Teacher Experiences with Professional Development and Virtual Labs:

A Mixed-Method Study Proposal

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Chapter 1: Introduction

Introduction

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 and facilities to provide students with lab experiences forcing teachers to use alternative methods like virtual labs (VL) (Marble, 2017). VLs, are digital simulations of the materials, settings, and outcomes of traditional physical labs (PL) that have been shown to have similar efficacy as PLs (Achuthan et al., 2017; Darrah et al., 2014). Most recently, school closures due to the ongoing health crisis limited access to traditional labs, leading to science teachers implementing alternative resources to supplement the lack of hands-on experiences (Chandrasekaran, 2020).

In addition to the emergency adoption of VLs due to school closures, a lack of proper professional development has impacted teachers' efficacy in using the technology in their lessons (Dolighan & Owen, 2021). Teacher preparation is crucial to adopting new technology programs in the classroom. Thus, professional training on new technology tools and instructional practices can positively impact the self-perceived efficacy of pre-service teachers (Joo et al., 2018). This study will explore science teachers' experiences with professional development and how their self-perceived preparedness impacts the effectiveness of virtual labs.

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 due to the pandemic directly impacts teachers and students in science courses by limiting access

to facilities and hands-on experimentation. Although schools are resuming in-person classes, student hands-on collaboration is still limited, 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). Similarly, poorly implementing virtual lab programs 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 on the effectiveness of VLs on student learning. Meanwhile, there is a gap in the literature discussing teachers' experiences during hybrid instruction.

Further literature review indicates that a rapid shift to virtual learning can impact teacher efficacy (Dolighan & Owen, 2021). Limited, or one-time, professional training workshops on using new technology, like VLs, are not practical enough to help teachers adopt new technology and successfully implement it into their daily lessons (Carlson & Gadio, 2002). The gap in research studies exploring the impact of teacher self-perceived preparedness on the successful implementation of virtual labs is limited. Thus, more research needs to be conducted on the relationship between professional development opportunities and teachers' self-perceived efficacy.

Purpose

This mixed methods sequential explanatory study aims to understand the factors that can impact the implementation and efficacy of virtual labs in high school science courses by obtaining quantitative results from a survey of teachers and then following up with purposefully selected participants to explore those results in depth through qualitative descriptive research

analysis. The research will explore teacher experiences with implementing and using virtual labs. In the first quantitative phase of the study, the survey will focus on how the quantity and quality of professional development related to teachers' self-perceived efficacy in using the platform in their lessons. Additionally, in the qualitative phase, descriptive research of two distinct participant groups will explore in-depth the results from the quantitative phase. In this phase, the interviews will focus on teachers' experience with professional training. Ultimately, the researcher will analyze the data obtained to determine whether the quantity and quality of professional training explain teachers' self-perceived preparedness to use VLs in their lessons.

Research Questions

This mixed method explanatory sequential study will investigate the impact of professional development on teachers' self-perceived efficacy and familiarity with the virtual lab platform. The following questions will help guide the researcher through the study:

RQ1 (QN): What is the impact of professional development on the teachers' self-perceived efficacy with the virtual lab platform?

RQ2 (QL): What are teachers' experiences with professional development for the virtual lab platform?

RQ3 (MM): In what ways does the interview data of teachers' experiences with professional development training explain the quantitative survey results on teachers' self-perceived efficacy using virtual labs?

Limitations

The participant sample will be limited by the number of teachers that use a VL platform in their science classes. Since VLs are a relatively new tool, not many teachers might not use them consistently. Additionally, many educational institutions might not provide professional development specific to VLs because many teachers implement the tool as a personal alternative or a supplement to traditional PL. Additionally, the schools selected to participate in the study had similar demographics, thus, the replicability of this study will be limited to institutions sharing similar characteristics. This study will be limited by the honesty of the teacher participants sharing their experience with professional development.

Chapter 2: Literature Review

Introduction

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, previously used when conducting physical labs were not feasible due to funding, access, or safety, became a popular alternative with science teachers. Although, quickly adapting to new teaching modalities and implementing new online programs without proper training has impacted teachers' experiences in the new classroom. The recent transition to hybrid learning presents unique challenges for teachers and students in science classrooms. 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. This chapter will discuss the following themes relevant to this study: labs in science, virtual labs, teaching during COVID, teacher experience with professional training, and teacher self-perceived efficacy.

