Virtual Labs in High School Biology: A Mixed-Method Study on Teacher Experiences and Student Academic Achievement

Giancarlo Perez-Flores

New Jersey City University Educational Technology Leadership Program

EDTC809: Assessment and Evaluation

Dr. Christopher Carnahan

October 26, 2021

Adaptive Learning Platforms in High School Biology: A Mixed-Method Study on Teacher Experiences and Student Academic Achievement

Background of the Study

Hands-on laboratory experiences are critical components of science learning. Laboratory experiments and investigations expose students to computational thinking and scientific skills (NRC, 2005). Unfortunately, some schools lack the funding, materials, and access to facilities to provide students with lab experiences forcing teachers to use alternative methods like virtual labs (VL) (Marble, 2017). VLs, digital simulations of the materials, settings, and outcomes of physical labs (PL), have been shown to have similar efficacy as PLs (Achuthan et al., 2017; Darrah et al., 2014). Additionally, emergency adoption of VLs due to school closures and lack of proper professional development can impact teachers' efficacy in using VL technology in their lessons (Dolighan & Owen, 2021). This study will explore teachers' experience and whether self-perceived teacher preparedness impacts the efficacy of virtual labs on student academic achievement.

Statement of the Problem

The lack of lab materials and sudden health emergency measures create a challenge for schools and educators around the globe. The transition to virtual education due to school closures and the ongoing health crisis directly impacts teachers and students in science courses by limiting access to lab materials and facilities. Meanwhile, some schools resuming in-person education are limiting students' hands-on collaboration, and several more schools still lack funding and materials. The absence of lab experiences could be detrimental to the students' construction of scientific skills like modeling, computational thinking, and collaboration (NRC,

2012). Failure to implement virtual labs properly could impact the development of critical scientific skills and the overall students' academic achievement. Research on the impact of virtual labs shows that VLs are as effective as PLs (Hamed & Aljanazrah, 2020), but further research is needed to investigate the effect of other factors, like instructor experience and feedback, on the effectiveness of VLs on student learning.

Further literature review indicates that a rapid shift to virtual learning can impact teacher efficacy (Dolighan & Owen, 2021). Limited or one-time training workshops on using new technology, like VLs, are not practical enough to help teachers adopt new technology and successfully implement them into their daily lessons (Carlson & Gadio, 2002). The gap in research studies exploring the impact of teacher self-perceived preparedness on the efficacy of virtual labs and its relationship to student academic achievement limits our understanding of the successful implementation of VLs in high school biology courses.

Purpose

This study aims to understand the factors that can impact the implementation and efficacy of virtual labs in high school biology courses. The research will explore teacher experiences with the implementation and use of virtual labs. The researcher will investigate the teachers' participation with professional development on virtual labs and their self-perceived efficacy to use the platform in their lessons through questionnaires and informal interviews. Additionally, this study will explore the impact of adaptive learning virtual labs on student academic achievement in state assessments. Ultimately, the researcher will analyze the data obtained to determine how the self-perceived teacher preparedness to use VLs impacts student academic achievement in state assessments.

Research Questions

This study will explore the teachers' experiences implementing virtual labs and their self-perceived preparedness and its relationship with student academic achievement in biology classes. The following questions will help guide the researcher through the study:

RQ1 (QN): Do virtual labs impact student academic achievement in a high school biology course?

RQ2 (QL): What are teachers' experiences in high school biology classes utilizing virtual labs?

a. What are the teachers' experiences with professional development?
b. What are the teachers' experiences using VLs in their lessons?

RQ3 (MM): How does self-perceived teacher preparedness to implement virtual labs impact student academic achievement?

Literature Review

Conducting hands-on lab investigations in science courses is crucial to developing scientific knowledge and skills in students. Many educators have used alternative methods to substitute the experience of PLs due to limited resources and health emergency measures. Virtual labs provide a potential alternative to replace and supplement lab experiences in science courses. Professional development on new technology for instructors is essential to the sustained implementation of new technology and the overall student success. The following sections in this literature review will explore available studies on virtual labs in science courses and the importance of professional development for teachers.

