Innovative Educational Practice: Using Virtual Labs in the Secondary Classroom

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Abstract

Two studies investigated the effectiveness of teaching science labs online to secondary students. Study 1 compared achievement among students instructed using hands-on Chemistry labs versus those instructed using virtual Chemistry labs (eLabs). Study 2 compared the same groups of students again while both teachers instructed using hands-on Chemistry labs to determine whether teacher or student characteristics may have affected Study 1's findings. Participants were high school Chemistry students from a Central Texas Independent School District. Results indicated that: students learn science effectively online, schools may experience cost savings from delivering labs online, and students gain valuable technology skills needed later in college and in the workplace.

Introduction

Distance education has received enough attention that many studies are now available in the research literature. As with any new technology, method, or theory, there is the need to compare it to the current standard. Therefore, student success in the online classroom has been compared to student success in the traditional face-to-face classroom. Surprisingly for some, the outcomes of these studies are similar – most found that there are no significant differences in student performance in online courses versus traditional courses (Clark & Jones, 2001; Day, Raven & Newman, 1998; Waschull, 2001). The findings of "no difference" in the current studies likewise suggest that students have an equal chance of success in online courses and traditional courses. In addition to testing the existing instructional standard, other issues emerged to provide an impetus for the current study.

Those employed in public education in the last year personally felt effects of budgetary fallout. State budget cuts require public schools to serve increasingly more students with fewer personnel, materials, and financial resources. Meanwhile, states' student populations continue to grow in number and diversity. Additionally, to meet curriculum requirements, secondary science courses require costly laboratory supplies and safety materials. These trends together create quite a challenge for public educators. Public school needs continue to grow exponentially, while budgets remain the same or are reduced.

The studies reported here were conducted in a Central Texas Independent School District. Texas, like many states, requires student mastery of technology as part of the curriculum. For example, Texas requires student technology proficiency as expressed in Chapter 126 of the Texas Essential Knowledge and Skills (TEA, 2003) curriculum requirements. To this end, significant efforts were made to equip Texas classrooms with needed technology infrastructure (e.g., TIF grants, E-Rate discounts). Consequently, policy researchers reported that 98% of Texas public classrooms now have Internet access (eEducation, 2002). Unfortunately, this same report indicated that only 21% of districts reported that their teachers use online resources in their instruction (eEducation, 2002). These findings together create reason for concern. Our students cannot become proficient in new technologies required in the workforce if teachers do not use or understand new technologies in the classroom.

Project Goals

A state-level initiative for increasing public-school university collaborations provided the funding for a series of two studies that investigated how to meet the demand for student-centered learning experiences in a secondary Chemistry class, while reducing the number of physical supplies needed by students, and increasing students' proficiency in the use of technology. The goal of Study 1 was to determine if there were differences in student achievement for students instructed via traditional hands-on Chemistry labs versus those instructed via virtual Chemistry labs that utilized Internet resources. Study 2 was conducted to ensure that the results of Study 1 occurred due to the different instructional delivery used (i.e., traditional vs. online) and not due to other variables such as student and/or teacher characteristics. Thus, the goal of Study 2 was to demonstrate that when both instructors used traditional instruction (i.e., hands-on labs), achievement would be the same for both teachers' students. Each study is discussed in turn.

Study 1: Method

Participants

Two-hundred and seven high school Chemistry students from Belton Independent School District volunteered to participate in the study. The sample (96 males and 111 females) had a median age of 17 years. The sample was fairly diverse regarding ethnicity. Fifty-six percent of the participants were Caucasian, 26% were Hispanic, 6% were African American, and the remaining 12% were of mixed heritages. Thirty-two percent of the student participants were identified as economically disadvantaged and six percent were identified as having limited English proficiency.

