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Examination of Students' Academic Performance in Selected Mechanical Engineering Courses Prior-to-and-During COVID-19 Era

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Abstract

Advances in Information and Communications Technology (ICT) as well as the present challenges of COVID-19 have led to a new paradigm causing an absolute or partial transition from in-person classroom teaching-learning to online. There is little information available on research efforts that investigated the impact of an online learning approach on the academic performance of students in mechanical engineering-based courses. Therefore, the objective of this paper is the impact study of online learning mode as compared to in-person on academic performance of students in selected mechanical engineering courses in one of the Universities in South Pacific Islands prior-to-and-during COVID-19 Era. Data on grades obtained for 178 students that offered Fluid Mechanics, Thermodynamics, Heat Transfer, and Advanced Thermofluids (FTHA) courses were subjected to descriptive and non-parametric (Mann-Whitney and Kruskal-Wallis) statistical tests. Although descriptive analysis showed that online mode of instruction might influence a better academic performance in FTHA courses in comparison with in-person mode of instruction, the outcome of Mann-Whitney U and Kruskal-Wallis tests at specific p-values and corresponding z-values generally exhibited p-values higher than of 0.05, implying insignificant difference in performance between the two modes of learning investigated. Though the non-parametric statistical test results showed there was no significant difference in academic performance of students when online and in-person modes of learning were used, this, however, does not imply that a difference does not exist at all. Although the difference may be very trivial, descriptive analysis has shown that the online learning mode has at least exhibited better students' academic performance when compared to in-person. It can be inferred from the foregoing that the online learning mode does not yield a negative response in respect of the performance of students who offered all four mechanical engineering courses. Based on the findings of this study, online is considered a reliable alternative to in-person or at least a suitable complement to in-person in the in-person-online hybrid mode during the ongoing COVID-19 era and other inevitable constraints in the future.

Keywords:

COVID-19;
In-person-online;
FTHA Courses;
Academic Performance;
Non-parametric Statistical Tests.
Information and Communications Technology;
ICT.

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1- Introduction

Over the years, the traditional mode of teaching-learning in universities across the globe has been face-to-face [1-3]. Face-to-face mode of teaching-learning refers to a scenario where teaching and learning of course content occurs physically or via in-person thus providing opportunity for live interaction between teacher and students. However, new technologies and advances in Information and Communications Technology (ICT) have led to a new paradigm where knowledge delivery and classroom teaching-learning can be achieved online [4, 5]. The challenges associated with the

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emergence of COVID-19 have accelerated this shift, as educational institutions have moved to an online mode to explore ICT [6]. COVID-19, which was declared by the world health organization in January 2020 as an outbreak, has since made online education inevitable [7-16].

In this COVID-19 era, the online mode of education is considered quintessential as an alternative means for facilitating teaching and learning of engineering-based course content. Engineering is one of the key Science, Technology, Engineering, and Mathematics (STEM) fields that focuses on design, fabrication, hands-on, and Project Based Learning (PBL) activities, thus developing the critical thinking, problem solving, and creativity of learners [9, 17]. Many research efforts on the influence of the online mode of teaching and learning on the attitude, readiness, and academic performance of students in STEM courses have been carried out. While a few authors' findings indicated a negative influence of the online learning mode on engineering students' readiness for academic performance and this was largely attributed to poor quality or ineffective use of ICT, several other authors reported a beneficial influence of the online learning mode in this regard.

For instance, the impact of online pedagogy on the academic performance in a mechanics of materials engineering course was investigated [18]. The author found that the online mode adversely affected the performance of students when compared to the category of students taught using the offline mode. Notwithstanding, the use of online pedagogy showed promise for high-performing students. An observational investigation on the influence of the online mode on engineering education for 627 students was conducted by Asgari et al. (2021) [17]. Findings show that the use of online mode can adversely affect the learning outcome of engineering education due to associated problems of privacy and security, poor funding, and technical know-how in handling online resources. It was reported that a significant number of students indicated poor class engagement and fatigue, often set in multiple zoom-based online sessions. Baltà-Salvador et al. (2021) [10] investigated the engineering students' online experience and emotional effect during COVID-19. It was found that the poor quality of their online education during the pandemic affected their psyche for online education.

Although very few authors' studies showed that online mode had negative outcome effects as indicated in the preceding paragraph, several authors have found that the use of online mode for teaching and learning in the delivery of engineering courses' content positively influences students' attitude, readiness, and academic performance. Some of the findings of the authors are summarized in this paragraph. For instance, student performance in engineering drawing using an online experiential learning mode was studied and compared with that of in-class by Wang et al. (2018) [19], Findings obtained by the authors showed that there was no significant difference between the two modes of learning based on the academic performance of students in the taught engineering drawing content. Although the authors found no significant improvement in the use of the Internet, findings showed that it did not negatively influence academic performance. In the work of Naji et al. (2020) [8], the initial readiness of engineering students to transit from in-person mode to an emergency online approach was examined. The outcome of their study revealed that courses taught using the PBL technique yielded students' better readiness for online learning mode.

In Darius et al. (2021) [20], an engineering course was among the courses considered in an attempt to study the effectiveness of teaching-learning using online mode. It was reported by the authors that online methods using animations, digital collaborations, and videos enhanced the effectiveness of teaching-learning in the courses in the study. The authors observed that the online teaching mode enabled students to enjoy the benefits of access to student versions of software, robust student-lecturer interactions, and a conducive atmosphere for receiving lectures. Based on the aftermath effect of the COVD-19 pandemic, the influence of a sudden transition to an online mode of teaching-learning on the performance of mechanical engineering students (with a specialization in manufacturing technology) was investigated by Grodotzki et al. (2021) [21]. The outcome of the study showed that the shift to an online learning style did not negatively influence the academic performance of the students. Moreover, Thurab-Nkhosi et al. (2021) [22] studied the impact of emergency remote teaching on blended engineering courses. The outcome showed the convenience pace of learning and accessibility to lecture materials, which are associated with online teaching and which positively influence students' performance. In Yu et al. (2022) [23], the use of online and offline modes of learning for undergraduate students in the safety engineering major was studied. Although it was found that online teaching activities can promote students' interest, attention, and class participation at a given stage of classroom teaching, the adoption of an online-offline blended approach yielded a more student-centered teaching effect.