Labs and Virtual Labs

Science labs are indispensable tools in developing essential skills like computational thinking, inquiry, and collaboration in science courses (NGSS, 2020; NRC, 2005). The absence of lab experiences is detrimental to the development of scientific skills and 21st-century competencies. VLs are computer-generated simulations of traditional PLs that can be used when resources or access to lab facilities are unavailable (Carnevale, 2003; Jones, 2018; Son et al., 2016). Studies show that VLs can potentially provide comparable learning outcomes to traditional labs in diverse settings like undergraduate engineering (Achuthan et al., 2017), hybrid learning (Darrah et al., 2014; Son et al., 2016), and can improve student scientific discourse (Gnesdilow et al., 2016). Similar studies show that VLs are vial alternatives to PLs and suggest further research on the role of teachers and other factors in the effectiveness of virtual labs (Reece & Butler, 2017).

Teacher Experiences and Professional Development

Quality professional training is critical to developing the foundational skills teachers need to adopt and implement new technology and programs (Alneyadi, 2019; Akiba & Liang, 2016; Taylor et al., 2017). Recent studies show that professional development and familiarity with technology positively impacted the teachers' ability to conduct virtual lessons and implement new digital platforms (Dolighan & Owen, 2021; Marek et al., 2021). The studies support the need for professional training and examine additional factors like computer skills, collaboration, and previous program experience. Additionally, the researchers suggest that more studies are needed to fully understand instructors' experiences when implementing new educational technology programs (Alneyadi, 2019; Dolighan & Owen, 2021; Marek et al., 2021).

The literature reviewed in this section shows the relevant studies on labs and teacher experiences. Labs are critical to the overall development of scientific skills, and VLs are suitable alternatives to replace and supplement traditional labs. Although, quality professional development is vital to the successful adoption of new technology. Further research is required to understand the impact of professional development on the successful implementation and effectiveness of new technologies.

Methodology

Schools are continuously implementing new technologies to improve student education and bridge the gap in educational equity. The literature review discusses the importance of labs and the potential of virtual labs to replace traditional labs (Son et al., 2016). Although, research shows that teacher preparation is critical in the successful adoption of new technology. The purpose of this mixed-method study is to explore the role of self-perceived teacher preparedness on the effectiveness of virtual labs on student academic achievement. This section will discuss the research design, participant sampling, instruments, and procedures in this study.

Research Design

This study will use a convergent parallel mixed-methods design to explore the use of virtual lab platforms in high school biology courses. A mixed-method design is an ideal approach to integrate the strengths of qualitative and quantitative methods to gain a deeper understanding of the issue (Creswell & Creswell, 2018). The researcher will evaluate the data collected in this study through a pragmatic lens by converging data collected from quantitative and qualitative designs to best answer the research questions in this study, which is more important than either choice of design alone (Patton, 2015). Similarly, Creswell and Guetterman

(2019) remark that identifying the procedures to collect the data in each design strand is essential to develop the procedures for collecting data. Considering the main research question in this study seeks to investigate whether teachers' self-perceived preparedness impacts the success of virtual labs, quantitative data will present the impact of VLs on student academic achievement, and qualitative data will explore teacher experiences with the platform and its respective training.

The researcher will collect qualitative data on the experiences and attitudes of teachers using virtual labs and quantitative data from their student scores in the state's biology assessment. Creswell & Plano Clark (2018) state that convergent designs intend to combine diverse data types, quantitative and qualitative, to gain a deeper understanding of the problem. Thus, the researcher will collect quantifiable data from a quasi-experiment on the impact of virtual labs on student academic achievement compared to the usage in biology courses of participating teachers. Simultaneously, the researcher will gather qualitative data from case studies, as match comparisons, of teacher experiences that use virtual labs and receive professional development through interviews, on professional development & familiarity with the technology, and lesson observations (Patton, 2015). Ultimately, the researcher will analyze the data collected for each strand independently and compare the results for emergent themes and potential connections to answer the research questions.