Materials

The teachers chose Stoichiometry as the content unit for Study 1. Stoichiometry is the measurement of chemical substances in masses, moles, or percentages using chemical equations. The unit consisted of three modules: an Introduction to Stoichiometry, Ideal Stoichiometric Calculations, and Limiting Reactants. There was one lab for each of the three modules. Students participated in one of two groups based upon their assigned teacher. The traditional instruction teacher used guided practice, independent practice, chapter reviews, and section assessments in a paper-pencil format. Specific activities included the teacher's in-class demonstration of how to

solve stoichiometric equations given different known and unknown variables, in-class group practice solving equations, independent practice solving equations, chapter reviews from the text that assessed one's knowledge of basic terms such as moles, limiting reagents, and reactants, and finally an end-of-unit exam that assessed their ability to balance different chemical equations.

Virtual Labs

The online instruction teacher used the same kind and number of assignments; however, they were delivered online. The three virtual labs were created by the online instructor using Microsoft FrontPage for web authoring and free images, borders, and icons from various websites. Similar to the sequence of the traditional labs/lectures, the virtual labs began with an introduction, 1-2 demonstrations via streaming video or flash animation, and a series of important terms with definitions and examples. The labs likewise included opportunities for group and/or independent practice and concluded with an end-of-lab review of materials covered.

Instructors

Other than their instructional method, the two Study 1 teachers were very similar in their education, years spent teaching science, and technology proficiency. Both teachers were State of Texas certified secondary teachers in composite science (all sciences). At the time of the studies, the traditional teacher had six years experience teaching in public school, and the online teacher had taught for seven years. Regarding technology proficiency, both teachers had completed the district's required technology training modules; however, the online teacher completed these in his prior school district. Additionally, the traditional teacher served as the faculty trainer for the operation of the electronic faculty grade book system. At the time, the online teacher was completing a Masters degree in educational technology. The two teachers' technological skills were fairly equivalent as was their desire to create and conduct the study.

Procedures

Together, the two teachers developed a 33-item end-of-unit exam to measure student achievement for both groups. Prior to instruction, both groups of students completed the end-of-unit exam as a pretest measure of their knowledge of Stoichiometry. For a two-week period both

teachers taught their respective students in their assigned manner (i.e., traditional versus online). At the end of the two-week period, both groups of students completed the end-of-unit exam as a posttest measure. Then students' pretest scores were subtracted from their posttest scores to create unit achievement scores (gain scores).

Study 1: Results

In Study 1, the two student samples were statistically similar regarding age, gender, and ethnicity. There were no significant differences in achievement for the traditional versus online students on the pretests [t (205) = 1.498, p = .136] nor the posttests [t (205) = -.390, p = .697]. More importantly, there were no significant differences in achievement gain scores for the traditional versus the online students, t (205) = -1.044, p = .298. These findings demonstrate that students who completed the traditional, hands-on labs performed as well as students who completed the virtual labs. Therefore, the online students acquired the necessary science knowledge and skills when instructed in a manner that results in improved technology skills for the students as well as potentially significant cost-savings for the school (i.e., fewer textbooks, quizzes, exams, scantrons, and lab equipment).

Study 2: Method

Participants

Two-hundred and forty-seven high school Chemistry students from Belton Independent School District volunteered to participate in the study. The sample (111 males and 136 females) had a median age of 17 years. As in Study 1, the majority of the students were juniors or seniors, with 56% of the participants reporting Caucasian as their ethnicity, 26% reporting Hispanic ethnicity, 6% reporting African-American ethnicity, and 12% reporting other heritages. As the same students participated in Study 1 and Study 2, other characteristics remained the same.

Materials

For Study 2, the teachers chose Volume-Mass Gas Relationships and The Ideal Gas Law as the content unit. Both teachers used traditional expository instruction to deliver the content to their students. That is, they used guided practice, independent practice, chapter reviews, and section assessments in a traditional paper-and-pencil format. Specific activities included the teacher's

in-class demonstration of the measurement and comparison of the volumes of different reacting gases, group guided practice measuring different gases, independent practice measuring gas volumes, chapter reviews from the text that covered basic terms such as diatomic molecules, gas density, and the Ideal Gas law, and finally an end-of-unit exam that assessed students' conceptual and mathematical knowledge of gas measurement and the Ideal Gas law. Similar to Study 1, the teachers worked together to create a 13-item end-of-unit exam to measure the students' achievement before and after instruction.

