labs and still others showed a positive effect on student belief in their lab abilities (Hensen & Barbera, 2019; Enneking et al, 2019; Kolil et al. 2020; Pyatt & Sims, 2012; Miller et al., 2018). The disagreement of research led to the emphasis on studying how students feel about performing virtual labs as compared to in-person, and how their attitude towards chemistry as a subject may be impacted.

At times, virtual labs resulted in a decrease in student attitudes towards chemistry. Hensen & Barbera (2019) split a group of undergraduate chemistry students into groups where some completed traditional hands-on labs and others did similar labs in virtual settings. The study focused on how changing the setting affected the affective domain, including student perceptions of their knowledge and their emotional satisfaction when completing the lab activity. The Attitude toward the Subject of Chemistry Inventory (ACSI) was blended with the Chemistry Laboratory Anxiety Instrument (CLAI) and the Virtual and Physical Experimental Questionnaire (VPEQ) to create a student survey addressing the affective domain of student learning. Initially, the results showed that students completing the virtual lab had lower emotional satisfaction. However, after evaluating the data, it was seen that certain sections of students using the virtual lab setting had significantly lower emotional satisfaction scores than others. After sorting the data by teaching assistant (TA), it was found that certain sections had significantly lower scores, which may have been related to the TA assigned to that section. Therefore, the results may indicate that the mode of the lab (virtual versus in-person) had less to do with emotional satisfaction than the TA for the class. Enneking et al. (2019) drew similar conclusions in a comparable study of undergraduate students in chemistry. Additionally, Enneking et al. found that the students completing virtual labs half the time saw less connection to the real-world than students doing all in-person labs. However, students doing all in-person labs also did a wider variety of labs, which may have provided more opportunities to see real-world connections.

In other research, no significant difference was found in student attitude towards virtual or in-person labs. Pyatt & Sims (2012) utilized scales about the usefulness of computers and anxiety towards computers to measure how students felt about using computers in the laboratory setting, as well as the equipment usability and open-endedness scales to determine how students felt about the operation of the virtual lab experience. Students showed a preference for virtual labs in terms of open-endedness and equipment usability. Students also preferred the inclusion of computers in the lab setting. Paour & Ayoubi (2018) studied grade 10 physics students and showed similar results of no significant effect on student attitudes. Pyatt & Simes (2012) suggested that because of the students' preferred interaction and the ability to test their ideas, virtual labs may be preferred because of the flexibility allowed by that medium and Paour & Ayoubi (2018) suggest that the virtual labs allowed students to continue their studies at home, allowing for further exploration of the material, which both provide the possibility for promoting an increase in student attitude if there was a desire to explore scientific concepts.

Miller (2018) included an attitudinal component to their pre-test and post-test in addition to their content questions. Through a set of Likert-style questions, they asked students about their preferences in laboratory instruction methods. Students showed no significant preference for virtual versus in-person lab settings. Additionally, an open-ended question asked students to discuss why they would choose virtual instead of in-person settings. Results showed that the major reason for choosing virtual was the convenience of being able to do the lab outside of class time. A major reason for in-person was getting immediate feedback from an instructor and wanting to work with others.

Theoretical Framework

Attitude is commonly understood as a set of psychological ideas where a person feels favor or disfavor towards an object, person, or idea (Hitlin & Pinkston, 2013). Focus was placed on students' attitude towards the object of chemistry as a subject. Understanding that attitude has conscious and unconscious aspects, and study evaluated the conscious, self-reported attitude of the students (Hitlin & Pinkston, 2013). Although attitude is based on individual beliefs, it can be changed in the presence of new information (Hitlin & Pinkston, 2013). The idea of attitude being a moldable construct created a framework for focusing on the idea that a teaching technique can alter a student's attitude towards chemistry.

Research Question

How will the implementation of virtual laboratory experiences affect student attitudes towards science?

Conclusions

Virtual laboratory activities may be used as an alternative to hands-on, physical laboratory activities. Research has shown that these activities are effective in teaching science content, but research is not as clear on how students feel about the use of virtual labs, or how virtual labs may affect students' outlook on chemistry. Additionally, research has shown that student attitude may be a contributing factor in student achievement, motivation, and future career choice. The research study focused on evaluating how student attitudes towards chemistry are influenced by the implementation of virtual labs in a high school chemistry classroom through the use of a survey and interview, to inform the researcher about the future use of virtual labs in the chemistry classroom.

Chapter 3

Methods

Research has shown that virtual lab activities can add to student content knowledge and are therefore an appropriate teaching method (Davenport et al., 2018; Miller et al., 2018; Tatli & Ayas, 2013). However, teaching science is not just about advancing student content knowledge, but also, according to the American Association for the Advancement of Science (1989), should include the acquisition of attitude along with content knowledge and skills. This research was focused on how this attitudinal component is affected by the implementation of virtual lab experiences. To determine the impact a virtual lab experience had on student attitudes towards chemistry, the researcher determined that a mixed-methods action research project utilizing a longitudinal survey as the quantitative component and an interview as the qualitative component was an appropriate method. By measuring student attitudes towards chemistry in a quantitative format before and after doing a virtual lab, the researcher could determine if a significant change had occurred in student attitudes towards chemistry. The additional component of the qualitative survey allowed for further insight into why student attitudes may have changed. Quantitative results could reflect student preference, comfort levels with technology, or student views on the specific material covered by the lab versus the use of virtual labs as a whole. By utilizing a mixed-methods approach, the researcher gained insight to determine if virtual lab experiences should continue to be a tool utilized in the researcher's chemistry classroom.

