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A Comparative Analysis of Student Performance in an Online vs. Face-to-Face Environmental Science Course From 2009 to 2016

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A growing number of students are now opting for online classes. They find the traditional classroom modality restrictive, inflexible, and impractical. In this age of technological advancement, schools can now provide effective classroom teaching via the Web. This shift in pedagogical medium is forcing academic institutions to rethink how they want to deliver their course content. The overarching purpose of this research was to determine which teaching method proved more effective over the 8-year period. The scores of 548 students, 401 traditional students and 147 online students, in an environmental science class were used to determine which instructional modality generated better student performance. In addition to the overarching objective, we also examined score variabilities between genders and classifications to determine if teaching modality had a greater impact on specific groups. No significant difference in student performance between online and face-to-face (F2F) learners overall, with respect to gender, or with respect to class rank were found. These data demonstrate the ability to similarly translate environmental science concepts for non-STEM majors in both traditional and online platforms irrespective of gender or class rank. A potential exists for increasing the number of non-STEM majors engaged in citizen science using the flexibility of online learning to teach environmental science core concepts.

Keywords: face-to-face (F2F), traditional classroom teaching, web-based instructions, information and communication technology (ICT), online learning, desire to learn (D2L), passive learning, active learning

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INTRODUCTION

The advent of online education has made it possible for students with busy lives and limited flexibility to obtain a quality education. As opposed to traditional classroom teaching, Web-based instruction has made it possible to offer classes worldwide through a single Internet connection. Although it boasts several advantages over traditional education, online instruction still has its drawbacks, including limited communal synergies. Still, online education seems to be the path many students are taking to secure a degree.

This study compared the effectiveness of online vs. traditional instruction in an environmental studies class. Using a single indicator, we attempted to see if student performance was effected by instructional medium. This study sought to compare online and F2F teaching on three levels—pure modality, gender, and class rank. Through these comparisons, we investigated whether one teaching modality was significantly more effective than the other. Although there were limitations

to the study, this examination was conducted to provide us with additional measures to determine if students performed better in one environment over another (Mozes-Carmel and Gold, 2009).

The methods, procedures, and operationalization tools used in this assessment can be expanded upon in future quantitative, qualitative, and mixed method designs to further analyze this topic. Moreover, the results of this study serve as a backbone for future meta-analytical studies.

Origins of Online Education

Computer-assisted instruction is changing the pedagogical landscape as an increasing number of students are seeking online education. Colleges and universities are now touting the efficiencies of Web-based education and are rapidly implementing online classes to meet student needs worldwide. One study reported "increases in the number of online courses given by universities have been quite dramatic over the last couple of years" (Lundberg et al., 2008). Think tanks are also disseminating statistics on Web-based instruction. "In 2010, the Sloan Consortium found a 17% increase in online students from the years before, beating the 12% increase from the previous year" (Keramidas, 2012).

Contrary to popular belief, online education is not a new phenomenon. The first correspondence and distance learning educational programs were initiated in the mid-1800s by the University of London. This model of educational learning was dependent on the postal service and therefore wasn't seen in American until the later Nineteenth century. It was in 1873 when what is considered the first official correspondence educational program was established in Boston, Massachusetts known as the "Society to Encourage Home Studies." Since then, non-traditional study has grown into what it is today considered a more viable online instructional modality. Technological advancement indubitably helped improve the speed and accessibility of distance learning courses; now students worldwide could attend classes from the comfort of their own homes.

Qualities of Online and Traditional Face to Face (F2F) Classroom Education

Online and traditional education share many qualities. Students are still required to attend class, learn the material, submit assignments, and complete group projects. While teachers, still have to design curriculums, maximize instructional quality, answer class questions, motivate students to learn, and grade assignments. Despite these basic similarities, there are many differences between the two modalities. Traditionally, classroom instruction is known to be teacher-centered and requires passive learning by the student, while online instruction is often student-centered and requires active learning.

In teacher-centered, or passive learning, the instructor usually controls classroom dynamics. The teacher lectures and comments, while students listen, take notes, and ask questions. In student-centered, or active learning, the students usually determine classroom dynamics as they independently analyze the information, construct questions, and ask the instructor for clarification. In this scenario, the teacher, not the student, is listening, formulating, and responding (Salcedo, 2010).