Procedures

Prior to instruction, both groups of students completed the end-of-unit exam as a pretest measure of their knowledge of gas relationships. For one week, both teachers taught their students in the manner mentioned prior. At the end of the one-week period, both groups of students completed the end-of-unit exam as a posttest measure. Again, students' pretest scores were subtracted from their posttest scores, yielding achievement gain scores for the unit.

Study 2: Results

Similar to Study 1, the student samples were statistically indistinguishable regarding age, gender, and ethnicity. There were no significant differences in achievement for either group of students on the pretests [t (245) = .911, p = .363] nor the posttests [t (245) = -.909, p = .364]. Likewise, there were no significant differences in achievement gain scores for the two teachers' students, t (245) = -1.341, p = .181. These results suggest that when both teachers used traditional expository instruction, their students performed equally well on the unit. Regarding the specific goal of Study 2, the result of no significant differences suggests that the instructor characteristics and student characteristics examined, did not have systematic effects on the results of Study 1, lending validity to the findings of the first study.

General Discussion

Overall, the goals of the project were accomplished. The results showed that students learned effectively from the online delivery of science materials. Second, learning science content and acquiring laboratory skills occurred online, which significantly reduces the cost of materials and

equipment for the school. Finally, students gained valuable technology skills while working through the virtual labs.

The researchers are aware that the objective in most research endeavors is to find significant differences that support one's hypotheses. Yet, in the current studies, the results of no significant difference are actually positive outcomes. In any instance when significance is not found, there is the possibility of a Type II error. Therefore, the researchers conducted a power analysis for a Test of the Null Hypothesis (Borenstein, Rothstein, & Cohen, 1997). The analysis yielded a power of .98, indicating that the probability of a Type II error was only two percent. That is, the sample sizes in the two studies were large enough to detect a difference if in fact, a true difference in achievement existed.

The educational contributions of this investigation are fivefold. First, these findings suggest that online delivery is an acceptable instructional method for science. It may not be the case that all high school science labs should be offered online. Instead, perhaps team teachers could alternate online and traditional labs so to provide their students requisite science and technology skills. Second, we demonstrated that this instructional method might result in significant cost savings for school districts. Specifically, for this school district, online labs significantly reduced the number of textbooks needed, the number of copies made (e.g., exams, reviews, quizzes), the lab space needed to ensure appropriate student/teacher ratios (Texas Education Code Guidelines, Chapter 25, Section D, Student/teacher ratios), as well as student safety (Texas Education Code Guidelines, Chapter 38, Health and Safety). The authors wish to point out that an actual cost analysis comparing these traditional instruction expenditures to those incurred by the school for technology infrastructure, software, training, and maintenance was not performed. In order to determine whether schools and districts would benefit from virtual labs as this district did, a cost analysis would be necessary. In addition to these savings, the teachers' time and efforts regarding planning, instructing, and grading also were reduced. Third, the online students gained technology skills that will benefit them later in college and the workplace. Fourth, the online tasks completed by the Study 1 students incorporated many different learning objectives (Bloom, 1956) that align with the State's curriculum requirements:

- They read and reviewed equations, definitions, and assignments online.
- They researched, accessed, and read needed content online using a search engine.
- They evaluated sought information for scholarly merit and usefulness.
- They observed and examined chemical reactions via streaming video.
- They had to identify reactants, products, and calculate correct formulas.
- They had to analyze and summarize their findings on quizzes and in scientific reports.

Finally, these findings have added to our knowledge of the usefulness of technology to student learning.

The current studies are not without limitations. Specifically, these studies compared two teachers at the same high school. Larger studies utilizing more teachers and students in both the experimental and control groups are needed. Furthermore, similar studies should be conducted in urban and larger school districts and in districts with more ethnic diversity. Finally, using virtual labs in other sciences and in other disciplines would add to our understanding of using technology in education.

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