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A Gender-Based Comparison of the Effects of Face-to-Face and Online Learning on Student Performance in Introductory Computer Science Courses

Ali Alshammari
University of Tabuk, Tabuk, Saudi Arabia

Abstract. Introductory computer science courses help students, regardless of their majors, keep up with the rapid pace of change in the workplace. However, such courses are commonly perceived as being difficult. Although many studies have discussed the importance of online introductory computer science courses, there is a dearth of studies investigating the effectiveness of this delivery mode when the same assessment tools are used as in the traditional delivery mode. Moreover, it is unclear how students of different genders perform in both online and traditional face-to-face introductory computer science course sections when they receive the same instructional content. The purpose of this study is to expand the existing literature by examining the academic achievement of students in an introductory computer science course through the evaluation of grades obtained from online and traditional face-to-face course sections. Additionally, the study aims to explore any gender-based variations between the two delivery modes. The sample size included 589 first-year students in an introductory computer science course at a public university in Saudi Arabia. The participants were selected randomly from different sections. The results confirm the findings of previous studies suggesting that there are no gender-based differences in students' performance in introductory computer science. Additionally, this study makes a valuable contribution to the existing body of literature by demonstrating that students who receive introductory computer science instruction through online delivery mode achieve significantly higher performance than students who receive the same instruction through traditional face-to-dace delivery mode. Moreover, this study found that both female and male students who receive introductory computer science instruction through online delivery mode perform significantly better than male students who receive instruction through traditional face-to-face delivery mode, indicating that online learning may be a more effective mode of delivery for students of both genders.

Keywords: Computer Science; Gender studies; Introductory Computer Science teaching; Online Learning

1. Introduction

1.1 Purpose of the Study

Computing is for everyone, not just for those who major in computer science (CS). In an age characterized by a high-tech economy, many jobs, regardless of whether they are computer-related occupations, require basic to advanced computer skills. According to the U.S. Bureau of Labor Statistics (2021), the workforce engaged in computer-based occupations is expected to grow rapidly between 2020 and 2030 due to the strong demand for computer-related skills. Currently, computing is deeply linked to other STEM disciplines (Pereira et al., 2018); as a result, new computing subfields, such as bioinformatics, computational statistics, computational chemistry, and computational biology, have been created (Pappas et al., 2017). Therefore, computer science education is important for a 21st-century workforce.

Due to the importance of computer science, many universities offer introductory computer science courses under different names depending on the specific focus of the course, including Introduction to Programming, Introduction to Computer Science, Introduction to Computing, or Computer Science 101 (Srivatanakul, 2022). These courses usually cover different fundamental computer science topics and prepare students for the digital workplaces of the future. Introductory computer science courses offer a foundation for exploring specialized areas of computer science, such as computer literacy, key programming concepts and valuable technical and soft skills necessary for success in a constantly evolving digital world.

As a discipline, computer science is facing many pedagogical challenges (Gülbahar & Kalelioğlu, 2017). Despite the importance of computer skills, there remain students who lack digital literacy (Bresnihan et al., 2021; Daungtod, 2019), and this issue exists worldwide. Moreover, introductory computer science courses are known to have high drop-out rates (Long & Harrington, 2019). Another issue is the gender-based differences in students' perceptions and academic achievements (Alshammari, 2018; Finlayson, 2020). However, with effective pedagogical practices, and by taking advantage of modern technology, these challenges can be overcome.

Due to the increasing importance of online learning in higher education, and its several advantages and benefits, many universities offer introductory computer science courses online. This mode of course delivery has become increasingly popular as it provides a flexible way for college students to learn the essential concepts and skills of computer science from anywhere and at any time.

1.2 Purpose of the Study

Although online learning has been shown to be effective, there is a dearth of studies investigating the effectiveness of online introductory computer science courses for students, especially when the same assessments are used as for a traditional delivery mode. Moreover, it is unclear how students of different genders perform in online and traditional face-to-face courses if they are taught in the same way. Therefore, this study aims to expand the existing literature by

examining the academic achievement of students in an introductory computer science course through the evaluation of grades obtained from online and traditional face-to-face course sections. Additionally, the study aims to investigate any gender-based differences between the delivery modes.