In education, change comes with questions. Despite all current reports championing online education, researchers are still questioning its efficacy. Research is still being conducted on the effectiveness of computer-assisted teaching. Cost-benefit analysis, student experience, and student performance are now being carefully considered when determining whether online education is a viable substitute for classroom teaching. This decision process will most probably carry into the future as technology improves and as students demand better learning experiences.

Thus far, "literature on the efficacy of online courses is expansive and divided" (Driscoll et al., 2012). Some studies favor traditional classroom instruction, stating "online learners will quit more easily" and "online learning can lack feedback for both students and instructors" (Atchley et al., 2013). Because of these shortcomings, student retention, satisfaction, and performance can be compromised. Like traditional teaching, distance learning also has its apologists who aver online education produces students who perform as well or better than their traditional classroom counterparts (Westhuis et al., 2006).

The advantages and disadvantages of both instructional modalities need to be fully fleshed out and examined to truly determine which medium generates better student performance. Both modalities have been proven to be relatively effective, but, as mentioned earlier, the question to be asked is if one is truly better than the other.

Student Need for Online Education

With technological advancement, learners now want quality programs they can access from anywhere and at any time. Because of these demands, online education has become a viable, alluring option to business professionals, stay-at home-parents, and other similar populations. In addition to flexibility and access, multiple other face value benefits, including program choice and time efficiency, have increased the attractiveness of distance learning (Wladis et al., 2015).

First, prospective students want to be able to receive a quality education without having to sacrifice work time, family time, and travel expense. Instead of having to be at a specific location at a specific time, online educational students have the freedom to communicate with instructors, address classmates, study materials, and complete assignments from any Internet-accessible point (Richardson and Swan, 2003). This type of flexibility grants students much-needed mobility and, in turn, helps make the educational process more enticing. According to Lundberg et al. (2008) "the student may prefer to take an online course or a complete online-based degree program as online courses offer more flexible study hours; for example, a student who has a job could attend the virtual class watching instructional film and streaming videos of lectures after working hours."

Moreover, more study time can lead to better class performance—more chapters read, better quality papers, and more group project time. Studies on the relationship between study time and performance are limited; however, it is often assumed the online student will use any surplus time to improve grades (Bigelow, 2009). It is crucial to mention the link between

flexibility and student performance as grades are the lone performance indicator of this research.

Second, online education also offers more program choices. With traditional classroom study, students are forced to take courses only at universities within feasible driving distance or move. Web-based instruction, on the other hand, grants students electronic access to multiple universities and course offerings (Salcedo, 2010). Therefore, students who were once limited to a few colleges within their immediate area can now access several colleges worldwide from a single convenient location.

Third, with online teaching, students who usually don't participate in class may now voice their opinions and concerns. As they are not in a classroom setting, quieter students may feel more comfortable partaking in class dialogue without being recognized or judged. This, in turn, may increase average class scores (Driscoll et al., 2012).

Benefits of Face-to-Face (F2F) Education via Traditional Classroom Instruction

The other modality, classroom teaching, is a well-established instructional medium in which teaching style and structure have been refined over several centuries. Face-to-face instruction has numerous benefits not found in its online counterpart (Xu and Jaggars, 2016).

First and, perhaps most importantly, classroom instruction is extremely dynamic. Traditional classroom teaching provides real-time face-to-face instruction and sparks innovative questions. It also allows for immediate teacher response and more flexible content delivery. Online instruction dampens the learning process because students must limit their questions to blurbs, then grant the teacher and fellow classmates time to respond (Salcedo, 2010). Over time, however, online teaching will probably improve, enhancing classroom dynamics and bringing students face-to face with their peers/instructors. However, for now, face-to-face instruction provides dynamic learning attributes not found in Web-based teaching (Kemp and Grieve, 2014).

Second, traditional classroom learning is a well-established modality. Some students are opposed to change and view online instruction negatively. These students may be technophobes, more comfortable with sitting in a classroom taking notes than sitting at a computer absorbing data. Other students may value face-to-face interaction, pre and post-class discussions, communal learning, and organic student-teacher bonding (Roval and Jordan, 2004). They may see the Internet as an impediment to learning. If not comfortable with the instructional medium, some students may shun classroom activities; their grades might slip and their educational interest might vanish. Students, however, may eventually adapt to online education. With more universities employing computer-based training, students may be forced to take only Web-based courses. Albeit true, this doesn't eliminate the fact some students prefer classroom intimacy.