Research Question(s)

How will the implementation of virtual laboratory experiences affect student attitudes towards science?

Research Design

This research project was an action research study utilizing a mixed-methods approach. As an action research project, the results of this study will be used to determine if virtual labs affect the attitude towards chemistry of the researcher’s students. It is meant to inform the researcher’s classroom practices, and the results will be used to assist in the decision on whether to continue using virtual labs in the chemistry classroom. The study is based on a quantitative survey, followed by a qualitative researcher-led interview. This research followed the explanatory design, as described by Fraenkel et. al. (2015), where the quantitative study was the higher priority of the study, and the qualitative study was used to provide more explanation and context for the results of the quantitative survey. Quantitative results were important to the research because they were able to analyze if a change in student attitude had occurred. The qualitative portion of the study was included for the researcher to gain more feedback from the participants on how the independent variable (implementation of the virtual lab) affected the dependent variable (attitude towards chemistry) in a clear, conversational way. The researcher believed that this could help explain why any significant changes in student attitude appeared in quantitative research.

The survey was conducted as a longitudinal survey, where information was collected multiple times at different moments in time to see changes in the results of the survey (Fraenkel et al., 2015). This research was run as a panel study, where the sample of individuals surveyed stayed the same between the two points in time (Fraenkel et al., 2015). The use of a longitudinal survey was recommended by the creator of the survey utilized in the study because the survey itself does not have a particular score that is deemed “good” or “bad” but is a better tool for measuring how attitudes towards chemistry change over some time (Bauer, 2008). The use of a longitudinal survey provided an opportunity to compare the attitude of the participants before and after the participants completed the virtual lab activity.

The longitudinal survey created a potential problem with the retention of participants, as the loss of several participants between the surveys could have affected the overall results of the study. This was addressed by providing participants with multiple opportunities for completing the survey, and through multiple reminders for participants that did not complete the survey after the first request.

Setting

This study took place in a rural school district in central Minnesota. The district includes six towns and has approximately 1500 students K-12. The senior high is located in a town with a population of approximately 5500 people. The makeup of the town is as follows: generally high school educated, with approximately 14% of people over 25 years holding a bachelor’s degree or higher. Approximately 17% of the population was Hispanic or Latino, and approximately 80% was white. Industry and working-class jobs comprised the majority of the town’s economic output.

The participants of this study are all in the senior high of this district. The senior high has approximately 500 students enrolled. The breakdown of race mirrors that of the city, with 17% of students being Hispanic or Latino and 80% being white. English learner students make up 2.3% of the population, and special education students make up 11%. Approximately 24% of students are enrolled in the Free/Reduced Lunch program. The parents of students are typically farmers, manufacturing workers, or commute to jobs in larger cities.

Participants

The participants of the study were students enrolled in high school chemistry at the researcher's school. These students were all in their second trimester of the course and had been enrolled in the course for the entirety of the year. Students in this study were 38% male and 62% female. Non-white students made up 14% of the sample. The ages of the participants ranged between 16 and 18, and students were either juniors or seniors in high school.

Sampling

Participants were selected through a convenience sample. The sample was based on the students' enrollment in the researcher's chemistry class. All students in the course were asked to complete the survey before and after the virtual lab. The sample of ten students for the interview was randomly selected through a random number generator, where each student was assigned a number by alphabetical order, then when a number was drawn, that student was invited to participate in the interview. An additional ten students were drawn as alternates if students chose not to participate in the interview.

Instrumentation

The tool used in this research was called the Attitude toward the Subject of Chemistry Inventory (ASCI) as created by Bauer (2008). The ASCI was a self-administered survey that includes twenty questions in the format of a semantic differential. Each question begins with "Chemistry is . . ." and asked students to place themselves on a seven-point scale where the two ends of the scale are opposing adjectives. Examples of the adjectives include worthwhile vs. useless and interesting vs. dull. By starting each question with "Chemistry is . . ." students were focused on the subject of chemistry again and again. The survey took approximately ten minutes and was provided to students during class time through Google Classroom on a Google Form. A copy of the survey is in Appendix B.

The twenty items in the survey were separated into three factors and two items. The three factors include Interest and Utility, Anxiety, and Intellectual Accessibility. Interest and Utility includes items 2, 3, 6, 12, and 15 and addresses how students feel regarding chemistry being exciting, worthwhile, or interesting. Anxiety includes items 8, 13, 16, 19, and 20 which seek to explore how students feel about chemistry with words like fun, tense, and disgusting. Intellectual Accessibility includes items 1, 4, 5, 9, and 10, including words like confusing vs. clear, and complicated vs. simple. The items are Fear (item 18) and an Emotional Satisfaction set (items 7, 11, 14, and 17). Factors were determined by Bauer (2008) due to the adjectives grouping into specific patterns. Clear distinctions are found between the factors and they are shown to be independent of each other.

The ASCI was utilized to measure student attitudes towards chemistry and was shown to be valid and reliable as reported by Bauer (2008). By evaluating the responses for three different groups of students: general chemistry students, study group leaders, and chemistry majors, Bauer (2008) saw that students who had less experience with chemistry were significantly lower in their Interest and Utility and Emotional Satisfaction and higher in Anxiety, than students that were study group leaders or chemistry majors. It would be expected that students that have chosen to lead a study group or study chemistry would have a more positive attitude towards chemistry. The reliability coefficients reported by Bauer (2008) were close to or above 0.7, showing a strong internal consistency.