Instrumentation

The researcher will send participation request emails to high school teachers asking them to participate in the study (Appendix A), a participation questionnaire will be attached. The researcher will use a questionnaire to recruit participants and collect demographic and technology use in the classroom information about the participants (Appendix B). The interviews will explore the teacher reflections with professional development and utilizing VLs through a

modified version of the metacognitive awareness inventory (Schraw & Dennison, 1994). The interview questions (Appendix C) will be evaluated for relevance and alignment with the attributes in the study by experts in the education field and piloted with teachers outside of the study. Observations will be conducted and analyzed using the PICRAT model for technology integration in teacher preparation (Appendix D) (Kimmon et al., 2020). The participating teacher will provide the student state assessment scores and the number of virtual labs performed in class. An anticipated risk is participant withdrawal from the study. If this happens, the researcher will have to safely dispose of all data gathered and recruit new participants from the existing pool. To prevent participant withdrawal, the researcher will provide security that all data will be secured and that the anonymity of participants is a top priority of the study. Additional flexibility will be offered to participants that cannot participate in in-person observations by conducting video conferencing observations or recordings of lessons.

Population and Sample

The target population of this study will include high school biology teachers and their students using virtual labs in the North New Jersey school districts. The researcher selected this population due to the similarity in demographics and its potential for transferability. High school biology teachers will comprise the target population for the qualitative part of the study. Similarly, their student state assessment scores will be the target population for the quantitative part of the study. All selected teacher participants will meet the criteria of utilizing virtual labs and participating in professional development. Teachers meeting the requirements, 538 teachers, will be approached to participate. This study will use a convenience sample to select up to 50 participants, or until saturation is reached, that completed the questionnaire to participate in the qualitative phase of the study. Research shows that a range between five (5) and fifty (50)

participants is sufficient to reach saturation, the point at which no new information is collected from additional participants (Charmaz, 2006; Dworkin, 2012). Correspondingly, the students in each of the participants' biology classes will be the target for the quantitative part of the study. The student participant number, up to 1,500, would depend on parental consent. The teacher participants will be grouped based on the number of professional development hours accrued. The participants will be recruited proportionally into two groups, those with the most (n=25) and least (n=25) hours of professional development.

Procedures

June – July 2021

- Secure approval from the institutional review board (IRB).
- Seek information on the districts' use of virtual labs and permission to recruit participants from relevant administration by emailing the importance of the study (Appendix D).

August 2021

- Contact all biology teachers in the participating school districts to participate in the study (Appendix A) and complete the demographics questionnaire.
- Analyze the questionnaire and randomly select participants with the most and the least amount of professional development hours.
- Conduct initial discussions with participants about the role of the teacher, including interviews, observations, and sharing of student scores when available.

September – December 2021

- Distribute and collect student parental consent to participate (E)

- Conduct participant interviews (Appendix B)
- Conduct informal observations of lab lessons and follow observation guidelines (Appendix C).
- Transcribe data and consult with participants to corroborate accuracy.

January – February 2022

- Analyze qualitative data
- Request student state biology assessment scores
- Analyze quantitative data

March 2022

- Analyze quantitative and qualitative data together for relationships and emergent themes.
- Draft report
- Corroborate results with stakeholders for accuracy
- Finalize study.

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Appendix A

August 1, 2021

Biology Teacher's Name
Name of School
Dear Mr./Ms. _____,

I hope this email finds you in good health. My name is Giancarlo Perez-Flores. I am a middle school science teacher in Hudson county and a doctoral student at New Jersey City University in the Educational Technology Leadership Program. I am currently investigating the impact of teachers' self-perceived preparedness on the effectiveness of virtual labs on student academic achievement. I am looking for teachers presently using this type of platform and participating in professional development.