Third, face-to-face instruction doesn't rely upon networked systems. In online learning, the student is dependent upon access to an unimpeded Internet connection. If technical problems occur, online students may not be able to communicate, submit assignments, or access study material. This problem, in turn, may frustrate the student, hinder performance, and discourage learning.

Fourth, campus education provides students with both accredited staff and research libraries. Students can rely upon administrators to aid in course selection and provide professorial recommendations. Library technicians can help learners edit their papers, locate valuable study material, and improve study habits. Research libraries may provide materials not accessible by computer. In all, the traditional classroom experience gives students important auxiliary tools to maximize classroom performance.

Fifth, traditional classroom degrees trump online educational degrees in terms of hiring preferences. Many academic and professional organizations do not consider online degrees on par with campus-based degrees (Columbaro and Monaghan, 2009). Often, prospective hiring bodies think Web-based education is a watered-down, simpler means of attaining a degree, often citing poor curriculums, unsupervised exams, and lenient homework assignments as detriments to the learning process.

Finally, research shows online students are more likely to quit class if they do not like the instructor, the format, or the feedback. Because they work independently, relying almost wholly upon self-motivation and self-direction, online learners may be more inclined to withdraw from class if they do not get immediate results.

The classroom setting provides more motivation, encouragement, and direction. Even if a student wanted to quit during the first few weeks of class, he/she may be deterred by the instructor and fellow students. F2F instructors may be able to adjust the structure and teaching style of the class to improve student retention (Kemp and Grieve, 2014). With online teaching, instructors are limited to electronic correspondence and may not pick-up on verbal and non-verbal cues.

Both F2F and online teaching have their pros and cons. More studies comparing the two modalities to achieve specific learning outcomes in participating learner populations are required before well-informed decisions can be made. This study examined the two modalities over eight (8) years on three different levels. Based on the aforementioned information, the following research questions resulted.

RQ1: Are there significant differences in academic performance between online and F2F students enrolled in an environmental science course?

RQ2: Are there gender differences between online and F2F student performance in an environmental science course?

RQ3: Are there significant differences between the performance of online and F2F students in an environmental science course with respect to class rank?

The results of this study are intended to edify teachers, administrators, and policymakers on which medium may work best.

METHODOLOGY

Participants

The study sample consisted of 548 FVSU students who completed the Environmental Science class between 2009 and 2016. The final course grades of the participants served

as the primary comparative factor in assessing performance differences between online and F2F instruction. Of the 548 total participants, 147 were online students while 401 were traditional students. This disparity was considered a limitation of the study. Of the 548 total students, 246 were male, while 302 were female. The study also used students from all four class ranks. There were 187 freshmen, 184 sophomores, 76 juniors, and 101 seniors. This was a convenience, non-probability sample so the composition of the study set was left to the discretion of the instructor. No special preferences or weights were given to students based upon gender or rank. Each student was considered a single, discrete entity or statistic.

All sections of the course were taught by a full-time biology professor at FVSU. The professor had over 10 years teaching experience in both classroom and F2F modalities. The professor was considered an outstanding tenured instructor with strong communication and management skills.

The F2F class met twice weekly in an on-campus classroom. Each class lasted 1 h and 15 min. The online class covered the same material as the F2F class, but was done wholly on-line using the Desire to Learn (D2L) e-learning system. Online students were expected to spend as much time studying as their F2F counterparts; however, no tracking measure was implemented to gauge e-learning study time. The professor combined textbook learning, lecture and class discussion, collaborative projects, and assessment tasks to engage students in the learning process.

This study did not differentiate between part-time and full-time students. Therefore, many part-time students may have been included in this study. This study also did not differentiate between students registered primarily at FVSU or at another institution. Therefore, many students included in this study may have used FVSU as an auxiliary institution to complete their environmental science class requirement.

Test Instruments

In this study, student performance was operationalized by final course grades. The final course grade was derived from test, homework, class participation, and research project scores. The four aforementioned assessments were valid and relevant; they were useful in gauging student ability and generating objective performance measurements. The final grades were converted from numerical scores to traditional GPA letters.