The interview questions for this research were written by the researcher. These questions were selected to provide a deeper context for the survey results. The researcher selected four open-ended questions to ask the students during the interview. The questions can be found in Appendix C. Questions focused on student feelings during the lab, how their perceptions of chemistry changed because of the virtual lab, and how their understanding of chemistry changed through the use of the virtual lab. An opportunity for students to share any other information about the virtual lab concluded the interview. These researcher-led interviews lasted approximately 10 minutes.

Data Collection

Data was collected using a survey delivered online through Google Forms. The survey was distributed through the Google Classroom that students are enrolled in for the high school course. Students were asked to complete the survey during class time for both the pre-and post-test. The student responses were then transferred to an excel spreadsheet supplied by Bauer (2008) for analysis. Interviews were conducted through video conferences via Google Hangouts. Interview responses were transcribed and reviewed by the researcher to understand student attitude in more depth.

Data Analysis

Raw data were transferred to an Excel spreadsheet, with each response in numerical form. Before the data was analyzed, responses that were incomplete (#) or showed little to no thought (i.e., all the same number chosen throughout) were thrown out of the data set. Some items were reversed, due to the arrangement of the survey trying to avoid a consistent left or right selection as being “good” or “bad.” These items were reversed on another spreadsheet. The mean score was calculated for each item utilizing the calculation in Excel. Item averages were grouped into the factors and items or item sets described above. The scores for each factor and item or item set were averaged across the entire sample. A sample of the Excel spreadsheet is found in Appendix D. This process was repeated for the second administration of the survey after the completion of the virtual lab activity.

Finally, the data from the survey and interview were analyzed to determine if a significant change in student attitudes occurred before and after the virtual lab activity. This was done with a paired t-test to compare the mean values for each factor and item set. Excel was used to calculate the standard deviation and perform the t-test. After comparing the attitudinal scores for each factor to see if the mean changed significantly, the results were represented on a graph showing how the average shifted, as well as marking any changes in mean that were determined to be statistically significant.

The interview answers were reviewed to see if any patterns were observed and to provide more context for the quantitative data collected by the survey. The researcher reviewed transcripts of the interviews and determined if any themes appeared. A second review of the transcripts was performed to highlight any time the themes appeared in the interview process. Finally, the researcher did a comparison between the themes seen in the interviews with the change in attitudinal scores by the same student. Comparing the interview answers to attitudinal scores provided an opportunity to see correlations between the information shared in the interviews and the increase, decrease, or no change seen in attitude scores.

Research Question(s) and System Alignment

Table 3.1 describes the alignment between the study Research Question and the methods used in this study to ensure that all variables of study have been accounted for adequately.

Table 3.1

Research Question Alignment

Feature	Description
Research Question	How will the implementation of virtual laboratory experiences affect student attitudes towards science?
Variables	IV: Student completion of virtual lab activity DV: Student attitudes about Chemistry as a subject.
Design	Mixed Methods Action Research - Longitudinal Survey and Interview
Instrument	Attitude toward the Subject of Chemistry Inventory (ASCI) - Researcher written questions.
Validity & Reliability	ASCI is shown to assess student attitudes separate from aptitude and performance by Bauer (2008). Reliability coefficients near or above 0.7.
Technique	Longitudinal survey - with students completing surveys before and after completion of virtual lab activity and researcher-led interview.
Source	Bauer (2008)

Procedures

The research project took place over approximately two weeks, with the two administrations of the survey being approximately a week apart. To begin, students were asked to complete the survey through an invitation on Google Classroom and verbally from the researcher. The students were given a day to complete it due to asynchronous learning conditions. Any students that did not complete the survey that day were reminded each of the next two days through email and posted reminders on Google Classroom. Four days after the initial survey was conducted, the researcher assigned a virtual lab activity on the concentration of solutions. This virtual lab was set-up to be done independently and the activity asked students to utilize an online simulation from PhET to create different solutions and begin to understand the idea of molarity. Students had two days to complete the lab activity, including doing the virtual lab and completing the analysis questions at the end of the lab. During the lab activity, students were able to ask questions, and the researcher assisted students in completing the activity through video instructions and open help times. Any students that had not completed the lab after two days were given reminders on each of the subsequent two days to complete the activity. After the lab activity was completed, all students were asked to complete the survey again, with the same procedure as the pre-survey. Responses from any students that had not completed the virtual lab were removed from the data set for analysis.

In the two days following the completion of the lab activity, the researcher randomly selected ten students using a random number generator, with numbers assigned to each student in the course. Those ten students were invited to do a Google Hangout individually to participate in the interview portion of the study. Any students that did not want to participate in the interview were replaced by a randomly selected alternate, via the random number generator. These interviews were conducted across the span of two days, were led by the researcher, and each lasted approximately ten minutes. Students were asked four questions and allowed to respond as much as they wanted. The researcher asked some follow-up questions for clarification, as needed.

Ethical Considerations

This research was conducted only after students and parents had been informed of the study and consent was received. Students and parents were able to decline involvement in the study and informed that they could leave the study at any time. The use of a virtual lab does not create any concerns for student safety or concerns for negative effects on student learning progress. All survey responses and interview questions were coded to create anonymous data with no information that could identify individual students in the study.