As indicated by various authors in the preceding, the effects of the online teaching-learning mode on the attitude, readiness, and academic performance of engineering students are mixed. As the pandemic era is still on course, there is a need for many more studies in this regard in order to acquire more data that can help make informed decisions on effective planning and best practices in the use of online teaching-learning mode in engineering courses [17]. Therefore, the focus of this paper is to study the impact of online learning mode as compared to in-person on the academic performance of students in selected mechanical engineering courses before and during the COVID-19 era. This study is motivated by the paucity of information on research efforts that investigated the influence of an online learning approach on the academic performance of students in mechanical engineering-based courses.

2- Methodology

Data on performances of students in four mechanical engineering courses in one of the Universities in South Pacific Islands were obtained. The data were first subjected to descriptive analysis and measure of central tendency statistical tests. Non-parametric analyses (using Mann-Whitney and the Kruskal-Wallis tests) were carried out after a preliminary normality test indicated the non-suitability of parametric tests. Data on grades were obtained for 178 students that offered the FTHA courses. All the statistical analyses carried out were based on the following four research questions drawn for this study:

1) Research Question 1(RQ1): Does mode of instruction significantly influence academic performance of engineering students in Fluid Mechanics?
2) Research Question 2(RQ2): Does mode of instruction significantly influence academic performance of engineering students in Thermodynamics?
3) Research Question 3(RQ3): Does mode of instruction significantly influence academic performance of engineering students in Heat Transfer?
4) Research Question 4(RQ4): Does mode of instruction significantly influence academic performance of engineering students in Advanced Thermofluids?

The methodology used for this study is described in Figure 1, which gives step by step approach of the research in terms of flowchart.

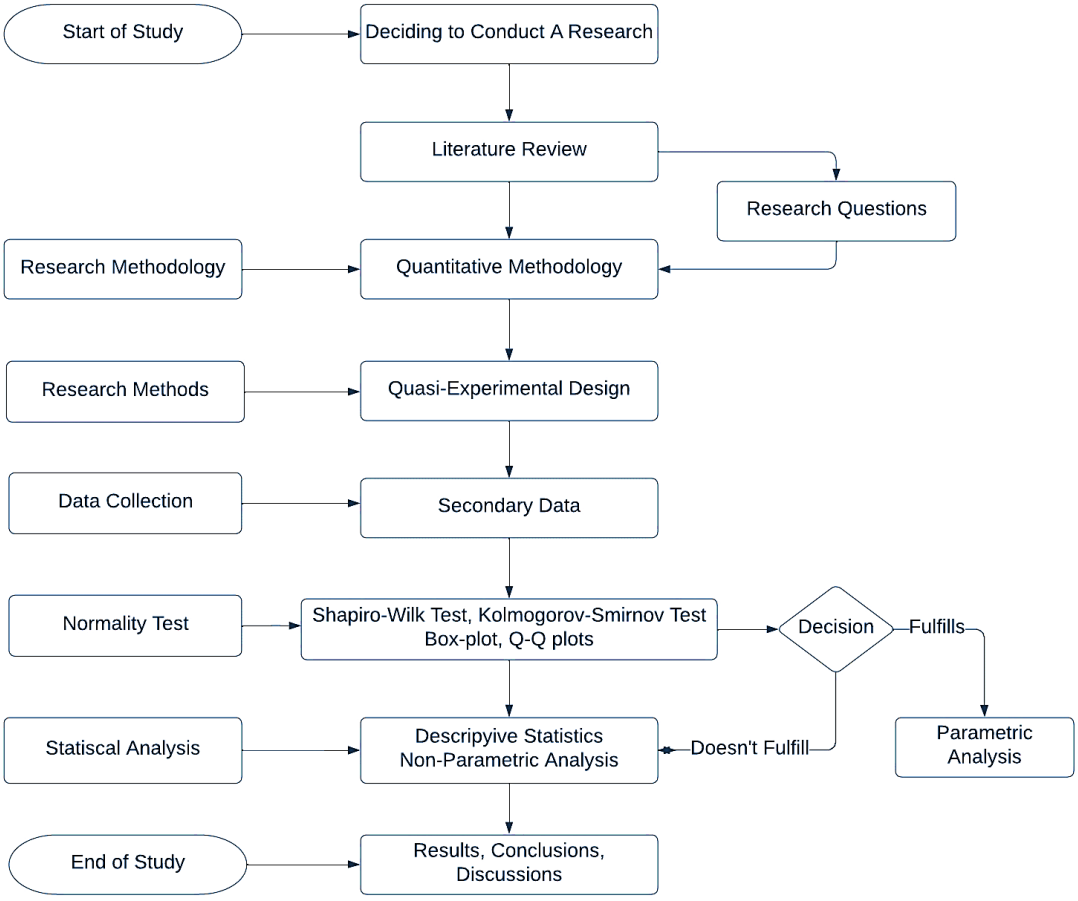

Figure 1. Research methodology flowchart

3- Results and Discussion

Results are presented and discussed based on the four research questions drawn for this study.

3-1- Descriptive Statistics Results

RQ1: Does mode of instruction significantly influence academic performance of engineering students in Fluid Mechanics?

Figure 2 suggests that online mode of instruction might predict better academic performance than in-person mode of instruction in the Fluid Mechanics course. Also, considering the modal score as a measure of central tendency, the modal

grade for online learning is B+, while that of in-person learning is C+. The foregoing is in agreement with findings of some authors such as [8, 9], The outcome of this descriptive analysis perhaps implies that digital mode of instruction in the Fluid Mechanics course showed potential for better academic performance influence in comparison to in-person learning.