Data Collection Procedures

The sample 548 student grades were obtained from FVSU's Office of Institutional Research Planning and Effectiveness (OIRPE). The OIRPE released the grades to the instructor with the expectation the instructor would maintain confidentiality and not disclose said information to third parties. After the data was obtained, the instructor analyzed and processed the data though SPSS software to calculate specific values. These converted values were subsequently used to draw conclusions and validate the hypothesis.

RESULTS

Summary of the Results: The chi-square analysis showed no significant difference in student performance between online and face-to-face (F2F) learners [χ^2 (4, $N = 548$) = 6.531, $p > 0.05$]. The independent sample t-test showed no significant difference in student performance between online and F2F learners with respect to gender [$t_{(145)}$ =1.42, $p = 0.122$]. The 2-way ANOVA showed no significant difference in student performance between online and F2F learners with respect to class rank (Girard et al., 2016).

Research question #1 was to determine if there was a statistically significant difference between the academic performance of online and F2F students.

Research Question 1

The first research question investigated if there was a difference in student performance between F2F and online learners.

To investigate the first research question, we used a traditional chi-square method to analyze the data. The chi-square analysis is particularly useful for this type of comparison because it allows us to determine if the relationship between teaching modality and performance in our sample set can be extended to the larger population. The chi-square method provides us with a numerical result which can be used to determine if there is a statistically significant difference between the two groups.

Table 1 shows us the mean and SD for modality and for gender. It is a general breakdown of numbers to visually elucidate any differences between scores and deviations. The mean GPA for both modalities is similar with F2F learners scoring a 69.35 and online learners scoring a 68.64. Both groups had fairly similar SDs. A stronger difference can be seen between the GPAs earned by men and women. Men had a 3.23 mean GPA while women had a 2.9 mean GPA. The SDs for both groups were almost identical. Even though the 0.33 numerical difference may look fairly insignificant, it must be noted that a 3.23 is approximately a B+ while a 2.9 is approximately a B. Given a categorical range of only A to F, a plus differential can be considered significant.

The mean grade for men in the environmental online classes ($M = 3.23$, $N = 246$, $SD = 1.19$) was higher than the mean grade for women in the classes ($M = 2.9$, $N = 302$, $SD = 1.20$) (see **Table 1**).

First, a chi-square analysis was performed using SPSS to determine if there was a statistically significant difference in grade distribution between online and F2F students. Students enrolled in the F2F class had the highest percentage of A's (63.60%) as compared to online students (36.40%). **Table 2** displays grade distribution by course delivery modality. The difference in

TABLE 1 | Means and standard deviations for 8 semester- "Environmental Science data set."

	F2F sections ($n = 401$)		Online sections ($n = 147$)		Men ($n = 246$)		Women ($n = 302$)	
Variable	**Mean**	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Grade received	69.35	12.128	68.64	14.125	3.23	1.19	2.9	1.20

TABLE 2 | Contingency table for student's academic performance ($N = 548$).

Comparison	A	B	C	D	F	Total
F2F	28	121	131	49	72	401
F2F % within grade	63.60%	79.10%	70.80%	77.80%	69.90%	73.20%
Online	16	32	54	14	31	147
Online % within grade	36.40%	20.90%	29.20%	22.20%	30.10%	26.80%

$\chi^2 = 6.531$, Critical value = 7.7, d.f.= 4.

student performance was statistically significant, χ^2 (4, $N = 548$) $= 6.531$, $p > 0.05$.

Table 2 shows us the performance measures of online and F2F students by grade category. As can be seen, F2F students generated the highest performance numbers for each grade category. However, this disparity was mostly due to a higher number of F2F students in the study. There were 401 F2F students as opposed to just 147 online students. When viewing grades with respect to modality, there are smaller percentage differences between respective learners (Tanyel and Griffin, 2014). For example, F2F learners earned 28 As (63.60% of total A's earned) while online learners earned 16 As (36.40% of total A's earned). However, when viewing the A grade with respect to total learners in each modality, it can be seen that 28 of the 401 F2F students (6.9%) earned As as compared to 16 of 147 (10.9%) online learners. In this case, online learners scored relatively higher in this grade category. The latter measure (grade total as a percent of modality total) is a better reflection of respective performance levels.