Labs in Science Courses

Lab experiences are indispensable tools in science learning that help students develop essential academic and life skills. The Next Generation Science Standards (NGSS, 2020) highlight the skills of critical thinking, collaboration, problem-solving, and conducting investigations as essential components of science learning. Similarly, the National Technology

Plan Update list of 21st-Century Competencies (21CC) includes similar skills like computational thinking, global collaboration, and holistic experiences (U.S. Department of Education, 2017). Hands-on science lab experiments engage students in collaborating with peers, conducting precise procedures, and critically analyzing data and observations. A report on the use of labs in American science education by the National Research Council (2005) describes the positive impact of lab experiences on the development of scientific knowledge. Lack of access to lab experiences can negatively impact student learning and halt the development of practical skills critical to the development of scientific knowledge.

Virtual Labs in Science Courses

Virtual labs (VL) are computer-generated simulations that recreate experimental conditions, materials, and outcomes of traditional PLs (Carnevale, 2003; Jones, 2018; Son et al., 2016). Although the use of VL is not new, recent funding by the U.S. Education Department for the development of different VL platforms like ChemLab and Learn Anytime Anywhere Physics to improve postsecondary education has increased interest in these platforms (Carnevale, 2003). Research on the impact of VL on student learning outcomes shows mixed results (Pyatt & Sims, 2011; Marble, 2017). Achuthan et al. (2017) report improved content retention and reflective learning when a VL is used in an undergraduate engineering class.

Studies exploring the impact of virtual labs in different instructional settings provide an insight into the application of these platforms to hybrid learning. Utilizing virtual labs in different settings like fully remote learning and hybrid learning can yield similar learning outcomes as traditional labs (Darrah et al., 2014). Research shows that students participating in a hybrid modality, utilizing a combination of virtual and physical labs, improved content

knowledge retention and reported positive attitudes toward science learning compared to students participating in either entirely VL or PL (Son et al., 2016).

Further exploring virtual labs, Gnesdilow et al. (2016) investigate the impact of virtual labs on different aspects of student learning. The study on middle school student discourse compared student communication and collaboration during virtual labs with discourse during physical labs. The researchers' teacher lesson observations revealed that instructor discourse and feedback could potentially impact the platform's effectiveness as teachers engaged in deeper conceptual discussions with students performing virtual labs (Gnesdilow et al., 2016). The literature review on the use of virtual labs provides a positive outlook on using the platform when physical labs are unavailable. However, further investigation of the teacher's role in the effectiveness of virtual labs needs to be conducted.

Adaptive Learning Virtual Labs

Current advances in technology have led to the development of virtual labs that implement adaptive learning technology (ALT) features. Platforms built on ALT use complex AI computer programs to personalize content and feedback to support the learners' needs (EDUCAUSE, 2020). Recent support from the U.S. Department of Education (2017) and the sudden school closures have pushed schools to implement these programs in their classrooms. Research on the impact of ALT platforms for higher and K-12 math and science courses has shown positive learning outcomes (Moltudal et al., 2020; Wilks, 2020; Dziuban et al., 2018). Similar studies on the impact of other ALT platforms show similar academic outcomes as traditional instruction (Thadani & Bouvier-Brown, 2016; White, 2020).

Research by Reece and Butler (2017) explores the impact of the adaptive learning virtual lab on student learning outcomes and motivation to learn. The study proposes that adaptive learning virtual labs in a college nursing class lead to similar learning outcomes as physical labs and do not provide any discernible changes to the students' motivation to learn (Reece & Butler, 2017). While the study shows the potential of adaptive learning virtual labs to substitute physical labs as needed, the researchers do not explore student or teacher experiences using the platform and how that might impact the results. The researchers suggest that additional studies must be conducted to determine learning outcomes in different settings and explore other factors influencing the platform's effectiveness.

Teacher Experiences Through COVID

Since the onset of the current global health crisis, teachers everywhere have been forced to quickly adapt their practices to the constant changes and emergency adoptions of programs. The initial transition to online remote lessons and the current shift to hybrid models has presented teachers with many challenges and required them to demonstrate flexibility under the uncertainty of uncharted territories. Marek et al. (2021) present their findings from worldwide surveys exploring educator experiences with the change to distance learning and explain the broad range of positive and negative experiences. Although their results might be limited by the responses obtained during the short period, the research suggests previous experience with distance was a positive factor in the motivation of instructors (Marek et al., 2021).