I ask for your participation in this study and sharing teachers' experiences using virtual labs, students' state assessment scores, and observing lab lessons. If granted, I am asking if you would complete the participation questionnaire attached to this email.

If you have any questions on this research or the data to be collected, please reach out to me at the email below. If you decide to participate in the study, note that all information will be anonymous and confidential. Similarly, you have the option to withdraw from the study at any moment.

Sincerely,

Giancarlo Perez-Flores
New Jersey City University
gperezflores@njcu.edu

Appendix B

Survey Sample Questions

1. What were your experiences, whether positive or negative, with professional development on virtual lab platforms?
2. How would you rate the depth of information and applicability of the trainings you attended?
3. How would you describe your understanding and familiarity with the platform before and after the trainings?
4. In which ways to feel that the professional development improved your instructional practices and ability to use the platform in your lessons?
5. How would you describe your use of technology in your lessons?
6. What is the impact of the platform on student academic achievement?

Appendix C

Observation Codes

Use the following codebook to analyze the observations of a virtual lab lesson.

1. Clear understanding: Instructor provides clear directions for using the platform and demonstrates a clear understanding of the functions and objectives of the virtual lab.
2. Compatible Replacement: the virtual lab platform is utilized to replace traditional labs and supplement scientific learning successfully.
3. Scope: the technology is presented in a manner that makes it accessible to students with minor technology issues.
4. Objective focus: The lab experience is successful in helping students achieve the learning objectives.
5. Unmeaningful: The lab virtual lab experience does not meet the technology objectives, and the instructor cannot maximize the potential of the technology.

Appendix D

Superintendent's Name
School District Board of Education
Dear Mr./Dr. _____,

I hope this email finds you in good health. My name is Giancarlo Perez-Flores. I am a middle school science teacher in Hudson County and a doctoral student at New Jersey City University in the Educational Technology Leadership Program. I am currently investigating the impact of teachers' self-perceived preparedness on the effectiveness of virtual labs on student academic achievement. I am looking for schools now using this type of platform and providing professional development to their instructors.

I am asking for your, and your school board's, permission to collect and use anonymous data about teachers' experiences using the virtual labs and their students' state assessment scores. If granted, I am asking if you would send the link for participation to the high school principal and biology teachers.

If you have any questions on this research or the data to be collected, please reach out to me at the email below. If your district participates in the study and wants to see my research results, please email the same place, and indicate where you would like the report sent.

Sincerely,

Giancarlo Perez-Flores
New Jersey City University
gperezflores@njcu.edu

Appendix E

Dear parent or guardian,

My name is Giancarlo Perez-Flores; I am a middle school science teacher and a doctoral student at New Jersey City University in the Educational Technology Leadership Program

I am asking for your permission to collect data about your child. Federal laws state that you must give written permission for researchers to access your child's school records. Please review the information below to clarify the research.

The purpose of the research is to investigate the impact of teachers' self-perceived preparedness on the effectiveness of virtual labs on student academic achievement. The researcher will collect data on the student's state scores in the biology assessment. All data and records will be kept confidential. If the results of this study are published, the data will be presented in group form, and individual names will not be shown.

Your participation is voluntary, and if you wish to terminate your participation at any point during the study, you will be able to do so.

If you have any questions regarding the research, please reach me at:

gperezflores@njcu.edu

Signing this form will allow me to collect the data mentioned above about your child.

Please return at your earliest convenience. If we do not receive this form by September 15, 2021, the researcher will understand that you do not wish to participate.

I, the parent or guardian of _____, permit participation in the research named above.

_____ _____ Signature of Parent or Guardian Date

Please print your name here.

Student Signature Box

Signature of Investigator _____Giancarlo Perez_____ Date____08/01/2021____