2. Literature Review

2.1 Computer Science Education

Computer science education is a field of study that focuses on the pedagogical practices involved in teaching computing. The field has emerged from other disciplines, such as education, psychology, engineering, and computing (including computer science, information technology, information science, and computer engineering) (Lunn et al., 2021). The importance of computer science education extends beyond the field of computing as it enhances students' abilities to solve problems and be creative; it also supports project management, supervision and communication, and interpersonal interactions (Pappas et al., 2017). It is currently unclear which topics should be the focus in computer science classes, but such classes usually cover programming and computational thinking skills (Burbaitė et al., 2018). Regardless of the different topics covered in computer science classes, course content is usually taught using individual-centric pedagogy.

There are some organizations that have set standards for computing education and digital literacy, such as The Global Digital Literacy Council, The Computing Technology Industry Association (CompTIA), the International Society for Technology in Education (ISTE), and the National Coalition of Certification Centers (NC3). Moreover, SkillsUSA has set the neutral vendor standard called the IC3 Digital Literacy Certification (IC3) (Daungtod, 2019). Such standards can be used as key performance indicators (KPIs) for student performance levels.
Many instructional methods can be used to teach computer science which have been identified in the previous literature, such as Computer Science Unplugged (Sendurur, 2019), direct instruction, project and free work. Learning forms for computer science instruction can also vary and include subject-related, interdisciplinary, and self-directed learning approaches (Zendler & Reile, 2018), and the Mastery Learning Model (McCane et al., 2017). In their research, Hao et al. (2018) found that the implementation of active learning methods, such as team-based learning or problem-based learning, had significantly positive effects on students' learning outcomes. Other emerging methodologies in computer science education include parallel and distributed computing (PDC) (Ghafoor et al., 2019), creative computation (Xu et al., 2018), computational creativity exercises (Peteranetz et al., 2019), and the use of blended learning, which has been shown to be important for reducing the number of students who drop out of courses (Förster et al., 2021).

In terms of teaching methods, Khan et al. (2020) conducted a study on the effectiveness of inductive teaching on students' performance in introductory computer science courses and found this method to be significantly effective compared to deductive teaching. In their study, Malik and Zhu (2023) found that using project-based learning, hands-on activities, and flipped teaching increased students learning and motivation in introductory computer science courses.

2.2 Introductory Computer Science Courses

Introductory computer science courses are very important for undergraduate students. These courses usually cover different fundamental computer science topics, such as programming, computer literacy, algorithms, data structures, and computer systems. The main goal of such courses is to provide students with a strong foundation in computer science principles and techniques, enabling them to pursue more advanced topics in the field. They help students, regardless of their majors, keep up with the rapid changes in the workplace (Daungtod, 2019). Introductory computer science courses focus on knowledge acquisition and retention, training, and comprehension (Jiang et al., 2018; Hao et al., 2018). However, introductory courses are commonly perceived to be difficult (Long & Harrington, 2019; Narasareddygari et al., 2018) with a high number of students dropping out.

2.3 Challenges in Introductory Computer Courses

Introductory computer science courses can be considered in the context of several challenges. In general, introductory computer science courses are difficult for new students (Brown et al., 2018), especially for non-CS majors (Dawson et al., 2018; Pereira et al., 2018). However, research in this area is still limited in terms of providing recommendations to enhance their effectiveness.

Previous exposure to computer science can also determine student performance in introductory courses (Wilcox & Lionelle, 2018). The literature demonstrates that students with previous experience in computer science subject will perform better than inexperienced students (Alvarado et al., 2018; Wilcox & Lionelle, 2018). Introductory courses are often taught using a one-size-fits-all approach to all students regardless of their prior computing experience (Dawsonet al., 2018), and the literature indicates that combining novice students with students with prior programming experience may negatively influence the performance of novice students (Ott et al., 2018). Therefore, some educational institutions give students a placement test in computer programming and separate them into two groups according to their abilities, offering one course for students with prior programming experience and another for students without prior programming experience.

