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Abstract

Science, technology, engineering, and mathematics (STEM) programs serving students from low socioeconomic areas are understudied in the literature. More research studies need to be conducted to make informed instructional decisions for students who may be at a disadvantage compared to their peers from higher socioeconomic areas. The purpose of this research study was to determine the effects of traditional science instruction and blended learning on STEM achievement of elementary school students from low socioeconomic areas. Third, fourth and fifth grade students (N = 129) from a low-socioeconomic school were randomly assigned to receive traditional science instruction or a blended learning science curriculum approach. The science, technology, engineering, and mathematics (STEM) achievement scores were analyzed by conducting a one-way two-group Multiple Analysis of Variance (MANOVA) implemented in *R* statistical computing platform (R Core Team, 2018). The results indicated that the teaching method had a statistically significant effect on the linear combination of the science, technology, mathematics and engineering scores ($F(4,124) = 80.27$, $p < .0001$, Pillai's Trace = .721, partial $\eta^2 = .721$), in favor of the blended learning approach.

Introduction

Science, technology, engineering and mathematics (STEM) programs have become an indispensable part of the elementary school curriculum (Brown, 2012). This can possibly be attributed to some of the valuable benefits that STEM programs offer for students (National Research Council, 2012). STEM programs encourage and support students to become critical thinkers, problem solvers and creative individuals. These and various other benefits of the STEM programs are well documented by the studies of several researchers (Baber, 2015; Basile & Lopez, 2015; Daugherty, 2013; Gough, 2015; McNally, 2012; Riegle-Crumb & King, 2010). Blended learning, as an instructional methodology, is also becoming an interest to a number of researchers (Bidarra & Russman, 2015; Brown, 2012; Owens, 2009; Sanders, 2009). STEM education is based heavily upon hands-on learning or experiential learning. Furthermore, the current trends towards blended learning and their impact on STEM education and achievement need to be investigated more. The Experiential Learning Theory (ELT) of Kolb (1984) describes a series of learning steps that take place when students are engaged with hands-on learning experiences, such as those in STEM programs. Kolb's ELT is viewed as the backbone of STEM learning (Brown, 2012; Sanders, 2009). It is necessary to investigate the impact blended learning may have on STEM achievement, with some portion of instructional time being given to experiential learning.

Schools view and use STEM education as a tool to prepare students for colleges and careers of the future. A wide range of skill sets students need later in life can be cultivated in STEM education programs at present. Such skills are necessary ingredients of the curriculum to prepare students for college and careers (Brown, 2012; Owens, 2009; Sanders, 2009). Hence, blended learning has come into focus, as it aims to provide these benefits to students. According to P21, Partnership for 21st Century Learning, which is a national nonprofit organization advocating for 21st century skills in the classroom, these skills include several key elements and they are divided into the 4 C's of 21st century learning: critical thinking, collaboration, communication and creativity (P21 Partnership for 21st Century Learning, 2015). Within STEM education programs, students learn and develop the 4 C's among a plethora of other useful skills. The blended learning approach aims to integrate these skills into the curriculum.

Although there is widespread agreement that STEM programs in elementary education are necessary components of the curriculum, the practical implementation of STEM programs has seen a variety of forms. Surprisingly, there is very little standardization among STEM curricula. The quality of each schools' program can vary greatly, and this generally depends upon funding (Brown, 2012; Gough, 2015; McNally, 2012). Schools with higher funding often have larger and more elaborate STEM programs, which are more likely to succeed. This is simply due to the fact that the higher funding can result in purchasing more resources, such as robots, tablets, mechanical cars, electrical circuits or computers to support the STEM program. Schools with lower funding may not be able to provide students with the vast array of resources in order for the program to reach its full potential. Unfortunately, such equity issues are far too common in education. Schools within the same school district have vastly different resources, depending upon the socioeconomic demographic that they serve. Although social, political and economic forces intertwine to form a complex social problem, the pedagogy of STEM programs is the sole focus of our research.

Even though STEM programs are seen in a wide variety of school demographics, the research about these programs has not been as diverse. Research studies focusing on students' learning experiences are typically from higher socioeconomic backgrounds and the learning experiences of students from low socioeconomic backgrounds are not researched as extensively (Baber, 2015; Basile & Lopez, 2015; Riegle-Crumb & King, 2010). Needless to say, more research studies need to be conducted in schools with students of low socioeconomic backgrounds. Students in these schools are considered to be the most vulnerable student populations and more research is needed to find out about their needs and be able support their needs better.