Given a critical value of 7.7 and a d.f. of 4, we were able to generate a chi-squared measure of 6.531. The correlating *p*-value of 0.163 was greater than our *p*-value significance level of 0.05. We, therefore, had to accept the null hypothesis and reject the alternative hypothesis. There is no statistically significant difference between the two groups in terms of performance scores.

Research Question 2

The second research question was posed to evaluate if there was a difference between online and F2F varied with gender. Does online and F2F student performance vary with respect to gender? **Table 3** shows the gender difference on student performance between online and face to face students. We used chi-square test to determine if there were differences in online and F2F student performance with respect to gender. The chi-square test with alpha equal to 0.05 as criterion for significance. The chi-square result shows that there is no statistically significant difference between men and women in terms of performance.

Research Question 3

The third research question tried to determine if there was a difference between online and F2F varied with respect to class rank. Does online and F2F student performance vary with respect to class rank?

Table 4 shows the mean scores and standard deviations of freshman, sophomore, and junior and senior students for both online and F2F student performance. To test the third hypothesis, we used a two-way ANOVA. The ANOVA is a useful appraisal tool for this particular hypothesis as it tests the differences between multiple means. Instead of testing specific differences, the ANOVA generates a much broader picture of average differences. As can be seen in **Table 4**, the ANOVA test for this particular hypothesis states there is no significant difference between online and F2F learners with respect to class rank. Therefore, we must accept the null hypothesis and reject the alternative hypothesis.

The results of the ANOVA show there is no significant difference in performance between online and F2F students with respect to class rank. Results of ANOVA is presented in **Table 5**.

As can be seen in **Table 4**, the ANOVA test for this particular hypothesis states there is no significant difference between online and F2F learners with respect to class rank. Therefore, we must accept the null hypothesis and reject the alternative hypothesis.

TABLE 3 | Gender *performance crosstabulation.

Gender	A	B	C	D	F	Total
Male count	15	54	89	34	54	246
Expected count	19.0	68.7	83.0	28.3	46.2	246
Female count	29	99	96	29	49	302
Expected count	24.0	84.3	102	34.7	56.8	302
Total count	44	153	185	63	103	548

Chi-square tests

	Value	*df*	Asymptotic significance
Pearson Chi-square	0.011	13.007[a]	4
Likelihood ratio	0.011	13.138	4
Linear-by-linear association	0.011	10.376	1
N of valid cases		548	

[a]*0 cells (0.0%) have expected count <5. The minimum expected count is 19.75.*
X^2 test of independence with alpha = 0.05.

TABLE 4 | Descriptive analysis of student performance by class rankings gender.

Class rankings	Female			Male		
	Mean	*N*	*SD*	Mean	*N*	*SD*
Freshman	1.1456	103	0.35446	1.1429	84	0.35203
Sophomore	1.3125	96	0.46595	1.1023	88	0.30474
Junior	1.5714	42	0.50087	1.2941	34	0.4625
Senior	1.5082	61	0.59408	1.4	40	0.49614

TABLE 5 | Analysis of variance (ANOVA) for online and F2F of class rankings.

Scale	Source	SS	*Df*	MS	*f*	*p*
Online	Rank	10.24	3	3.414	2.192	0.092
	Error	222.778	143	1.558		
Face to face	Rank	42.93	3	14.311	10.793	0.000
	Error	526.42	397	1.326	–	–

DISCUSSION AND SOCIAL IMPLICATIONS

The results of the study show there is no significant difference in performance between online and traditional classroom students with respect to modality, gender, or class rank in a science concepts course for non-STEM majors. Although there were sample size issues and study limitations, this assessment shows both online learners and classroom learners perform at the same level. This conclusion indicates teaching modality may not matter as much as other factors. Given the relatively sparse data on pedagogical modality comparison given specific student population characteristics, this study could be considered innovative. In the current literature, we have not found a study of this nature comparing online and F2F non-STEM majors with respect to three separate factors—medium, gender, and class rank—and the ability to learn science concepts and achieve learning outcomes. Previous studies have compared traditional classroom learning vs. F2F learning for other factors (including specific courses, costs, qualitative analysis, etcetera, but rarely regarding outcomes relevant to population characteristics of learning for a specific science concepts course over many years) (Liu, 2005).

In a study evaluating the transformation of a graduate level course for teachers, academic quality of the online course and learning outcomes were evaluated. The study evaluated the ability of course instructors to design the course for online delivery and develop various interactive multimedia models at a cost-savings to the respective university. The online learning platform proved effective in translating information where tested students successfully achieved learning outcomes comparable to students taking the F2F course (Herman and Banister, 2007).