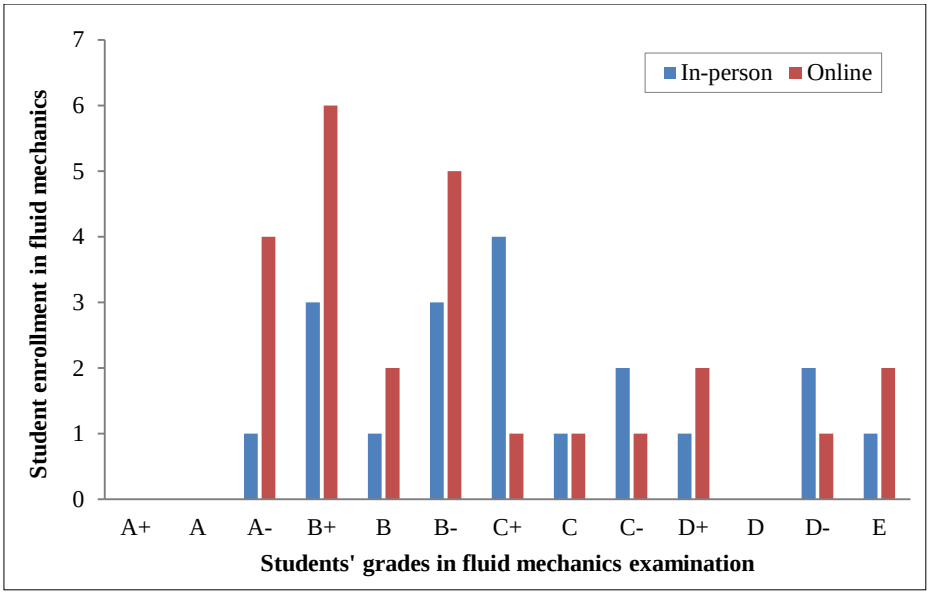

Figure 2. Grade distribution in Fluid Mechanics course in virtual and in-person learning

Figure 3 shows that students performed best in the years 2020 and 2021. It can also be deduced from Figure 3 that the least performances of students in Fluid Mechanics course was in 2018. Years 2020 and 2021 are in the era of COVID-19 whereas 2018 is a pre-COVID-19 era. The results obtained in the foregoing are comparable with the findings of [9, 22]. Higher performances of students in Fluid Mechanics in the years 2020 and 2021 is a further corroboration to the potential of online mode for enhancing students' academic performance when compared to offline mode

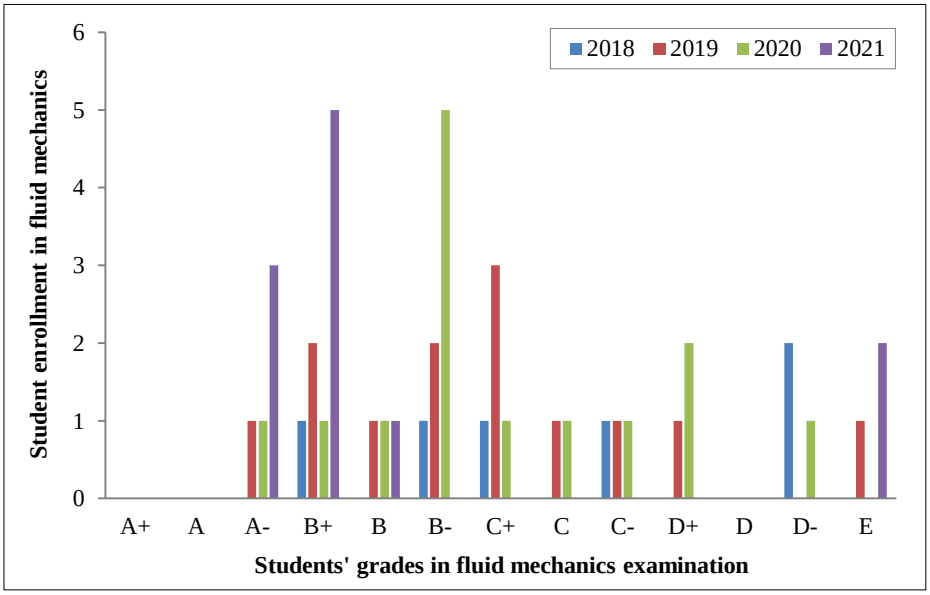

Figure 3. Grade distribution in Fluid Mechanics course across 4 years

RQ2: Does mode of instruction significantly influence academic performance of engineering students in Thermodynamics?

Figure 4 shows that online mode of instruction might influence a better academic performance than in-person mode of instruction. Also, considering the modal score as a measure of central tendency, the modal grade for online learning is B, while that of in-person learning is between B and C. The findings of [8, 20, 22] are in conformity with results obtained on the influence of online mode on the grades distribution in Thermodynamics course. The obtained descriptive analysis results obtained here may indicate a better potential of E-learning instructional mode for improved academic performance effects on students who offered Thermodynamics when compared to face-to-face mode.

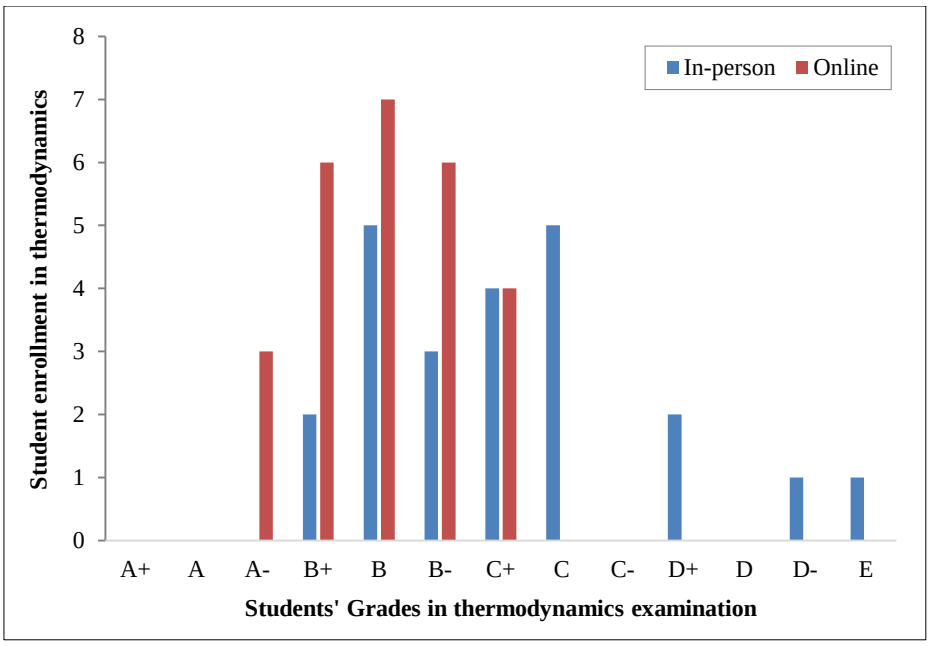

Figure 4. Grade distribution in Thermodynamics course in virtual and in-person learning

It is shown in Figure 5 that students who offered Thermodynamics course performed better in the years 2020 and 2021 during the COVID-19 era when online learning was the primary mode of instruction. It can also be implied from Figure 5 that the least performances of students in Thermodynamic course was in 2018. The results obtained based on the foregoing descriptive analysis agrees with some authors' findings reported in the literature [20, 22, 23]. Therefore, better academic performance of students in Thermodynamics in the years 2020 and 2021 may also indicate the potential of online mode for enriching students' academic performance when compared to in-person mode in the year 2018, a pre-COVID-19 era.