Furthermore, the research that does exist about STEM experiences from multiple socioeconomic status areas show astounding bias towards higher socioeconomic schools. Several research studies claim that learning experiences in STEM programs that use a traditional hands-on approach provide more benefits to students of high socioeconomic status when compared to the experiences of students from low socioeconomic status (Daugherty, 2013; Gough, 2015; McNally, 2012). The term 'benefits' in this context refers to higher test scores on standardized exams. Moreover, there are very few studies that use a blended learning approach to STEM education for low-socioeconomic schools. Students from low socioeconomic areas should be benefitting just as much from STEM programs as other students. There is very limited knowledge about the instructional methods used beyond traditional instructional methods. A deeper investigation of other instructional approaches, such as blended learning, is needed to better understand the STEM achievement of students from low socioeconomic areas.

Purpose of the Study

Although there have been several research studies on STEM achievement in elementary schools (Bidarra & Russman, 2015; Brown, 2012; Owens, 2009; Sanders, 2009), only few studies have examined STEM achievement in low socioeconomic settings. The purpose of this research study was to determine the effects of traditional science instruction and blended learning on STEM achievement of students from low socioeconomic areas. Since there is a gap in the literature concerning STEM achievement and blended learning, further research studies are much needed. This paper sought to investigate two instructional methods in a STEM program that serves a low socioeconomic area. By comparing STEM achievement of students, we can assess the efficacy of each instructional method. Furthermore, students from low socioeconomic backgrounds may have the same benefits that other students have.

Research Questions

1. Are there differences in STEM achievement between students of low socioeconomic backgrounds who received traditional instruction and those who received instruction in a blended learning environment?
2. What are the differences between science, technology, engineering and mathematics achievement scores of students of low socioeconomic backgrounds who received traditional instruction and those who received blended learning instruction?

Review of the Related Literature

The combination of science, technology, engineering, and mathematics form a collective subject called STEM. However, STEM is not seen as an individual subject matter. It is viewed as a curricular blend of all four subject areas contained within the acronym (Daugherty, 2013; Gough, 2015; McNally, 2012). Although STEM is treated as one idea, it is truly much more as a rich description of an integrated learning experience for students.

The learning experience for a STEM activity would typically have students working collaboratively in groups, using mathematical measurements or calculations, integrating technology to research scientific principles, and conducting experiments using the scientific method. Students devise their own solutions using engineering and design processes. Assessments of learning are generally focused on performance tasks or final products, perhaps evaluated based on a rubric. These are the typical aspects of learning experiences in a STEM program. Teachers and instructors in STEM classrooms typically function as facilitators of learning (Gough, 2015; McNally, 2012). A typical STEM teacher circulates throughout the class, providing support and challenging students to think critically by using higher order questioning techniques.

STEM Education

STEM education research is mostly concerned with the effectiveness and overall impact of STEM education programs on science or mathematics achievement among students. According to Owens (2009), STEM education improved science and mathematics achievement, but only slightly. Additionally, STEM education has been studied to determine the effectiveness on students learning holistically. STEM education relies on an integrated approach to curriculum where students are generally given a cognitively complex task of some type. Several researchers have pointed out that the difference between high or low quality STEM education laid in the planning and development of these tasks (Paik, Zhang, Lundeberg, Eberhardt, Shin and Zhang, 2011). In order to meet teacher needs better, Paik et al. (2011) conducted a study to improve STEM education though several professional development courses in problem-based learning. Their study proved to be a successful endeavor in helping teachers develop high quality STEM lessons and classroom experiences.

STEM education has been shown to be a highly meaningful experience for students. Although test scores may not improve dramatically, students and teachers alike have found STEM education to be a worthwhile use of instructional time. As an alternative approach, a study by Sanders (2009) indicated that meaningful STEM education did not always have to arise out of any traditional curriculum to be effective. Sanders noticed that some of the most effective STEM education was organic, informal and characterized by unique teaching styles. While this type of STEM education requires great flexibility of the teacher and the trust of the administration of the school (Brown, 2012; Sanders, 2009), with the proper support, organic and informal STEM education seems beneficial for students.

Experiential Learning Theory

Experiential Learning Theory (ELT) of Kolb (1984) provides the theoretical framework for this study. He suggests that experience is the source of learning and development. Science and STEM education have long used experience as a method for teaching. Kolb has provided the basis for how learning occurs through those experiences, and paved the way to using experiential learning based curriculum in STEM programs. In the first part of ELT, students engage in a concrete experience, where they actively engage in an activity such as a lab session or a field observation. In the next part of ELT, students engage in reflective observation, where the learners consciously reflect back upon their experience they just had. Abstract conceptualization is the next step in the process, where students attempt to conceptualize a theory or model of what was observed or experienced. Finally, students arrive at the last stage in ELT, active experimentation, where they attempt to create a plan for how to test their model or theory in a forthcoming experience. ELT describes the types of learning experience that students typically have in STEM programs.