Conclusions

The focus of this action research project was to conduct a longitudinal survey measuring student attitudes towards the study of chemistry, and how they were affected by the implementation of a virtual lab activity. The sample was a purposive sample consisting of students enrolled in the researcher's high school chemistry course. The Attitude toward the Subject of Chemistry Inventory (ACSI) and researcher-led interviews were used to collect data. Data were analyzed using descriptive statistics including averages and comparisons of scores before and after the lab activity using a paired t-test. Results of the research are discussed in detail in Chapter 4.

Chapter 4

Results

Through qualitative and quantitative methods, changes in student attitudes towards chemistry as a result of completing a virtual were analyzed. The following chapter presents a summary analysis of the data collected through the quantitative survey and qualitative interview. Survey data are presented in tabular and graphical formats. Interview data are presented through themes that showed up repeatedly in student interviews.

Research Question

How will the implementation of virtual laboratory experiences affect student attitudes towards science?

Data Collection

This research project was an action research study utilizing a mixed-methods approach. The study is based on a quantitative survey, followed by a qualitative researcher-led interview. Survey data were collected through the use of a survey online through Google Forms. The survey was distributed through the Google Classroom that students are enrolled in for the high school course. Students were asked to complete the survey during class time for both the pre- and post-test.

During the research project, students were attending school in a hybrid model due to COVID-19 precautions. This meant that approximately 40% of students were in school two days a week, and another 40% were in-person two different days. There were also approximately 20% of students attending school as full-time distance learners. This arrangement resulted in a large number of students having incomplete survey results. Table 4.1 shows how many students were sampled, as well as the total number of students with complete results. The retention issues resulted in a much smaller sample of the student population than was originally planned. More students may have completed both surveys during in-person learning, which returned about a week after the surveys were completed. However, due to the constant shifting of learning models in the 2020-2021 school year, it was not possible to know when students would return to full in-person learning.

Table 4.1

Student Sample and Retention Data

Description:	Number of Students:
Students enrolled in High School Chemistry	91
Students completing pre-survey	77
Students completing post-survey	64

To select interview participants, each student that participated in the virtual lab was assigned a number based on alphabetical order. A random number generator was utilized to select ten students to be initially invited to participate in the interview. An additional ten students were selected as alternates. Invitations were sent through school email accounts. Students were asked to reply if they were willing to participate in a short interview via Google Hangouts. Of the original ten students chosen, four responded that they would participate, three declined the invitation, and three did not respond within the two days provided for response. Invitations were sent to seven alternates, and two accepted, two declined, and three did not respond. Finally, invitations were sent to the final three alternates, and one student accepted while the other two did not respond. Due to the number of students declining participation or not responding to invitations, only seven interviews were completed instead of ten. Interviews were conducted through video conferences via Google Hangouts. Interview responses were transcribed and reviewed by the researcher to understand student attitude in more depth.

This study took place in a rural school district in central Minnesota. The participants of the study were students enrolled in high school chemistry at the researcher's school. These students were all in their second trimester of the course and had been enrolled in the course for the entirety of the year. Students in this study were 38% male and 62% female. Non-White students made up 14% of the sample. The ages of the participants ranged between 16 and 18, and students were either juniors or seniors in high school.

Research Question 1: How will the implementation of virtual laboratory experiences affect student attitudes towards science?

Survey Data.

Statistical values for the survey data collected can be seen in Table 4.2. Student survey scores were broken into five subscales, where scores for multiple questions relating to a similar theme were consolidated to show an overall score for that subscale. Student scores in each subscale were then averaged to give a score for the class mean. Finally, mean scores were compared through a paired t-test.

Statistical assumptions were analyzed to determine if a parametric test was a valid tool for comparing the means for each subscale. The data, collected through a Likert-scale, generated a score per participant. These scores were normally distributed. Additionally, the sample size was large enough to be representative of the whole population and the standard deviations of the subscale scores show homogeneity of variance. Finally, the data was collected from a sample of students.

Table 4.2

Statistical Values for Pre-Survey and Post-Survey

(n=63*)*

Subscale	Pre-Survey Mean (%)	Post-Survey Mean (%)	Change in Mean (%)
Emotional Satisfaction	52.8 (15.9)	50.4 (17.3)	-2.4
Anxiety	51.5 (12.3)	51.9 (12.7)	0.4
Intellectual Accessibility	38.2 (15.4)	37.2 (16.6)	-1.0
Interest and Utility	66.6 (17.8)	61.7 (17.1)	-4.9
Fear	33.6 (23.5)	36.8 (22.6)	3.2