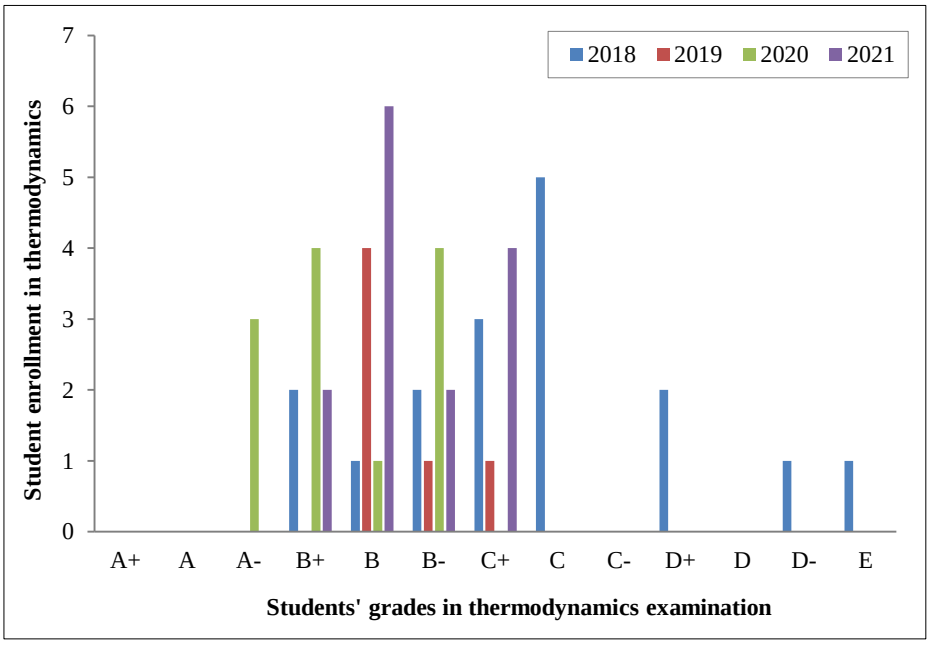

Figure 5. Grade distribution in Thermodynamics course across 4 years

RQ3: Does mode of instruction significantly influence academic performance of engineering students in Heat Transfer course?

In Figure 6, the online mode of instruction exhibits a higher academic performance than in-person mode of instruction. The modal grade for online learning is B, while that of in-person learning is C+. The results obtained from the descriptive analysis carried out was in agreement with the literature [8, 9, 22]. The foregoing outcome is perhaps an indication that electronic medium of learning has a more promising academic outcome in Heat transfer course in comparison to the use of in-person mode.

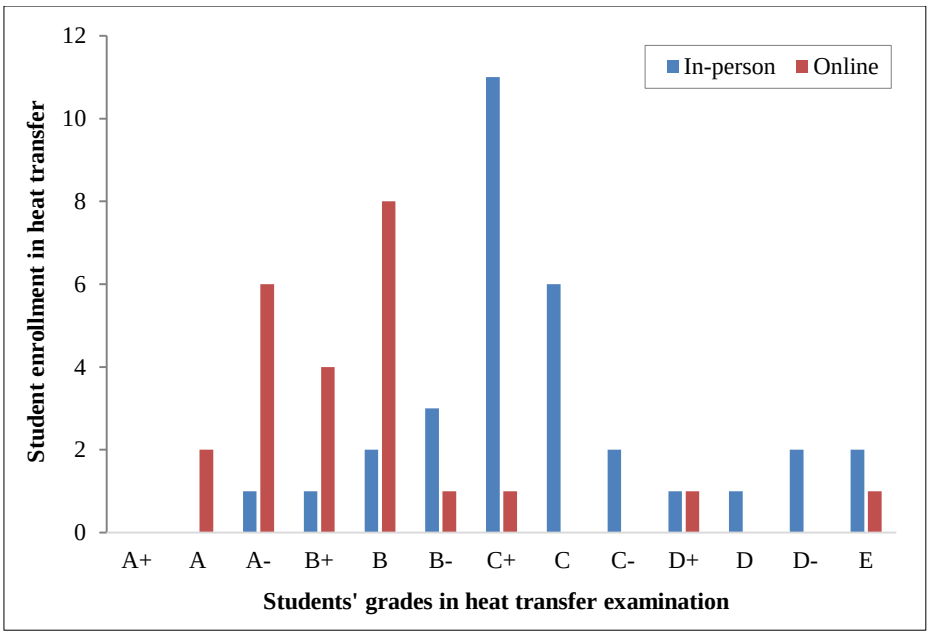

Figure 6. Grade distribution in Heat Transfer course in virtual and in-person learning

Moreover, Figure 7 shows that higher performance of students in Heat Transfer was obtained in the years 2020 and 2021 during the COVID-19 when online learning was the mode of instruction. It was also shown that the least performance of students in Heat transfer course was obtained in 2018. With reference to the low academic performance obtained in the year 2018, a pre-COVID-19 era. the use of virtual mode for learning was shown to exhibit a potential for better academic performance impact on students who offered Heat Transfer when compared to in-person learning mode. The positive impacts of digital mode of instruction was well corroborated in the works of Thurab-Nkhosi et al. (2021) and Yu et al. (2022) [22, 23].