In terms of gender considerations, female students in many countries are known to underestimate their abilities and rate themselves lower than male students, despite the fact that they often perform better (Finlayson, 2020). Wilcox and Lionelle (2018) found that female students with prior experience in programming performed better than male students in all areas. Although this confirms a recognized issue, performance differences only occur in specific circumstances (McBroom et al., 2020).

Introductory computer science courses are known to have high drop-out rates across many different institutions and countries (Long & Harrington, 2019). There is a dearth of literature about effective and ineffective behaviors of students in introductory computer science courses (Robins, 2019). Bennedsen and Caspersen (2019) conducted a study in 2007 on failure rates in introductory computer science courses and repeated the same study in 2017. The findings revealed that the failure

rates had reduced slightly from (33%) in 2007 to (28%) in 2017. However, the difficulty of such courses and the drop-out rates still need to be addressed. It is reasonable to assume that students drop out of introductory courses due to poor performance in the courses, but this assumption ought to lead to a better understanding of the assessment strategies used in such courses. Adkins and Linville (2017) conducted a study on the relationship between the number of exams and students' grades in the courses. The study found no significant differences in students' performance, even though students wanted more exams to reduce exam anxiety.

Coffman-Wolph and Gray (2019) identified another challenge in the area of computer science learning, namely that students are unaware of what computer scientists do. Computer science education research most often relies on the assumption that all students have access to computers and other required tools (Moissinac et al., 2020). This assumption sometimes negatively impacts the validity of many studies conducted on the predictors of student performance in computer science courses.

Other challenges facing students taking introductory courses include the typical teaching–learning process utilized in the delivery of such courses, which makes the course content difficult to learn (Narasareddygari et al., 2018). An examination of the evolution of introductory computer science courses indicates significant changes in the topics from 1970 to 2018. Some topics have disappeared as they are no longer relevant, while new topics such as gender and diversity in programming have become a new trend (Becker & Quille, 2019).

There are many different designs for introductory courses, such as massive open online courses (MOOCs) (Duran et al., 2020), microcontroller unit (MCU)-based courses (Brown et al., 2018), online courses (Shirai et al., 2021), and traditional (face-to-face) courses. Regardless of the delivery mode, however, interaction among peers is an essential component of many active learning strategies (Hao et al., 2018). Moreover, it is necessary to identify which factors play a significant role in student performance in introductory computer science courses.
Many studies have listed factors related to student success in introductory courses, such as student motivation, attitudes, domain identification, (Alshammari, 2018) and self-efficacy (Lishinski & Yadav, 2021). Another factor that can help to determine student success is student–instructor interaction (Blaney & Stout, 2017).

2.4 Online Introductory Computer Science Courses

Most often, introductory computer science courses are designed to be taught through lectures, with student learning supported by labs. The results are not satisfactory—approximately 30% of students fail such courses, and the majority do not even acquire basic skills (Watson & Li, 2014). Current students need more active learning opportunities, and enhanced teaching strategies need to be adopted to meet their needs. However, enhancing introductory courses with active learning strategies is not easy. With the growth of online learning in the past few decades, many universities currently offer their introductory computer science courses online.

In Saudi Arabia, for example, many universities offer fully online introductory computer science courses. There are many examples of such courses being delivered in blended formats, or in traditional formats supported by online instruction materials (Mason et al., 2019; Kortsarts et al., 2020; Förster et al., 2021; Bigman et al., 2021). Zeuch et al. (2019) investigated the impact of supporting traditional face-to-face introductory computer science courses with online learning resources and they demonstrated a positive impact on students' performance. Moreover, Kanika et al. (2020) recommended that computer science students should access massive open online courses (MOOCs). Although students may perceive online learning to be helpful (Marasco et al., 2018), a recent study found no differences in student performance and perceptions between students in a fully online introductory computer science course when compared with a traditional face-to-face version of the same course (He, 2020). Both delivery modes have advantages for students' learning. While students benefit from face-to-face interaction and feedback, students in online introductory courses benefit from the flexibility offered by online learning (Srivatanakul, 2022). Despite this, teaching introductory computer science courses fully online can be difficult, with more attendant challenges than are encountered when teaching traditional face-to-face courses.