Other studies support the results and add that training and experience are factors in the number of programs and how often they are used by instructors (Alneyadi, 2019). Likewise, Dolighan and Owen (2021) discuss the impact of skills like classroom management, computer skills, and professional development on teachers' effectiveness during the COVID-19 pandemic.

Together, the literature was analyzed to provide the foundation to develop further studies. Additionally, the researchers suggest that more studies are needed to fully understand instructors' experiences as learning alternates between remote, hybrid, and in-person modalities (Alneyadi, 2019; Dolighan & Owen, 2021; Marek et al., 2021).

Teacher Professional Development and Self-Efficacy

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).

Summary

The literature analysis explored national educational reports and empirical studies relevant to the questions in this research. The use of lab experiences in science courses is critical to developing scientific thinking and skills in students. Virtual labs that supplement and substitute physical labs have positively impacted student learning when in-person lab experiences are not feasible. While teachers continue to demonstrate the flexibility to adapt to new and unexpected teaching situations, lack of training can negatively impact their efficacy. Quality professional development is vital to developing teachers' self-perceived efficacy and the

adoption of new technology. Further research is required to understand the impact of professional development on the successful implementation and effectiveness of new technologies.

Chapter 3: Methodology

Introduction

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). Research shows that teacher preparation and familiarity with technology significantly impact teacher preparedness, but there is a literature gap on the relationship between professional development and teacher self-perceived efficacy. This mixed-method study aims to describe the role of professional development on teachers' self-perceived efficacy in implementing virtual labs. The following sections in this chapter will explain the reasoning behind the research design, participant selection, instruments, and procedures in this study.

Research Design

This study will use an explanatory mixed methods design to explore the impact of professional development on teachers' self-perceived effectiveness. A mixed-method design is an ideal approach to integrating the strengths of qualitative and quantitative methods to gain a deeper understanding of the issue (Creswell & Creswell, 2018). This study will collect quantitative data on the impact of professional development on teacher self-efficacy and qualitative data on teachers' experiences with professional training and technology implementation in their lessons. Further, the work by Creswell & Clark (2018) describes explanatory sequential designs in mixed-method research as the use of a qualitative design to rationalize the results of the quantitative phase. Therefore, the researcher will analyze the data

collected from each strand independently and evaluate the results for emergent themes and potential connections to answer the following research questions:

RQ1 (QN): What is the impact of professional development on the teachers' self-perceived efficacy with the virtual lab platform?

RQ2 (QL): What are teachers' experiences with professional development for the virtual lab platform?

RQ3 (MM): In what ways does the interview data of teachers' experiences with professional development training explain the quantitative survey results on teachers' self-perceived efficacy using virtual labs?

Since the intent of an explanatory sequential design is to obtain diverse data involving the problem in the study (Creswell & Clark, 2018), the researcher has determined that quantitative data will present the relationship between quantity and quality of professional development and self-perceived efficacy with the platform, while qualitative data will further explore teacher experiences with professional development and the virtual lab platform. 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 significant than either choice of design alone (Patton, 2015). As Creswell and Guetterman (2019) explained, identifying the procedures to collect the data in each design strand is necessary to establish the procedures for collecting data. Considering the purpose of this study is to examine how professional development impacts the teachers' self-efficacy, a correlation design will evaluate the impact of professional development, and a qualitative descriptive design will aid in the investigation of teachers' experiences with professional training. Figure 1 below

provides a visual representation of the researcher's approach to collecting and analyzing this study's data.