Socioeconomic Status and STEM

Equity issues in learning experiences of STEM programs have been studied by several researchers who have linked various STEM education programs to higher academic achievement in high socioeconomic areas as compared to low socioeconomic areas (Baber, 2015; Basile & Lopez, 2015; Riegle-Crumb & King, 2010). To corroborate these results, the recent cutbacks in STEM educational funding, particularly by private corporations, were disproportionate in programs supporting minorities and in some cases minority STEM funding was withdrawn altogether (Baber, 2015). This is just one example of how racial and ethnic inequalities in STEM education are manifested. Preparing students for STEM majors in college naturally start in elementary school STEM programs. Hence, the inequalities found in elementary school STEM programs have affected college enrollment a great deal. Several studies have shown that the majority of STEM education majors in college were white males (Basile & Lopez, 2015; Riegle-Crumb & King, 2010). African American women have been found to be the second largest group enrolled in STEM education, followed by African American men. Minority groups are severely underrepresented in STEM programs (Basile & Lopez, 2015; Riegle-Crumb & King, 2010).

Methodology

The purpose of this research was to determine the effects of traditional science instruction and blended learning on STEM achievement of students from low socioeconomic areas. This study compared the mean STEM scores in the two instructional method groups among students from low socioeconomic backgrounds in a public elementary school located in South Florida in the United States of America. The students were selected to participate in this study as a convenience sample consisting of the third, fourth and fifth grade students from the public elementary school where the first author is a science teacher. The demographic information, research design, instruments used, data collection and data analysis are outlined below.

Participants

Participants, who were students from low socioeconomic backgrounds, were selected in order to understand their needs as 21st century learners. A convenience sample of students in grade levels 3, 4 and 5 were selected to participate in our study (N = 129). The participants were enrolled in a Title 1 elementary school, located in a low socioeconomic neighborhood in South Florida in the United States of America. One of the researchers was employed as a science teacher at the school. Based upon limited family income, approximately 83% of the students at the school qualify for free or reduced lunch programs. The participants included 41 third grade, 43 fourth grade, and 45 fifth grade students. The sample was comprised of 46% African American, 41% Hispanic, and 10% White-Caucasian students and had a relatively balanced gender distribution of 53% male and 47% female students. Subsequently, the third, fourth and fifth grade classes were randomly assigned to receive either traditional science instruction or a blended learning approach.

Design of the Study

Beginning of the fall semester in 2017, third, fourth and fifth grade classes were randomly assigned to receive either traditional science instruction or a blended learning approach. Students assigned to receive traditional science instruction had eight weeks of activities that would typically take place in a traditional STEM classroom. The traditional STEM teaching method uses the 5-E model of instruction: engagement, explore, explain, elaborate, and evaluate. An instructional cycle was started with an engagement activity; something unusual presented by the teacher to capture the students' interest. This activity was a demonstration by the teacher, an interesting video, or an inquiry-type activity. Next, the students began exploring the concept through hands-on lessons. These hands-on activities were guided by the teacher in order for students to become familiar with the concept being taught. Then, students explained what they have observed in their own words, with support from the teacher. At this point, students generated their own line of questioning with regards to the topic and were given classroom time to develop those ideas. This was the elaboration of the concept. Finally, the teacher would assess students' understanding in the evaluation part of the 5-E model.

Students who were assigned to the blended learning curricular approach received eight weeks of face-to-face instruction and independent online learning. The face-to-face instruction part was centered on hands-on activities. The independent online learning took place on *Canvas,* a learning management system, which had modules of instruction for students to complete. Each of these modules had links to online labs, online textbooks, reference websites, educational videos, mini-quizzes, discussion boards, and academic games. Upon arriving to class, students would pursue a line of inquiry that was presented to them through online lessons. They would conduct a hands-on experiment based upon what they had learned through the *Canvas* lessons. These lessons were closely monitored by the teacher.

One of the researchers was the teacher of all the participants. Blended learning was chosen as an instructional strategy based upon a pedagogical model for science education outlined by Bidarra & Russman (2015). The teacher had previously used and was skilled in implementing both the 5-E model of instruction and the blended learning approach. As the classroom teacher, the researcher had the discretion to personally choose strategies to instruct students. Using two different teaching methods for different groups of students was a normal practice implemented as a classroom teacher. Students received instruction in their assigned method for eight weeks. On the ninth week, students took assessments according to their grade level in science, technology, engineering and mathematics (STEM) using the school's online testing system, *SchoolCity*. Student data were anonymized and compiled into a database using *Microsoft Excel*.