Another study evaluated the similarities and differences in F2F and online learning in a non-STEM course, "Foundations of American Education" and overall course satisfaction by students enrolled in either of the two modalities. F2F and online course satisfaction was qualitatively and quantitative analyzed. However, in analyzing online and F2F course feedback using quantitative feedback, online course satisfaction was less than F2F satisfaction. When qualitative data was used, course satisfaction was similar between modalities (Werhner, 2010). The course satisfaction data and feedback was used to suggest a number of posits for effective online learning in the specific course. The researcher concluded that there was no difference in the learning success of students enrolled in the online vs. F2F course, stating that "in terms of learning, students who apply themselves diligently should be successful in either format" (Dell et al., 2010). The author's conclusion presumes that the "issues surrounding class size are under control and that the instructor has a course load that makes the intensity of the online course workload feasible" where the authors conclude that the workload for online courses is more than for F2F courses (Stern, 2004).

In "A Meta-Analysis of Three Types of Interaction Treatments in Distance Education," Bernard et al. (2009) conducted a meta-analysis evaluating three types of instructional and/or media conditions designed into distance education (DE) courses known as interaction treatments (ITs)—student–student (SS), student–teacher (ST), or student–content (SC) interactions—to other DE instructional/interaction treatments. The researchers found that a strong association existed between the integration of these ITs into distance education courses and achievement compared with blended or F2F modalities of learning. The authors speculated that this was due to increased cognitive engagement based in these three interaction treatments (Larson and Sung, 2009).

Other studies evaluating students' preferences (but not efficacy) for online vs. F2F learning found that students prefer online learning when it was offered, depending on course topic, and online course technology platform (Ary and Brune, 2011). F2F learning was preferred when courses were offered late morning or early afternoon 2–3 days/week. A significant preference for online learning resulted across all undergraduate course topics (American history and government, humanities, natural sciences, social, and behavioral sciences, diversity, and international dimension) except English composition and oral communication. A preference for analytical and quantitative thought courses was also expressed by students, though not with statistically significant results (Mann and Henneberry, 2014). In this research study, we looked at three hypothesis comparing online and F2F learning. In each case, the null hypothesis was accepted. Therefore, at no level of examination did we find a significant difference between online and F2F learners. This finding is important because it tells us traditional-style teaching with its heavy emphasis on interpersonal classroom dynamics may 1 day be replaced by online instruction. According to Daymont and Blau (2008) online learners, regardless of gender or class rank, learn as much from electronic interaction as they do from personal interaction. Kemp and Grieve (2014) also found that both online and F2F learning for psychology students led to similar academic performance. Given the cost efficiencies and flexibility of online education, Web-based instructional systems may rapidly rise.

A number of studies support the economic benefits of online vs. F2F learning, despite differences in social constructs and educational support provided by governments. In a study by Li and Chen (2012) higher education institutions benefit the most from two of four outputs—research outputs and distance education—with teaching via distance education at both the undergraduate and graduate levels more profitable than F2F teaching at higher education institutions in China. Zhang and Worthington (2017) reported an increasing cost benefit for the use of distance education over F2F instruction as seen at 37 Australian public universities over 9 years from 2003 to 2012. Maloney et al. (2015) and Kemp and Grieve (2014) also found significant savings in higher education when using online learning platforms vs. F2F learning. In the West, the cost efficiency of online learning has been demonstrated by several research studies (Craig, 2015). Studies by Agasisti and Johnes (2015) and Bartley and Golek (2004) both found the cost benefits of online learning significantly greater than that of F2F learning at U.S. institutions.

Knowing there is no significant difference in student performance between the two mediums, institutions of higher

education may make the gradual shift away from traditional instruction; they may implement Web-based teaching to capture a larger worldwide audience. If administered correctly, this shift to Web-based teaching could lead to a larger buyer population, more cost efficiencies, and more university revenue.