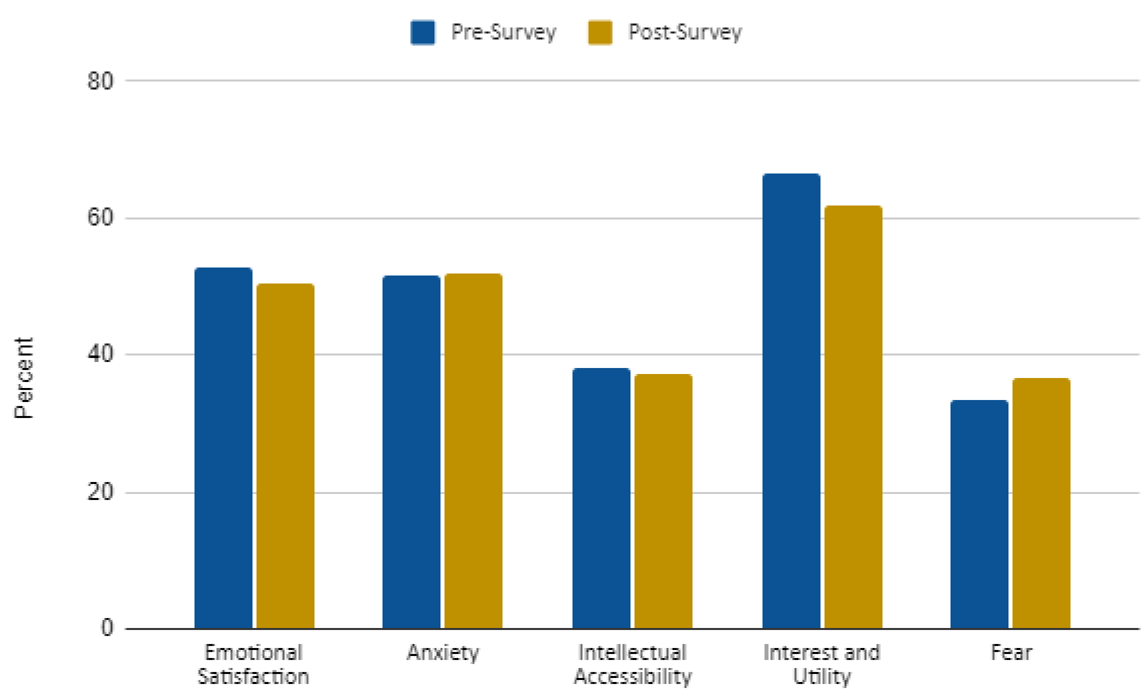
Note. Standard deviations are presented in parentheses.

Figure 4.1 shows the mean percentage scores broken down into subscales and compared between pre-survey and post-survey. The largest change in score between the surveys was in interest and utility, where the mean score decreased by 4.9 %. Emotional satisfaction (-2.4 %) and intellectual accessibility (-1.0%) also decreased in the mean score. Anxiety (0.4 %) and fear (3.2 %) subscales both increased after students had done the virtual lab.

Although a change in mean scores was seen for all subscales, statistical analysis through a t-test showed that there was no significant change at $p < .05$ in mean scores in any of the subscales. The results from the emotional satisfaction subscale means on the pre-survey ($M = 52.8$, $SD = 15.9$) and post-survey ($M = 50.4$, $SD = 17.3$) showed a lower emotional satisfaction, but the difference was not statistically significant, $t(63) = 0.797$, $p = .427$. A small increase in anxiety between pre-survey (*M = 51.5, SD = 12.3*) and post-survey (*M = 51.9, SD = 12.7*), t(63) = -0.136, p = .892 and small decrease in intellectual accessibility scores on pre-survey (*M = 38.2, SD = 15.4*) and post-survey (*M = 37.2, SD = 16.6*) were also not significantly significant t(63) = 0.333, p = .739. While interest and utility had the largest change in mean between pre-survey (*M = 66.6, SD = 17.8*) and post-survey (*M = 61.7, SD = 17.1*), with a decrease of 4.9% the change is still not significant, t(63) = 1.55, p = .123. Finally, fear increased from pre-survey (*M = 33.6, SD = 23.5*) to post-survey (*M = 36.8, SD = 22.6*), but was again not significant, t(63) = -0.765, p = .446.

Figure 4.1

Mean Percentage Scores for Pre-Survey and Post-Survey for ASCI Survey.