Instruments

In order to measure the science, technology, engineering and mathematics achievement of students, grade level appropriate quizzes were administered using assessments readily available at the school site. Science, technology and engineering assessments were taken from Houghton Mifflin's *Science Fusion* resource. Mathematics assessments were taken from the *Florida Go Math* curriculum.

In a controlled study conducted by the Educational Research Institute of America (2012), the reliability analyses using the Kuder-Richardson 20 formula yielded high to reasonable results. Science achievement measured by *Science Fusion* was found to be reliable in 5th grade (α = *.87*), 4th grade (α = .77), and 3rd grade (α = .75). Technology achievement measured by *Science Fusion* was found to be reliable in 5th grade (α = .82), 4th grade (α = .80), and 3rd grade (α = .81). Engineering achievement measured by *Science Fusion* was found to be reliable in 5th grade (α = .85), 4th grade (α = .80), and 3rd grade (α = .74). Mathematics achievement measured by *Florida Go Math* was found to be reliable in 5th grade (α = .85), 4th grade (α = .83), and 3rd grade (α = .86).

Data Analysis

Data were collected during the 9th week of instruction. The STEM achievement data were compiled and collected from *SchoolCity*, an online testing platform used at the school. The *Science Fusion* and *Go Math* assessments were hosted by *SchoolCity* for students to access using their personal login information. The data were retrieved from one of the researcher's teacher account with *SchoolCity*. The statistical computing platform R version 3.4.4 (R Core Team, 2018) was used to conduct a one-way two-group MANOVA to analyze the data to determine if there was an overall statistically significant mean difference between the two groups, if so, for which one of the four STEM scores the difference was significant.

Results and Discussion

It is hypothesized that there were statistically significant differences between the mean STEM achievement scores for students of low socioeconomic backgrounds who received traditional instruction and those who received instruction in a blended learning environment. We investigated whether the students in the blended learning group had significantly higher mean scores than the ones in the traditional group with respect to the four STEM scores of science, technology, engineering and mathematics. Each of the dependent variables comprised of continuous test score data.

The mean scores and standard deviations for the assessments completed by the participants in the two teaching method groups in each of the four STEM areas of science, technology, engineering and mathematics are reported in Table 1. The sample sizes for the groups are also reported in Table 1. There were little differences in variances. A two-group MANOVA was conducted to determine the effects of the teaching method on the linear combination of the four dependent variables; science, technology, mathematics and engineering scores.

Table 1. Descriptive Statistics for Science, Technology, Mathematics and Engineering Scores by Teaching Method

Outcome	Teaching Method Group					
	Traditional			Blended Learning		
	M	*SD*	*n*	*M*	*SD*	*n*
Science	2.58	0.73	64	3.58	0.66	65
Technology	4.72	2.08	64	6.89	2.55	65
Mathematics	8.45	2.18	64	14.97	3.25	65
Engineering	9.17	3.49	64	16.43	5.94	65

The results of a two-group MANOVA with four dependent variables of science, technology, mathematics, and engineering, obtained using R version 3.4.4, are summarized in Table 2. The two statistical test statistics, namely Pillai's Trace, and Wilks' Lambda, their converted *F*-statistic values, and the associated *p*-values are displayed in Table 2. The assumptions of normality, linearity, and multicollinearity were satisfied. Box's *M* test was conducted to determine the homogeneity of variance-covariance matrices. The Box's *M* test resulted in a violation of the assumption of equal variances (p = .013). Since the assumption of equal variances was violated, Pillai's Trace statistic was used in conjunction with the MANOVA to determine the significance of group differences. As displayed in Table 2, the MANOVA test results revealed that there was a statistically significant difference in the mean scores for the linear combination of the four STEM areas between the groups ($F(4,124)=80.27$, $p < .0001$, Pillai's = 0.721, partial η^2 = .721). The results reflected a very strong association between teaching method and the combined dependent variables of science, technology, mathematics and engineering test scores (partial η^2 =.721). Hence, based on the effect size index reported by Cohen (1988), the teaching method has a very large statistically significant effect on the combined dependent variables of science, technology, mathematics and engineering test scores. These results provided an affirmative answer to our first research question of whether or not there were differences in STEM achievement between students of low socioeconomic backgrounds who received traditional instruction and those who received instruction in a blended learning environment.