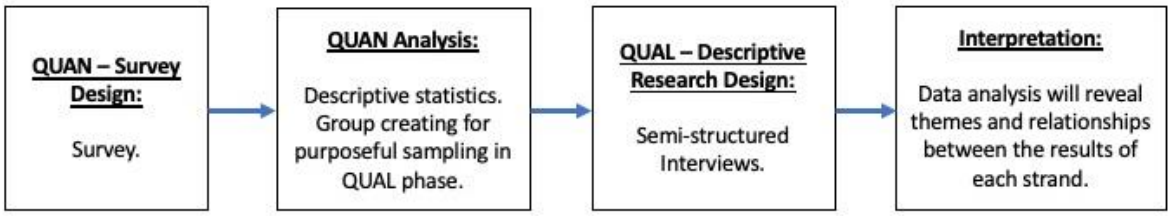

Figure 1: Overview of research design

First, the researcher will collect quantifiable data using a survey design. A survey design can determine trends and relationships between variables in a particular population (Creswell & Creswell, 2018). The survey questions will target the quantity, quality, and type of professional development on the functions and instructional techniques that teachers attended. The researcher will analyze the data collected using descriptive statistics. Then, the data will be used to create specific groups for purposeful sampling for the qualitative phase.

Next, the researcher will gather qualitative data using a descriptive research design. The researcher will explore teacher experiences with professional development through semi-structured interviews. Interview questions explore specific experiences while remaining broad to allow the participants to expand on their responses (Patton, 2015). The interview data will be analyzed using descriptive analysis through coding and evaluated for emergent themes. Then, the researcher will examine the data from both phases of the study. Ultimately, the researcher will analyze in which ways the results from the qualitative phase explain the results from the quantitative phase to answer the research questions in this study.

Instrumentation

This mixed-method study will combine data from quantitative and qualitative phases in the research. The quantitative data will be collected through a survey including biographical questions, quantity and quality of professional development questions, and Likert scale questions on their self-perceived efficacy with virtual lab platforms. The survey questions were created following applicable item categories like self-efficacy, usefulness, and intention to use from the metacognitive awareness survey developed by Joo et al. (2018). The researcher created the questions to collect nominal data for correlating the impact of professional development on teachers' self-perceived efficacy using the VL platform (Appendix A). The online survey, including the participant consent form, can be accessed at the following site: https://njcu.co1.qualtrics.com/jfe/form/SV_2ggb5HCLRtFfRoW

The qualitative phase of the study will seek to explore deeply into the teachers' experiences with professional development for the virtual lab platform using semi-structured interviews. The questions were developed to further understand teacher experiences with professional development and how it impacted their use of VLs in their classrooms (Appendix B), a modified version of the metacognitive awareness inventory (Schraw & Dennison, 1994). The instruments 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.

Population and Sample

The target population of this study will include high school science teachers 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 science teachers will

comprise the target population for the quantitative and qualitative parts of the study. All selected teacher participants will meet the criteria of utilizing virtual labs and participating in professional development. All teachers meeting the requirements, total population sample, will be approached to participate in the quantitative phase by email with the survey attached. The researcher will use a purposeful 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). The teacher participants will be grouped based on their self-efficacy ranking. The participants will be recruited proportionally into two groups, those with the highest (n=25) and lowest (n=25) ranking.

Potential Issues

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, participants that cannot meet in person will be given the option to interview through video conferencing.

Procedures

The researcher will begin the study by determining the feasibility of the research as described in Table 1. To investigate the problem in this study, the researcher placed equal importance on both design strands since quantitative and qualitative data are necessary to

understand the problem thoroughly. First, the researcher will seek permission from the Institutional Review Board to conduct the study. Once the researcher identifies the potential high schools meeting the criteria for the study, the researcher will request approval from their Board of Education by sending emails (Appendix C) detailing the purpose and importance of the study.

During the month prior to the study, the researcher will contact the science teachers at each school to explain and discuss the purpose and importance of the study (Appendix D). The potential participants will be contacted through email, including the survey. Additional email reminders will be sent during the first two months to ensure maximum participation. Then, the data collected through surveys will be analyzed using descriptive statistics for relationships between the variables through an SPSS platform. Additionally, the results of the quantitative phase will be used to direct the qualitative phase of the study.

Next, the researcher will use the data collected to determine the purposeful sampling for the qualitative phase. Teachers meeting the criteria will be contacted for follow-up interviews. The researcher will conduct semi-structured interviews. The interviews will be transcribed using an online tool. The researcher will share the transcripts with the participants for accuracy. Then, the data collected from the interviews will be coded and analyzed for emergent themes.

Following the data collection period, the researcher will analyze the results of each design strand. The researcher will quantify the impact of professional development on teacher self-efficacy. Similarly, the researcher will analyze the data collected from teacher interviews for emergent themes. Once the results for each design strand have been completed, the researcher will analyze both sets of data to determine their impact or relation to the problem of the study; the professional development impact on teachers' self-perceived efficacy. The following timeline describes the procedures for this study:

July 2022

- 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.