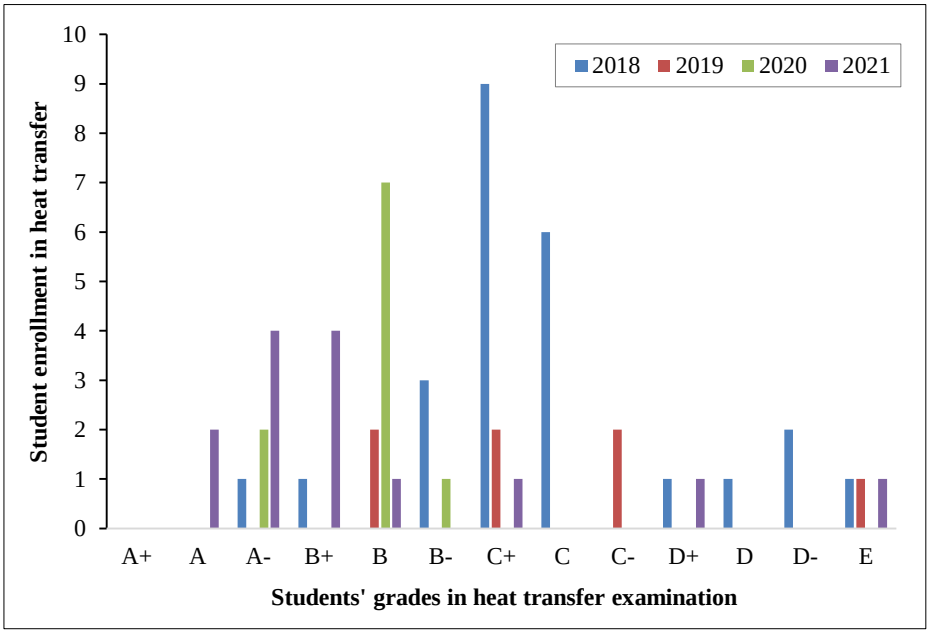

Figure 7. Grade distribution in Heat Transfer course across 4 years

RQ4: Does mode of instruction significantly influence academic performance of engineering students in Advanced Thermofluids?

Although the non-availability of year 2018 data on students' performance in Advanced Thermofluids as shown in Figure 8 may affect the confidence level in making overall judgment on the potential influence of online learning mode as compared to offline, the descriptive analysis of results illustrated in Figure 8 notwithstanding shows the betterment of virtual learning mode as against in-person approach. The foregoing results are comparable with the results obtained from many authors such as [9, 20, 23] on the beneficial influence of virtual mode of instructions.

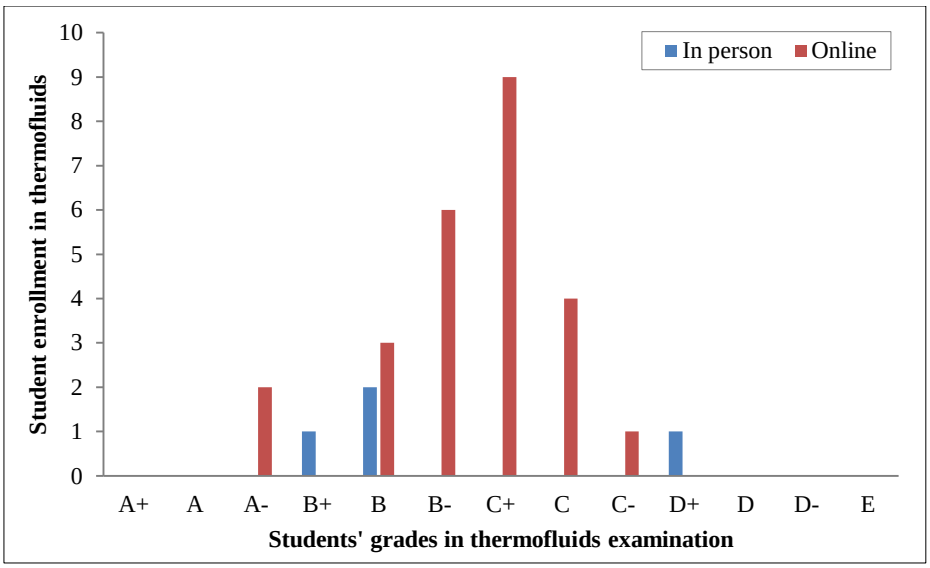

Figure 8. Grade distribution in Advanced Thermofluids course in virtual and in-person learning

Again, it can be seen in Figure 9 that there was no available data for students' performance in Advanced Thermofluids in the year 2018. Although the reason for lack of access to 2018 data was not ascertained as at the time of data collection, it may not be unconnected with the deferment of the course to subsequent year perhaps due to the unavailability of the course lecturer for the year under consideration. However, results obtained from descriptive analysis showed better performance in Advanced Thermofluids in the years 2020 and 2021 during COVID-19 era when online learning mode was used in comparison to year 2019 when the mode of instruction was wholly in-person. The deduction that can be made from the foregoing results are well reflected in the works of some authors [8, 20, 22, 23]. Consequently, the potential better impact of web-based learning mode on academic performance of mechanical engineering students as compared to offline learning mode is again sustained in Advanced Thermofluids course.

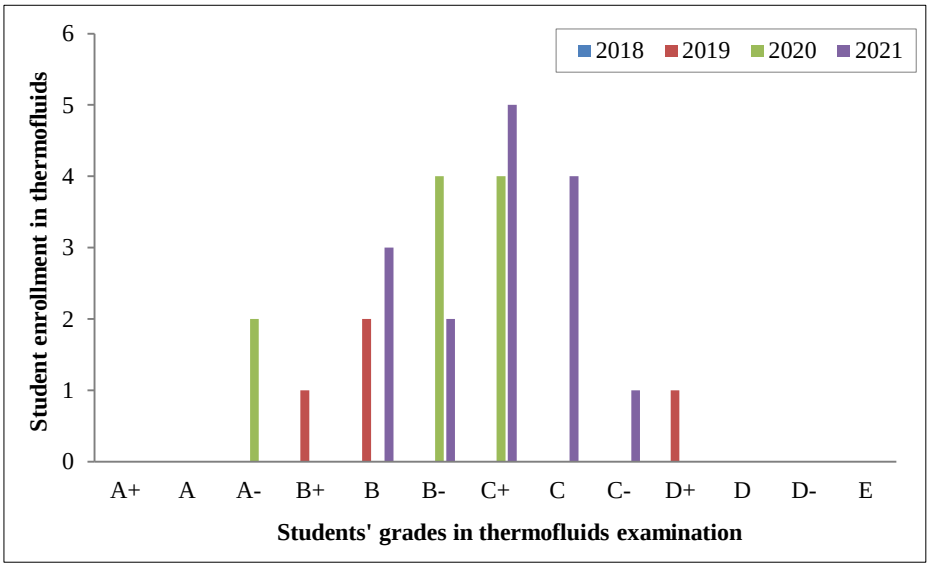

Figure 9. Grade distribution in Advanced Thermofluids course across 4 years

3-2- Normality Tests Results (Preliminary Analysis Results on the Suitability of Parametric/Non-parametric Test)

RQ1: Does mode of instruction significantly influence academic performance of engineering students in Fluid Mechanics?