3. Research Questions

RQ1: Are there any statistically significant differences in student performance in introductory computer science courses between face-to-face and online delivery modes?
RQ2: Are there any statistically significant gender-based differences in student performance in introductory computer science courses based on course delivery mode?

4. Methods

In this quantitative study, the sample size included 600 first-year students in an introductory computer science course at a public university in Saudi Arabia. The participants were selected randomly from different sections. All sections were taught the same course content, either online or via traditional face-to-face delivery mode. It was a requirement for all students, across different colleges and majors, to take the introductory computer science course for a total of 15 weeks. The course focuses on a variety of topics, such as Microsoft Office, essentials of information technology, and fundamentals of operating systems. The students who were enrolled in online sections participated in synchronous learning during each lecture. Although there were two different delivery modes, all students took their mid-term examinations and final examinations face-to-face regardless of the way in which they had been taught.

This study analyzed students' performance as evaluated according to grades collected from different course sections. The data cleaning process included detecting and removing outliers from the dataset. As shown in Figure 1, the boxplots showed that there were no outliers after removing 11 observations from the dataset. Therefore, the final sample size becomes 589 first-year students.

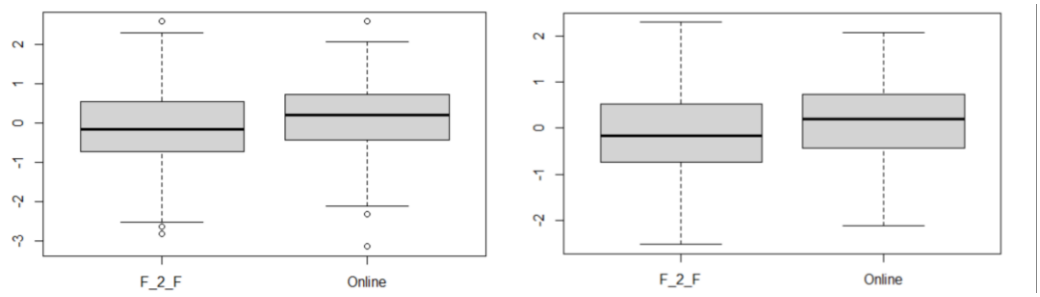

Figure 1: Boxplots of student performance before(left) and after(right) removing the outliers

5. Data Analysis and Results

5.1 Phase #1: Checking Assumptions

From the histogram (Figure 2), it is noticeable that the data follow a non-normal distribution; therefore, several normalizing transformation techniques were used, as shown in Table (1), and the best was selected based on the Pearson P/df value. The histogram in Figure 3 shows a normal distribution after implementing the normalizing transformation.

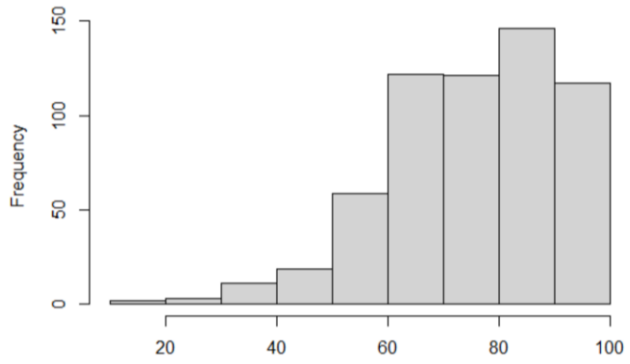

Figure 2: Histogram of student performance before data transformation

Table 1: Selecting the best normalizing transformation techniques

Method	Pearson P / df
arcsinh(x):	3.4202
Box-Cox:	2.1039
Center+scale:	2.5723
Exp(x):	57.9665
Log_b(x+a):	3.4202
orderNorm (ORQ):	1.5081
sqrt(x + a):	2.7566
Yeo-Johnson:	2.1442
Estimation method: Out-of-sample via CV with 10 folds and 5 repeat	