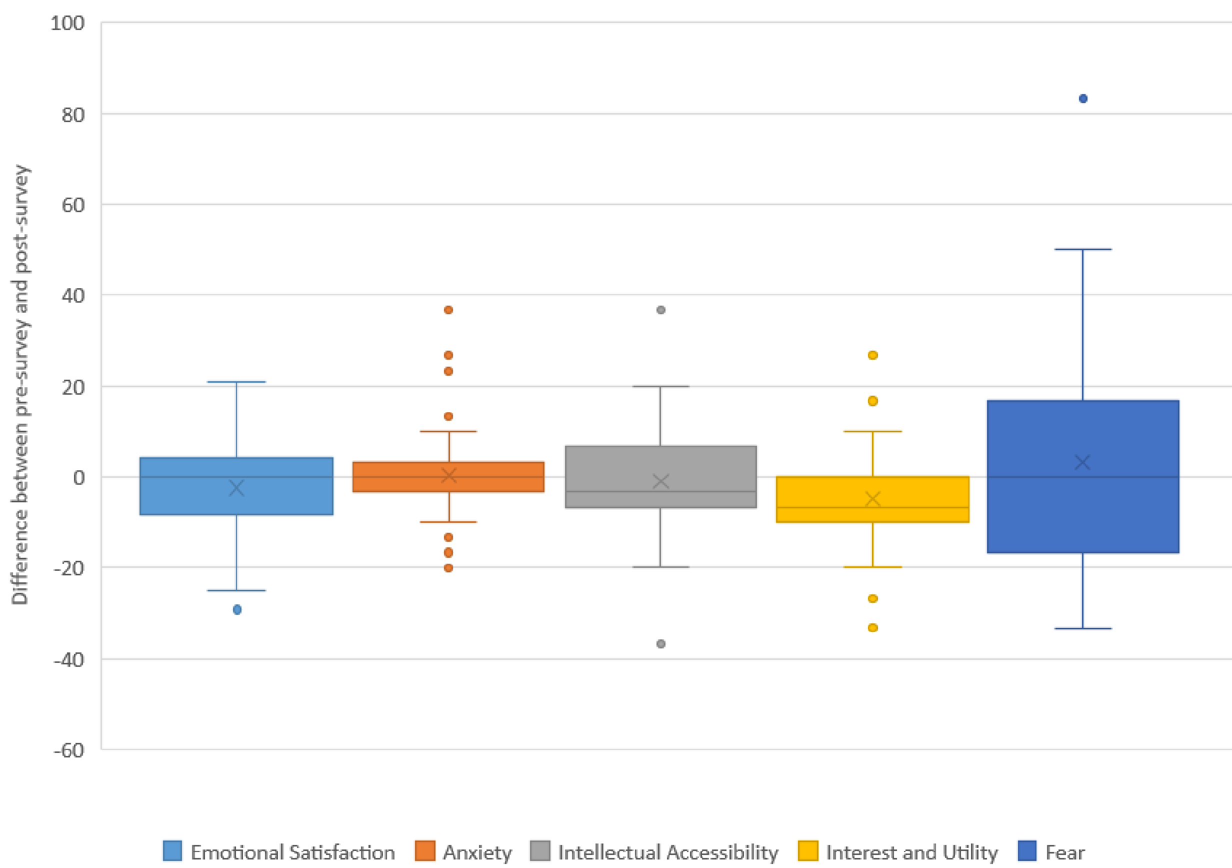


Note. Mean Percentage Scores for Pre-Survey and Post-Survey for each subscale are presented.

Additionally, student scores were compared between the pre-survey and post-survey to determine the change in individual student scores. A box and whisker plot showing the difference between individual student scores in each subscale is shown in Figure 4.2. Figure 4.2 shows that, although statistical analysis suggests no significant change in average scores for the total population surveyed, the distribution of the difference in student responses for Interest and Utility does show a decrease in scores.

Figure 4.2

Difference in Student Responses between Pre-Survey and Post-Survey



Note: Shaded box represents the range between first and third quartile. The upper and lower whiskers represent the minimum and maximum data, while individual points represent outliers in the data. X represents the mean and the line in the box represents the median.

Interview Data.

Student interviews were transcribed and themes between the interviews were analyzed. Due to the brevity of the interview, only three themes were noted: No change in student perception of chemistry, enjoyment of the lab experience, and an increase in understanding of a chemistry concept. Table 4.3 shows the three themes, as well as the number of student interviews that included the theme. Quotes from interviews are given to show the student language that met that theme.

Table 4.3

Tally and Summary of Themes in Student Interviews.
(n=7)

Theme	Tally	Quote (Interview number)
No change in perception of chemistry.	6	“I don’t know how my whole perception changed.” (4)
Enjoyed the lab experience.	5	“I enjoy those kinds of labs a lot like the virtual ones, that are like here - you choose what you can do and we’ll give you the stuff to do it.” (3)
Increased understanding of a chemistry concept.	5	“My understanding changed because I was able to take the pieces one by one and understand each piece and that led me to understand the idea of what we were learning as a whole.” (6)

Data Analysis

The overall data for this study suggests that the answer to the research question: how will the implementation of virtual laboratory experiences affect student attitudes towards science, is complex. Survey data suggest that student attitude was not significantly affected in the five subscales outlined in the ASCI. Additionally, interview themes show that students did not personally think that their attitude towards chemistry changed due to their participation in the virtual lab experience. However, the minimal change in attitudinal scores does suggest that virtual lab experiences are not significantly detrimental to student attitudes towards chemistry but may have slightly decreased student perceptions of interest and utility.

Reviewing previous literature showed that there was not a consensus on how virtual labs may affect student attitudes towards chemistry. The study completed within this research shows that it is likely that student attitude is not significantly changed, but that there may be trends towards a decrease in student attitude. For instance, in the subscale of interest and utility, the class average score decreased from 66.6% to 61.7%. Although the data was too varied to show that the decline was a statistically significant change, looking at the distribution of changes in student scores shows that the middle quadrant of students all decreased in their rating between the first and second survey. This shows that 75% of students had no change or a decrease in feelings of interest and utility towards chemistry. This could have been because of the content within the virtual lab, which was related to the concentration and dilution of solutions. Concentration and dilution are not a flashy part of the chemistry curriculum. It could be possible that a virtual lab on chemical reactions or nuclear chemistry may have increased interest, purely due to the nature of the chemistry content being more engaging for students.

Some themes from the literature review showed up when asking students about their feelings and perceptions of chemistry due to the virtual lab, including what Pyatt & Sims (2012) found: that students preferred virtual labs in terms of open-endedness and equipment usability. This was reflected in a quote from student number 3, “I enjoy those kinds of labs a lot like the virtual ones, that are like here - you choose what you can do and we’ll give you the stuff to do it.” Student number 7 also stated, “it was cool being able to do it so quick without having to clean up or keep adding or taking something out. And not having to dump everything out, you could just press a button. That was cool I guess." Students expressed that there is an ease to a virtual lab as compared to a physical lab. This could contribute to students being able to see the concepts presented in the lab without the barrier of physically having to measure and manipulate equipment. It would be expected that if this were a common feeling of students, the survey results for intellectual accessibility would increase, but that was not reflected in the survey scores.