Table 2. MANOVA Test Results

Effect	*Test Name*	*Statistic*	*F*	*df*	*p*	*Partial* η^2
Method Group	Pillai's Trace	0.721	80.27	(4,124)	0.000*	0.721
	Wilks' Λ	0.279	80.27	(4,124)	0.000*	0.721

Note. *p < .0001.

Having found a statistically significant result in the two-group MANOVA, we conducted a series of univariate ANOVA tests as a follow-up analysis to determine if there was a statistically significant group difference for each of the four STEM areas, which are science, technology, engineering and mathematics. The results of the multiple follow-up ANOVA tests are summarized in Table 3.

Table 3. Follow-up ANOVA Test Results

Dependent Variable	Source	*df*	*SS*	*MS*	*F*	*p*	*Partial* η^2
Science	Method Group	1	32.67	32.67	67.58	0.000*	0.347
	Residual	127	61.39	0.48			
	Adjusted Total	128	94.37				
Technology	Method Group	1	152.35	152.35	28.08	0.000*	0.181
	Residual	127	689.18	5.43			
	Adjusted Total	128	841.53				
Mathematics	Method Group	1	1369.24	1369.24	178.57	0.000*	0.584
	Residual	127	973.80	7.67			
	Adjusted Total	128	2343.04				
Engineering	Method Group	1	1699.20	1699.20	71.24	0.000*	0.359
	Residual	127	3029.10	23.85			
	Adjusted Total	128	4728.30				

Note. *p < .0001.

Statistically significant group differences were found for each of the four STEM areas of science, technology, engineering and mathematics. Based on Bonferroni corrected multiple ANOVA tests, the results revealed that teaching method had a statistically significant effect on science (F (1, 127) = 67.58, p < .0001; partial η^2 = .347), technology (F (1, 127) = 28.08, p < .0001; partial η^2 = .181), mathematics (F (1, 127) = 178.57, p < .0001; partial η^2 = .584), and science scores (F (1, 127) = 71.24, p < .0001; partial η^2 = .359). Therefore, based on the effect size index established by Cohen (1988), all the effect sizes reported here were quite large. These results provided an affirmative answer to our second research question of whether or not there were differences between science, technology, engineering and mathematics achievement scores of students of low socioeconomic backgrounds who received traditional instruction and those who received blended learning instruction.

Conclusions

The purpose of this research study was to determine the effects of traditional science instruction and blended learning on STEM achievement of students from low socioeconomic areas. We sought to investigate two instructional methods in a STEM program that serves a low socioeconomic area. By comparing STEM achievement of students, we assessed the efficacy of each instructional method. Although the sample was a convenience sample and relatively small (N=129), some patterns emerged that could benefit elementary school students, teachers, and administrators. Furthermore, students from low socioeconomic backgrounds may have the same benefits that other students have. The research questions were as follows:

1. Are there differences in STEM achievement between students of low socioeconomic backgrounds who received traditional instruction and those who received instruction in a blended learning environment?
2. What are the differences between science, technology, engineering and mathematics achievement scores of students of low socioeconomic backgrounds who received traditional instruction and those who received blended learning instruction?

In order to answer the research questions, we conducted a two-group MANOVA. As an answer to the first research question, the comparison of the 64 students who received traditional instruction and the 65 students who received a blended learning approach provided evidence for statistically significantly higher mean STEM achievement scores for those in a blended learning approach. As for the second research question, the achievement mean scores for the blended learning approach, in the four areas of STEM education of science, technology, engineering and mathematics, were shown to be statistically significantly higher than the mean scores for the traditional instruction setting.

As indicated by these results, students from low socioeconomic backgrounds tend to achieve higher STEM scores when placed in a blended learning environment. These findings are supported by Bidarra and Russman (2015) who also claimed that blended learning bridged academic gaps for students. Blended learning has the benefit of hands-on learning, as well as independent, self-motivated learning. In the blended learning curricular approach, students have first-hand experience with the content and take ownership of their learning. If implemented with fidelity, the blended learning method of instruction should be taken seriously by administrators and other school decision makers who serve low-socioeconomic areas.

Future research studies should place more emphasis on low-socioeconomic schools to investigate the blended learning curricular approach and its potential benefits. In 21st century education, there are many inequalities that affect vulnerable populations of students. As public servants, educators need to be aware of how to better serve those students. Blended learning has been shown to be a promising method of instruction, but superior methods might arise in future research. This project reminds teachers to always be on the cutting edge of research in order to support all types of students in the best ways possible.

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