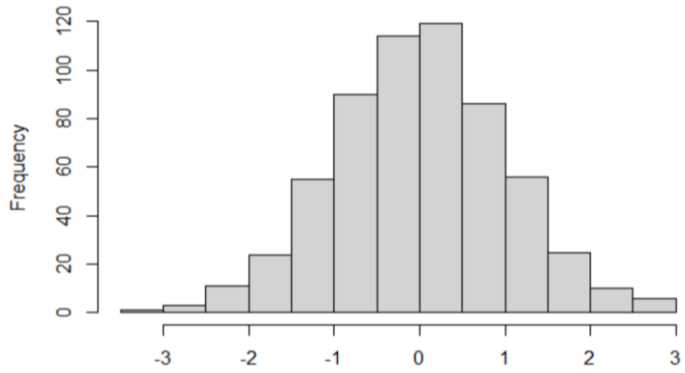

Figure 3: Histogram of student performance after data transformation

The qq plot and the density plot (Figure 4) support the validity of the normality assumption for these data. Homogeneity was assessed using the Bartlett test of homogeneity of variances to ascertain whether the variances were equal, and the null hypothesis was tested against the alternative hypothesis that the variances were not equal. Based on the results in Table 2, we accept the null hypothesis; it was, therefore, assumed that the populations were homoscedastic.

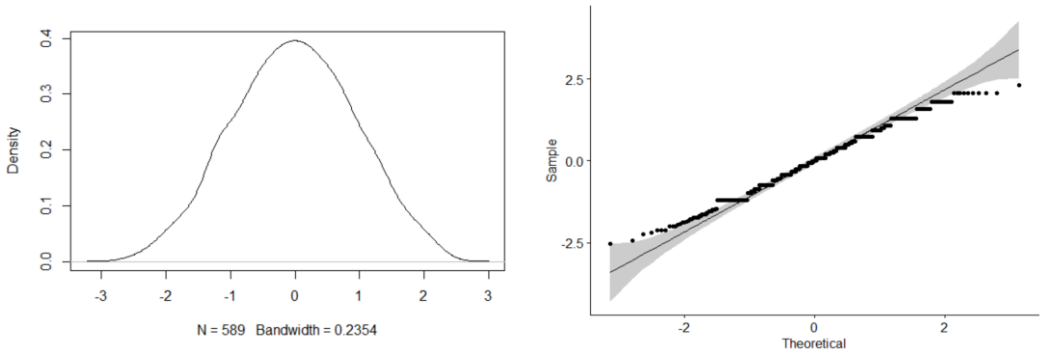

Figure 4: Checking the normality assumption for these data

Table 2: Bartlett test of homogeneity of variances

Bartlett test of homogeneity of variances		
Bartlett's K-squared	df	p-value
0.3702	1	0.5429

5.2 Phase #2: Answering the Research Questions

To answer the first research question, a Welch Two Sample T-test was performed to determine if there were significant differences in achievement in an introductory computer science course between students who were taught online and students who were taught face-to-face (F-2-F). The T-test was conducted to test the following hypotheses:

H_0: μOnline = μF-2-F

H_α: μOnline ≠ μF-2-F

From Table (3), the results reveal statistically significant differences between the groups (t = -3.7023, p value = 0.0002364). Therefore, the null hypothesis was rejected. From the means of the groups and the boxplot (Figure 5), there were

significant differences in achievement in an introductory computer science course between students who were taught online and students who were taught in a traditional face-to-face delivery mode, with the former students demonstrating higher achievement.