The social implications of this study should be touted; however, several concerns regarding generalizability need to be taken into account. First, this study focused solely on students from an environmental studies class for non-STEM majors. The ability to effectively prepare students for scientific professions without hands-on experimentation has been contended. As a course that functions to communicate scientific concepts, but does not require a laboratory based component, these results may not translate into similar performance of students in an online STEM course for STEM majors or an online course that has an online laboratory based co-requisite when compared to students taking traditional STEM courses for STEM majors. There are few studies that suggest the landscape may be changing with the ability to effectively train students in STEM core concepts via online learning. Biel and Brame (2016) reported successfully translating the academic success of F2F undergraduate biology courses to online biology courses. However, researchers reported that of the large-scale courses analyzed, two F2F sections outperformed students in online sections, and three found no significant difference. A study by Beale et al. (2014) comparing F2F learning with hybrid learning in an embryology course found no difference in overall student performance. Additionally, the bottom quartile of students showed no differential effect of the delivery method on examination scores. Further, a study from Lorenzo-Alvarez et al. (2019) found that radiology education in an online learning platform resulted in similar academic outcomes as F2F learning. Larger scale research is needed to determine the effectiveness of STEM online learning and outcomes assessments, including workforce development results.

In our research study, it is possible the study participants may have been more knowledgeable about environmental science than about other subjects. Therefore, it should be noted this study focused solely on students taking this one particular class. Given the results, this course presents a unique potential for increasing the number of non-STEM majors engaged in citizen science using the flexibility of online learning to teach environmental science core concepts.

Second, the operationalization measure of "grade" or "score" to determine performance level may be lacking in scope and depth. The grades received in a class may not necessarily show actual ability, especially if the weights were adjusted to heavily favor group tasks and writing projects. Other performance indicators may be better suited to properly access student performance. A single exam containing both multiple choice and essay questions may be a better operationalization indicator of student performance. This type of indicator will provide both a quantitative and qualitative measure of subject matter comprehension.

Third, the nature of the student sample must be further dissected. It is possible the online students in this study may have had more time than their counterparts to learn the material and generate better grades (Summers et al., 2005). The inverse holds true, as well. Because this was a convenience non-probability sampling, the chances of actually getting a fair cross section of the student population were limited. In future studies, greater emphasis must be placed on selecting proper study participants, those who truly reflect proportions, types, and skill levels.

This study was relevant because it addressed an important educational topic; it compared two student groups on multiple levels using a single operationalized performance measure. More studies, however, of this nature need to be conducted before truly positing that online and F2F teaching generate the same results. Future studies need to eliminate spurious causal relationships and increase generalizability. This will maximize the chances of generating a definitive, untainted results. This scientific inquiry and comparison into online and traditional teaching will undoubtedly garner more attention in the coming years.

SUMMARY

Our study compared learning via F2F vs. online learning modalities in teaching an environmental science course additionally evaluating factors of gender and class rank. These data demonstrate the ability to similarly translate environmental science concepts for non-STEM majors in both traditional and online platforms irrespective of gender or class rank. The social implications of this finding are important for advancing access to and learning of scientific concepts by the general population, as many institutions of higher education allow an online course to be taken without enrolling in a degree program. Thus, the potential exists for increasing the number of non-STEM majors engaged in citizen science using the flexibility of online learning to teach environmental science core concepts.

LIMITATIONS OF THE STUDY

The limitations of the study centered around the nature of the sample group, student skills/abilities, and student familiarity with online instruction. First, because this was a convenience, non-probability sample, the independent variables were not adjusted for real-world accuracy. Second, student intelligence and skill level were not taken into consideration when separating out comparison groups. There exists the possibility that the F2F learners in this study may have been more capable than the online students and vice versa. This limitation also applies to gender and class rank differences (Friday et al., 2006). Finally, there may have been ease of familiarity issues between the two sets of learners. Experienced traditional classroom students now taking Web-based courses may be daunted by the technical aspect of the modality. They may not have had the necessary preparation or experience to efficiently e-learn, thus leading to lowered scores (Helms, 2014). In addition to comparing online and F2F instructional efficacy, future research should also analyze blended teaching methods for the effectiveness of courses for non-STEM majors to impart basic STEM concepts and see if the blended style is more effective than any one pure style.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Fort Valley State University Human Subjects Institutional Review Board. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

JP provided substantial contributions to the conception of the work, acquisition and analysis of data for the work, and is the corresponding author on this paper who agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. FJ provided substantial contributions to the design of the work, interpretation of the data for the work, and revised it critically for intellectual content.

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