The Kolmogorov-Smirnov test of normality at t (26) = 0.242, p value < 0.001 which is less than the p value= 0.05 yielded a non-significant result and therefore violates normality assumption. Also, the Shapiro-Wilk test of normality conducted at t (26) = 0.860 yielded results with p value = 0.002. Since the obtained p value is less than 0.05, it can be deduced that the outcome is non-significant. The foregoing also implies violation of normality assumption. The normality plots in Figures 10 and 11 (the Q-Q and box plots) also show evidence of violation of normality assumption. Hence, non-parametric test was used to analyze the obtained data.

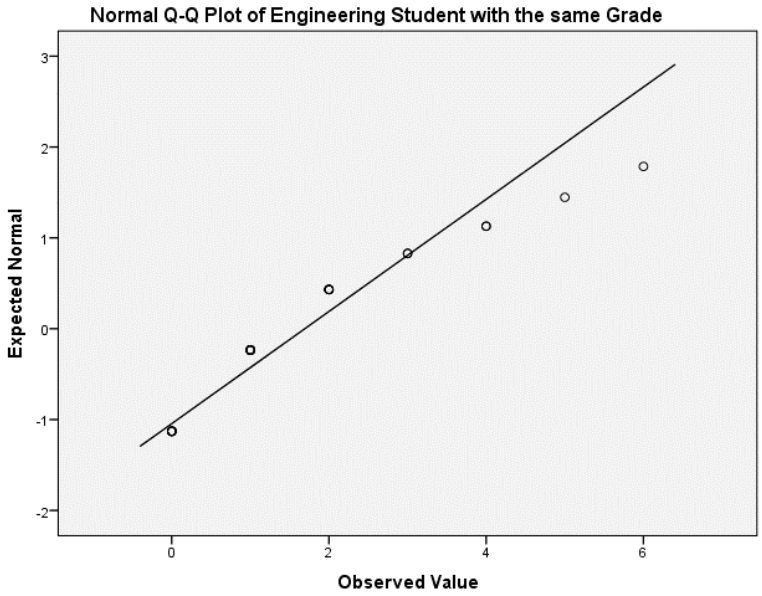

Figure 10. **Q-Q plots test for normality assumption**

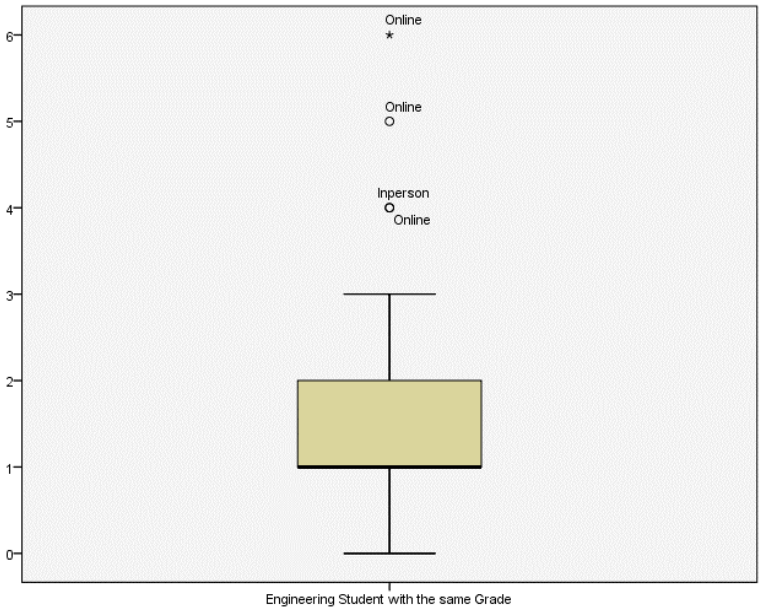

Figure 11. **Box plots test for normality assumption**

RQ2: Does mode of instruction significantly influence academic performance of engineering students in Thermodynamics?

The Kolmogorov-Smirnov test of normality at t (26) = 0.288, p value < 0.001 which is less the than p value= 0.05 yielded a non-significant result and therefore violates normality assumption. Also, the Shapiro-Wilk test of normality conducted at t (26) = 0.787 yielded results with p value < 0.001. Since the obtained p value is less than 0.05, it can be deduced that the outcome is non-significant. The foregoing also implies violation of normality assumption. The normality plots in Figures 12 and 13 (the Q-Q and box plots) also show evidence of violation of normality assumption. Hence, non-parametric test was used to analyze the obtained data.

RQ3: Does mode of instruction significantly influence academic performance of engineering students in Heat Transfer course?

The Kolmogorov-Smirnov test of normality at t (26) = 0.292, p value < 0.001 which is less than p value= 0.05 yielded a non-significant result and therefore violates normality assumption. Also, the Shapiro-Wilk test of normality conducted at t (26) = 0.292 yielded results with p value < 0.001. Since the obtained p value is less than 0.05, it can be deduced that the outcome is non-significant. The foregoing also implies violation of normality assumption. The normality plots similar to the Q-Q plots in Figures 10 and 12 and box plots in Figures 11 and 13 also show evidence of violation of normality assumption. Hence, non-parametric test was used to analyze the obtained data.