August 2022

- Contact all science teachers in the participating school districts to participate in the study and complete the demographics questionnaire (Appendix A)
- Analyze the questionnaire and randomly select participants with the highest and the lowest self-efficacy ranking.
- Conduct initial discussions with participants about interview dates.

September – December 2022

- Conduct participant interviews (Appendix B)
- Transcribe data and consult with participants to corroborate accuracy.

January – February 2023

- Analyze qualitative data

March 2023

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

Table 1

Mixed Methods Data Collection

Research Question	**Data Type**	**Format of Data Collection**
What is the impact of professional development on the teachers' self-perceived efficacy with the virtual lab platform?	Quantitative	Survey
What are teachers' experiences with professional development for the virtual lab platform?	Qualitative	Interviews
In what ways does the interview data of teachers' experiences with professional development training explain the quantitative survey results on teachers' self-perceived efficacy using virtual labs?	Mixed Methods	Analysis of qualitative data themes (teacher experiences) related to professional development and teacher self-efficacy

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Appendix A

Survey Instrument

Consent Form

Consent Form I agree to participate in this study entitled "Teacher Experiences with Professional Development and Virtual Labs," which will be conducted by Mr. Giancarlo Perez of the New Jersey City University's Educational Technology Department. This study aims to explore teachers' experiences with professional development and virtual labs. The data collected in this study will be combined with data from previous studies and will be submitted for publication in a research journal.

I understand that I will be required to answer questions, and I will be assigned to work either individually or as part of a group. My participation in the study should not exceed one hour.

I understand that my responses will be anonymous and that all data gathered will be confidential. I agree that any information obtained from this study may be used in any way thought best for publication or education, provided that I am in no way identified and my name is not used.

I understand that there are no physical or psychological risks involved in this study and that I am free to withdraw my participation at any time without penalty.

I understand that my participation does not imply employment with the state of New Jersey, New Jersey City University, the principal investigator, or any other project facilitator.

If I have any questions or problems concerning this study, I may contact Dr. Meriem Bendaoud, interim chair of the NJCU Institutional Review Board, at 201-200-2400 or mbendaoud@njcu.edu.

- ○ Yes, I consent to participate in the study mentioned above (1)
- ○ No, I do not consent to participate in the study mentioned above (2)

Q1 How many years have you been teaching?

▼ 1 to 2 years (77) ... 20+ years (81)

Q2 How often do you use virtual labs in your lessons?

- ○ Once a month (1)
- ○ twice a month (2)
- ○ three times a month (3)
- ○ four or more times a month (4)

Q3 How many professional development sessions have you received on virtual labs?

- ○ one (1)
- ○ two (2)
- ○ three or more (3)
- ○ none (4)

Q4 How much would you agree with the following statements?

	Strongly Agree (1)	Agree (2)	Neither Agree Nor Disagree (3)	Disagree (4)	Strongly Disagree (5)
I am comfortable learning from the district-mandated professional development	○	○	○	○	○
The professional development covered all basic features of the program	○	○	○	○	○
I can align virtual labs to state standards	○	○	○	○	○
I can efficiently implement virtual labs in my lesson	○	○	○	○	○
I consider myself tech savvy	○	○	○	○	○
I feel comfortable using technology in the classroom	○	○	○	○	○

Q5 How would you rank your confidence with the following?
Definitely true being the most confident, and definitely false being the least confident.

	Definitely false (65)	Probably false (66)	Neither true nor false (67)	Probably true (68)	Definitely true (69)
I am confident using all the virtual lab tools (5)	○	○	○	○	○
I am confident using virtual labs in your lesson (1)	○	○	○	○	○
I am confident explaining virtual lab features to your students (2)	○	○	○	○	○
I am confident using virtual labs to model complex scientific concepts (3)	○	○	○	○	○

Appendix B

Semi-structured Interview Questions

1. What were your experiences, whether positive or negative, with professional development on virtual lab platforms?
2. How would you describe 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?

Appendix C

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 professional development on teachers' self-perceived efficacy. 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 D

August 1, 2021

Science 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 professional development on teachers' self-perceived efficacy. 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 your experiences with professional development and using virtual labs. 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