As a whole, student interviews showed that students did not have strong feelings for or against the use of the virtual laboratory exercise in the chemistry classroom. While the majority of interview participants stated that they enjoyed the lab experience and they felt they learned something, they did not feel that the experience changed their perception of chemistry as a whole. Matching survey data to the interview data supports the conclusion that the virtual lab experience did not significantly change student attitudes towards chemistry.

While the results of the research showed no significant changes in student attitudes, this may be a result of the brevity of the research. Due to COVID-19 uncertainties and shifting learning models, it was not possible to plan for a longer study where multiple virtual labs were conducted between surveys 1 and 2. It would also be beneficial to survey student attitudes over a longer period, for example, a semester or year, to see how attitudes changed in a longer time frame.

Conclusions

The results of the research through a survey and interview show that student attitudes were not significantly changed through participating in a single virtual lab. However, some trends in the data suggest that students may experience a decrease in their perception of the interest and utility of the subject of chemistry after completing the virtual lab on the concentration of solutions. Students expressed through interviews that the lab was fun, and they felt like they increased their understanding of a chemistry concept, but that they did not feel that their perception of chemistry changed.

Chapter 5

Implications for Practice

Completing this action research project provided an opportunity for me to reflect on my teaching methods, specifically how teaching methods may change student attitudes towards chemistry. This chapter discusses how I will use the information I learned through my research to benefit my classroom, students, co-workers, and other science teachers.

Action Plan

Researching the effect virtual lab experiences have on student attitudes has been very relevant to my teaching due to distance teaching and learning during the COVID-19 pandemic. Due to this research, I am going to continue utilizing virtual lab experiences when I feel they are beneficial while evaluating their effectiveness and how students perceive them in the context of a science classroom. I believe there are many ways that virtual labs may continue to be valuable tools in a chemistry classroom. The survey I utilized in this research will become a frequent tool that I utilize to evaluate my students' attitudes towards chemistry or other science content.

Virtual lab experiences will continue to be a part of my teaching toolbox. Although there was a trend in a decrease in student attitudes on the interest and utility of chemistry after doing a single virtual lab, there are many times that a virtual lab experience may be a better choice than a physical lab. For instance, some physical labs require a lot of technical steps, including very precise measurement and several chemicals and labware. When these steps become overwhelming for a student, they may lose interest in the outcomes of the lab, instead only focusing on finishing the required steps. Additionally, having many steps or difficult procedures can result in poor results, which can be discouraging to a student who has put a lot of effort into the lab. I will use virtual labs in these instances because the student interviews I conducted showed an appreciation for the ease of the virtual lab.

I also think virtual labs are very helpful as a pre-lab or in addition to a physical lab. In the student interviews, students said they learned from the virtual lab and mentioned being able to connect the chemistry concepts by seeing the representations in the virtual setting. I believe this will be a powerful teaching tool to incorporate into an otherwise difficult-to-understand lab. By incorporating both the virtual lab and physical lab, I hope that students will gain a deeper understanding of the scientific principles presented in addition to enhancing student engagement through the physical lab.

Another way that this research will affect my teaching practice is through the awareness and evaluation of student attitudes. Although my action research did not provide a strong argument for how virtual labs affect student attitudes, it did provide me with an enhanced view of how student attitudes can be evaluated and considered in making decisions about teaching. I will continue to evaluate student attitudes towards chemistry and use the Attitude Toward the Subject of Chemistry Inventory as a tool in my evaluations. I plan to use this survey every year at least three times, at the beginning, middle, and end of the year. By doing this, I will be able to see how my class is changing student attitudes towards chemistry. I believe this will provide me with valuable insight into how my curriculum can be adjusted to make chemistry more interesting, intellectually accessible, and emotionally satisfying to students while decreasing student feelings of anxiety and fear towards the subject. As a chemistry teacher, I believe that providing students with a positive chemistry experience, while also learning meaningful content, will encourage students to continue studying and thinking about science when they leave my classroom.

Finally, this research will add to the collection of research that has been completed on student attitudes in chemistry courses. Throughout my research on student attitudes and the effects of virtual labs on student attitudes, there were not a large number of studies evaluating the specific population I have studied: high school chemistry students. I believe that although my research was somewhat inconclusive because of the brevity and small sample of high school students, it provides another lens to look through when discussing how virtual labs may be changing student attitudes towards chemistry. I believe my research can provide an example for other high school science teachers to evaluate their students' attitudes as well as how other teaching techniques may change attitudes towards a subject area.

Plan for Sharing

A large number of science teachers turned to virtual labs as a way to engage students with scientific content during distance teaching and learning. In my district, there are six 7-12 science teachers, most of whom have utilized the same virtual lab platform, PhET, that I utilized in this study. I plan to share the results of my study with them, to engage in discussion about the effectiveness of virtual labs and how they might affect student attitudes. Other discussions will focus on the research I found through my literature review to express how virtual labs are effective but should be used judiciously, due to the uncertainty around how they might affect student attitudes.

I believe it is very important to consider how the methods we use to teach students may change their view of a subject area. Through this research, I have learned about ways to measure student attitudes and also how student attitudes can affect them in classroom achievement and choice of future careers. I plan to share the methods of attitudinal measurement with the rest of the science department, as well as ask them to consider implementing an attitudinal survey at the beginning, middle, and end of each year. Through a consistent surveying process, we as staff will be able to look for patterns in how student attitudes change with each science course they take. This will provide us with insights into how we may alter our curriculum to continue to teach scientific content, but also encourage a positive attitude towards science throughout middle and high school.