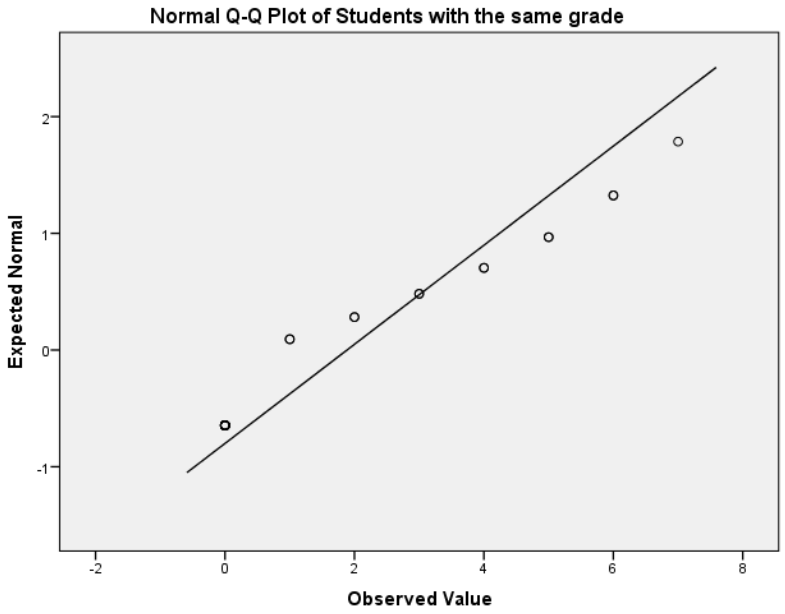

Figure 12. **Q-Q plots test for normality assumption**

Figure 13. **Box plots test for normality assumption**

RQ4: Does mode of instruction significantly influence academic performance of engineering students in Advanced Thermofluids?

The Kolmogorov-Smirnov test of normality at t (26) = 0.348, p value < 0.001 which is less the than p value= 0.05 yielded a non-significant result and therefore violates normality assumption. Also, the Shapiro-Wilk test of normality conducted at t (26) = 0.592 yielded results with p value < 0.001. Since the obtained p value is less than 0.05, it can be deduced that the outcome is non-significant. The foregoing also implies violation of normality assumption. The normality plots similar to the Q-Q plots in Figures 10 and 12 and box plots in Figures 11 and 13 also show evidence of violation of normality assumption. Hence, non-parametric test was used to analyze the obtained data.

3-3- Non-parametric Statistical Test Results

1. Independent-Samples Mann-Whitney U Test

Sequel to the violation of normality assumption, a non-parametric Mann-Whitney U tests were conducted to determine if there is a significant or insignificant difference in academic performance of students in mechanical engineering courses when online mode of instruction was used as compared to in-person mode. Table 1 is a summary of the outcome of Mann-Whitney U statistical tests carried out.

Table 1. Mann-Whitney U tests for academic performance of students in four courses

	Fluid Mechanics	Thermodynamics	Heat Transfer	Advanced Thermofluids
Mann-Whitney U	92.000	79.000	63.500	110.500
Wilcoxon W	183.000	170.000	154.500	201.500
Test Statistic	92.000	79.000	63.500	110.500
Standard Error	18.901	18.225	18.956	16.538
Standardized Test Statistic	0.397	-0.302	-1.108	1.572
Asymptotic Sig. (2-sided test)	0.692	0.763	0.268	0.116
Exact Sig. (2-sided test)	0.724	0.801	0.287	0.186

RQ1: Does mode of instruction significantly influence academic performance of engineering students in Fluid Mechanics?

From Table 1, the Mann-Whitney U test with p-value of 0.724 at z-value of 0.397, which is greater than p-value of 0.05 indicates that mode of instruction whether online or in-person does not predict differently the academic performance of engineering students in Fluid Mechanics course. The outcome of this study is in agreement with the works of [5, 25]. The obtained Mann-Whitney U value was 92.000. Even though the outcome of the non-parametric statistical tests showed insignificant difference, the data obtained is suggesting that the virtual mode of instruction do not pose adverse effect on students' academic performance in Fluid Mechanics.

RQ2: Does mode of instruction significantly influence academic performance of engineering students in Thermodynamics?

From Table 1, the Mann-Whitney U test with p-value of 0.801 at z-value of -0.302, which is greater than p-value of 0.05 indicates that mode of instruction whether online or in-person does not affect the academic performance of engineering students in Thermodynamics course, which conforms with the reported findings of [19, 21]. The Mann-Whitney U value obtained was 79.00. It can however be inferred from the results that the web-based learning mode can be a reliable alternative or at least a complement to in-person mode of learning in Thermodynamics course.

RQ3: Does mode of instruction significantly influence academic performance of engineering students in Heat Transfer course?

From Table 1, the Mann-Whitney U test with p-value of 0.287 at z-value of -1.108, which is greater than p-value of 0.05 indicates that mode of instruction whether online or in-person does not affect the academic performance of engineering students in Heat Transfer course. The Mann-Whitney U value obtained was 63.5. There was no evidence from the non-parametric statistical tests that suggested that the online mode of learning can negatively affect the students' academic performance in Heat Transfer course. The deduction made from the foregoing results in respect of Heat Transfer course are in agreement with some reported works [19, 21, 25]. Consequently, the online learning mode is a suitable substitute or complement to in-person teaching mode for Heat Transfer course in the ongoing COVID-19 pandemic or similar crisis that may invoke restrictions.

RQ4: Does mode of instruction significantly influence academic performance of engineering students in Advanced Thermofluids?

From Table 1, the Mann-Whitney U test with p-value of 0.186 at z-value of 1.572, which is greater than p-value of 0.05 indicates that mode of instruction whether online or in-person does not affect the academic performance of engineering students in Advanced Thermofluids course. The Mann-Whitney U value obtained was 110.50. Although the result of Mann-Whitney U tests showed there was no significant difference between students' academic performance in Advanced Thermofluids when online learning mode was used in comparison to the face-to-face which is in agreement with some other similar research works such as [5, 19, 21] , the implication of the foregoing results is that online learning mode will be a good alternative or complement to in-person mode at least in order to sustain the students' academic performance level obtained in wholly offline mode.

2. Independent-Samples Kruskal-Wallis Test

To further elucidate the academic performance of the students' prior and during COVID-19 era, independent-samples Kruskal-Wallis test was carried out. This test was aimed to evaluate if there is a significant difference in academic performances of engineering students across the 4 years for the selected mechanical engineering courses considered in this study and this is shown in Table 2.