Table 3: Comparing student performance in the introductory computer science course: Face-to-Face vs. Online Delivery Modes

Welch Two Sample t-test			
	DF	**t**	**p-value**
Face-2-Face vs. Online Delivery Modes	524.48	-3.6405	0.0002991
	Sample Estimates		
	F-2-F		Online
	-0.1150707		0.1645384

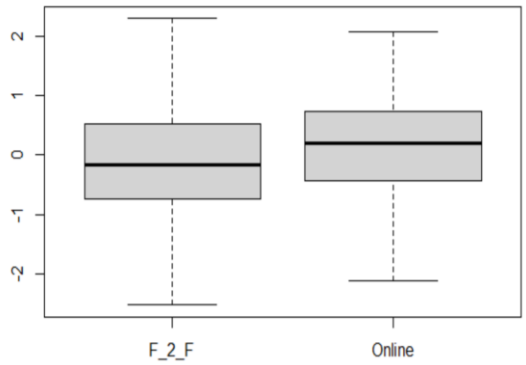

Figure 5: Boxplot chart of student performance in the introductory computer science course across the delivery modes

To answer the second research question, an Analysis of Variance (ANOVA) was performed. The boxplot (Figure 6) shows the gender-based differences in achievement in an introductory computer science course between students who were taught with two different delivery modes (i.e., face-to-face and online). The interaction plot (Figure 7) shows an interaction between gender and the mode of course delivery. Therefore, type III sums of squares were used to test the following hypotheses:

H_0: There is no interaction between course delivery mode and students' gender.
H_α: There is interaction between course delivery mode and students' gender.

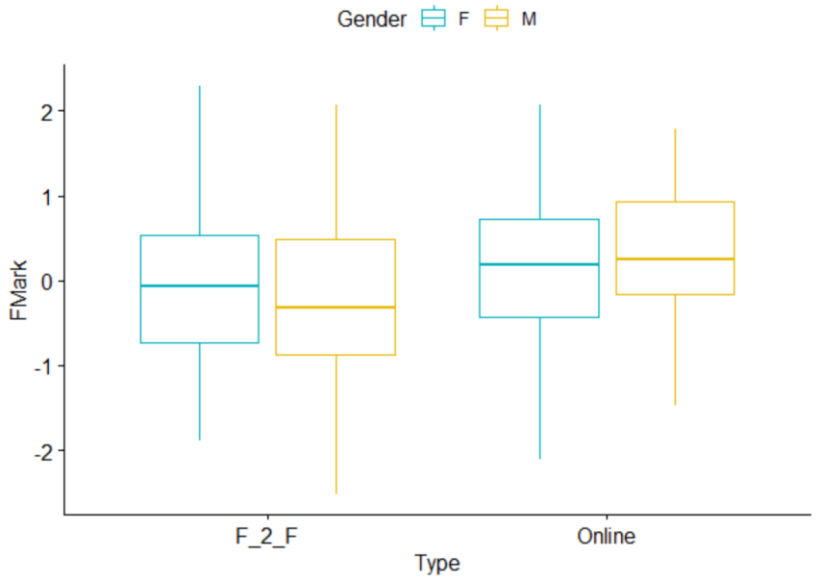

Figure 6: Boxplot chart of gender-based differences in student performance in the introductory computer science course across the delivery modes

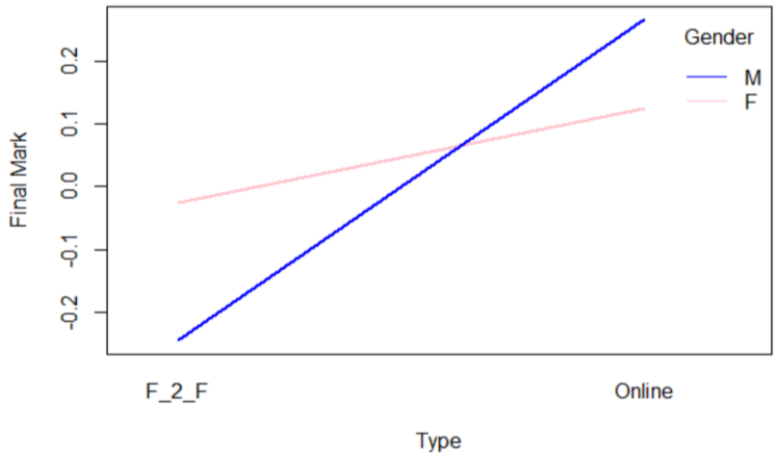

Figure 7: Interaction plot for gender-based differences in student performance across the delivery modes

To examine the gender-based differences in student performance based on the course delivery mode, ANOVA with Tukey adjustment was utilized for pairwise comparisons. Table 4 shows a significant interaction between student gender and mode of delivery.