Additionally, I would like to present my information to the broader chemistry education community. To do this, I plan on writing an article on my study and the insight I gained by measuring student attitudes and submitting it to some publications, including *Chemistry Solutions* from the American Association of Chemistry Teachers and the Minnesota Science Teacher's Association (MnSTA) newsletter. I will also submit a proposal to present at the MnSTA annual Conference on Science Education, where I would review my research and discuss the implementation of attitudinal measurements in secondary science classes.

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Appendix A

Informed Consent Letter

Emily Koehler
Glencoe-Silver Lake Senior High
1825 16th St E
Glencoe, MN 55336

Dear Parent or Guardian,

Your student has been invited to participate in a study to measure how student attitudes towards chemistry are affected by the use of virtual labs. Your student was chosen because they are enrolled in my high school chemistry course. If you decide to have your student participate in the study, they will be asked to complete two surveys asking about their attitude toward chemistry. All students, regardless of participation in the research study, will be completing virtual labs. Only those involved in the study will be asked to complete the surveys. Additionally, ten randomly selected students will be asked to participate in a one-on-one interview with me regarding their attitude towards the virtual lab.

Student participation in the study will involve no risk to the students, and is not required. Participation will not affect their grade. However, students that complete both the pre-test and post-test survey will be entered into a drawing for a gift card.

Principal Matt Foss has granted me permission to conduct this study, and results will be used in my thesis for completion of my master's degree at Minnesota State University. Due to this, I need parental consent to use this information in my final paper. Student names and information will be completely confidential. Also, students can choose not to participate at any time without any consequences.

Please contact me with any questions you have regarding this study. You may call me at (320) 433-3911 or email me at ekoehler@gslpanthers.net.

If you would like a copy of this form to keep, a copy will be provided. By signing this form you are stating that you have read and understood the information on this document and are granting permission for your student to participate in the study. You may withdraw at any time without prejudice after signing this form if you choose to discontinue your student's participation in this study.

____
Student Full Name (Last, First)

____________________________________ ______________________
Signature of Parent or Guardian Date

____________________________________ ______________________
Signature of Investigator Date

Appendix B

Survey Questions

Attitude-to-Subject-of-Chemistry Inventory
Christopher F. Bauer, University of New Hampshire

A list of opposing words appears below. Rate how well these words describe your feelings about **chemistry**. Think carefully and **try not to include** your feelings toward chemistry teachers or chemistry courses. For each line, choose a position between the two words that describes **exactly how you feel**. Mark that number here or on the standard answer sheet. The middle position is if you are undecided or have no feelings related to the terms on that line.

CHEMISTRY IS

1.	easy	1 2 3 4 5 6 7	hard
		middle	
2.	worthless	1 2 3 4 5 6 7	beneficial
3.	exciting	1 2 3 4 5 6 7	boring
4.	complicated	1 2 3 4 5 6 7	simple
5.	confusing	1 2 3 4 5 6 7	clear
6.	good	1 2 3 4 5 6 7	bad
		middle	
7.	satisfying	1 2 3 4 5 6 7	frustrating
8.	scary	1 2 3 4 5 6 7	fun
9.	comprehensible	1 2 3 4 5 6 7	incomprehensible
10.	challenging	1 2 3 4 5 6 7	not challenging
11.	pleasant	1 2 3 4 5 6 7	unpleasant
		middle	
12.	interesting	1 2 3 4 5 6 7	dull
13.	disgusting	1 2 3 4 5 6 7	attractive
14.	comfortable	1 2 3 4 5 6 7	uncomfortable
15.	worthwhile	1 2 3 4 5 6 7	useless
16.	work	1 2 3 4 5 6 7	play
		middle	
17.	chaotic	1 2 3 4 5 6 7	organized
18.	safe	1 2 3 4 5 6 7	dangerous
19.	tense	1 2 3 4 5 6 7	relaxed
20.	insecure	1 2 3 4 5 6 7	secure

Appendix C

Interview questions

1. How did you feel when doing the virtual lab?

2. How did your perception of chemistry change by completing the virtual lab?

3. How did your understanding of chemistry change by completing the virtual lab?

4. Tell me anything else you want to share about the virtual lab.

Appendix D

Spreadsheet Example

Subscale Results		Range:	4 to 28		5 to 35		5 to 35		5 to 35		1 to 7	
		Mean:	4	50	4	50	4	50	4	50	4	50
Identification Parameters			Emotional Satisfaction		Anxiety		Intellectual Accessibility		Interest & Utility		Fear	
ID1	ID2	ID3	Average	Percent	Average	Percent	Average	Percent	Average	Percent	Score	Percent
This was the	0	0	6	75	7	100	3	40	6	80	1	0
used on ED3	0	0	5	67	6	83	4	43	5	70	2	17
0	0	0	5	58	5	67	4	47	5	60	3	33
0	0	0	4	50	4	50	4	50	4	50	4	50
0	0	0	4	42	3	33	4	53	3	40	5	67
0	0	0	3	33	2	17	4	57	3	30	6	83
0	0	0	3	25	1	0	5	60	2	20	7	100
0	0	0										