Table 4: Analysis of variance (ANOVA) of student performance in introductory computer science courses

	Df	Sum SQ	F Value	Pr(>F)
Intercept	1	0.14	0.1692	0.68099
Type	1	2.14	2.5058	0.11397
Gender	1	4.15	4.8548	0.02796 *
Type:Gender	1	3.96	4.6373	0.03169 *
Residuals	585	499.8		

Table 5: Pairwise gender differences in student performance across delivery modes

	Tukey multiple comparisons of means 95% family-wise confidence level			
$Type				
Online-F_2_F	diff	lwr	upr	p adj
	0.2796091	0.1266337	0.4325844	0.0003586
Gender				
M-F	0.09063369	-0.2469699	0.06570248	0.2553289
Type:Gender				
Online:F-F_2_F:F	0.1511341	-0.09484989	0.39711811	0.3891363
F_2_F:M-F_2_F:F	-0.2199284	-0.47709432	0.03723757	0.1234874
Online:M-F_2_F:F	0.2927807	0.04485850	0.63041997	0.1152968
F_2_F:M-Online:F	-0.3710625	-0.64150753	-0.10061743	0.0024776*
Online:M-Online:F	0.1416466	-0.20621319	0.48950645	0.7205468
Online:M-F_2_F:M	0.5127091	0.15685429	0.86856393	0.0012852*

The Tukey multiple comparisons of means show significant differences in student performance between male students who were taught using the face-to-face mode and female students who were taught using the online mode. In this comparison, female students performed significantly better than male students. Although there are no significant differences between male and female students when the mode is not considered, the comparison indicates that male students who were taught online performed significantly better than male students who were taught face-to-face.

6. Discussion

There has been exceptional growth in online learning globally in recent years, and it has become the learning mode of choice for many students since it can allow some of the limitations of traditional face-to-face courses to be overcome. While there is evidence that there are no differences between students' perceptions of online introductory computer science courses and traditional face-to-face courses (He, 2020), the current enhances the existing body of research by analyzing the academic performance of students in an introductory computer science course. The analysis involved comparing the grades of students from both online and traditional face-to-face course sections. Moreover, the study adds to the literature by investigating gender-based differences in student performance between the two delivery modes when the assessment methods were the same.

In general, the current study confirms the findings of previous studies in indicating that there were no gender-based differences between students with regard to learning computer science (Alshammari, 2018; Drabowicz, 2014; Sáinz & López-Sáez, 2010). Since performance differences occur in specific circumstances (McBroom et al., 2020), this study adds to the literature by demonstrating that students who were taught introductory computer science online perform significantly better than those who were taught in traditional face-to-face delivery mode. With regard to gender-based differences, both female and male students in online introductory computer science course sections perform better than male students receiving instruction in a traditional face-to-face

delivery mode. Such findings suggest the need for an important shift towards leveraging the powerful features of online learning for both male and female students in introductory computer science courses.

7. Conclusion

In conclusion, online learning has become the norm for many of today's students taking introductory computer science courses. Many universities offer introductory computer science courses online, which raises the question of whether online learning has a significant impact on students' academic performance. The current study provided empirical evidence to support the effect of online learning on students' academic performance in introductory computer science courses. Moreover, the study analyzed the gender-based differences in student performance based on course delivery mode. The findings from this study provide insights into the effectiveness of online learning in introductory computer science courses and inform educators on the gender-based differences in students' performance across the delivery modes.

8. Future Work

The role that introductory computer science courses play in introducing students to the field is critical, although these courses are commonly perceived to be difficult. The current study yielded interesting findings about the differences in student performance between the two modes of delivery for the same course (i.e., face-to-face and online). A follow-up study is needed to analyze the factors that play a significant role in the effectiveness of online learning in introductory computer science courses and that can be used as predictors of student performance. Moreover, it is important to perform a qualitative study to identify which elements of introductory computer science courses result in them being perceived as difficult and therefore negatively affect male students' performance.

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