Table 2. Kruskal-Wallis tests for academic performance of students in four courses

	Fluid Mechanics	Thermodynamics	Heat Transfer	Advanced Thermofluids
Test Statistic	4.196	3.735	5.636	6.020
Degree Of Freedom	3	3	3	3
Asymptotic Sig. (2-sided test)	0.241	0.292	0.131	0.111

RQ1: Does mode of instruction significantly influence academic performance of engineering students in Fluid Mechanics?

From Table 2, the Kruskal-Wallis test with p-value of 0.241 at z-value of 4.196, which is greater than p-value of 0.05 indicates that the academic performance of engineering students in Fluid Mechanics course are not significantly different from one another across the years. The outcome obtained based on non-parametric Kruskal-Wallis tests showed a perfect corroboration of the result obtained using Mann-Whitney U tests and the implications are in agreement with [21, 25]. Therefore, there is evidence to support that online learning mode is a suitable substitute or complement to in-person teaching mode for Fluid Mechanics course especially when restrictions of people are inevitable.

RQ2: Does mode of instruction significantly influence academic performance of engineering students in Thermodynamics?

From Table 2, the Kruskal-Wallis test with p-value of 0.292 at z-value of 3.735, which is greater than p-value of 0.05 indicates that the academic performance of engineering students in Thermodynamics course are not significantly different from one another across the years. The outcome of this study is in conformity with similar research works [5, 19]. The data obtained based on Kruskal-Wallis tests is an affirmation of Mann-Whitney U tests result. It can be inferred that online learning mode do not yield negative response in respect of the performance of students who offered Thermodynamics thus making it a reliable alternative learning mode to in-person approach.

RQ3: Does mode of instruction significantly influence academic performance of engineering students in Heat Transfer course?

From Table 2, the Kruskal-Wallis test with a p-value of 0.131 at a z-value of 5.636, which is greater than the p-value of 0.05 indicates that the academic performance of engineering students in heat transfer courses is not significantly different from one another across the years. The foregoing is in agreement with the reported work of Wang et al. (2018) [19]. Again, the implication of Kruskal-Wallis test results is in perfect agreement with the outcome of Mann-Whitney U tests. It can therefore be deduced from Kruskal-Wallis statistical tests that the online learning mode is a reliable substitute or complement to the in-person teaching mode for the Heat Transfer course.

RQ4: Does mode of instruction significantly influence academic performance of engineering students in Advanced Thermofluids?

From Table 2, the Kruskal-Wallis test with a p-value of 0.111 at a z-value of 6.020, which is greater than the p-value of 0.05 indicates that the academic performance of engineering students in the Advanced Thermofluids course is not significantly different from one another across the years. The implication of results obtained using Kruskal-Wallis and Mann-Whitney U statistical tests is in complete agreement, which also conforms with the findings of Ghorbani et al. (2020) [25] and Setiyawan (2019) [30]. Sequel to the fact that there is no evidence of findings suggesting an adverse effect of the online learning mode on the academic performance of students who offered Advanced Thermofluids, it is therefore a reliable alternative to in-person or online-offline hybrid mode during inevitable constraints.

4- Discussion

According to the descriptive analysis results shown in Figures 1–8, students performed well in FTHA courses used as case studies in the years 2020 and 2021 when online learning was the mode of instruction. The academic performance of the students in the years 2018 and 2019, a pre-COVID-19 era, was low when an in-person mode of learning was used. Although there is no available data on students' performance in Advanced Thermofluids in the year 2018, the outcome of descriptive analysis carried out on 2019 data notwithstanding, showed low academic performance when in-person learning was used. Generally, descriptive analysis has shown that the online learning mode yielded better academic performance for students when compared to the in-person mode in respect of all the four mechanical engineering courses considered in this study. The beneficial influence of the online learning mode, deduced based on the results obtained from the preliminary descriptive analysis carried out, was similarly reflected in the findings of many authors [8, 9, 20–23]. Relying on the preliminary outcomes acquired from the descriptive analysis used in this study, the perceived positive impacts of the online learning mode can be attributed to some of its associated advantages. During the years 2019 and 2020, when the online learning approach was deployed in the teaching of the four mechanical engineering courses (Fluid Mechanics, Thermodynamics, Heat Transfer, and Advanced Thermofluids) considered in this study, a variety of online

platforms and electronic tools such as animations, videos, and free software applications were used to enrich the teaching. The adopted online platforms and electronic tools enhanced the robustness of student-lecturer interactions and created a more conducive atmosphere for both teachers and learners [20], thus facilitating better students' academic performance [24]. The online mode promotes students' interest, attention, class participation, and retention [23] and provides an opportunity for students' pace of learning. Lifelong learning and easy access to lecture materials via a learning management system have further contributed to the better academic performance of students [6, 22].

Data obtained from the Kolmogorov-Smirnov statistical tests showed that the normality condition was violated. Hence, the choice of the non-parametric statistical tests using Mann-Whitney U and Kruskal-Wallis tests. The tests at specific p-values and corresponding z-values generally exhibited p-values higher than 0.05. The foregoing implies that there is no significant difference in the academic performance of students in the four courses, whether the mode of instruction was online or in-person. The outcome of this study is in agreement with many other similar research studies [5, 19, 21, 25].

Although the non-parametric statistical test results showed there was no significant difference in academic performance of students in the four mechanical engineering courses when online and in-person modes of learning were used, this does not imply that a difference does not exist at all. This assertion has been reflected in the preliminary results of this study using descriptive analysis. Although the difference may be very small, descriptive analysis has shown that the online learning mode has at least exhibited better students' academic performance when compared to in-person.

It can be inferred from the foregoing that the web-based learning mode does not yield negative response in respect of the performance of students who offered all the four mechanical engineering courses, thus making it a reliable alternative to in-person or at least a suitable complement to in-person in the online-offline hybrid mode during the ongoing COVID-19 era and other inevitable constraints in the future. Self-regulation, flexibility, and continuity in learning, which have been identified as key merits of the online learning mode [6], confirm the choice of the online mode as a suitable alternative [26-28] or complement to in-person learning in the online-offline hybrid mode, otherwise known as the blended learning mode, which has been advocated in a number of previous studies [23, 29-36].

5- Conclusions

The dearth of information on documented research efforts on the effects of an online learning approach on students' academic performance in selected mechanical engineering courses (Fluid Mechanics, Thermodynamics, Heat Transfer, and Advanced Thermofluids) abbreviated as FTHA, was the motivation for the present studies. In this work, the comparative impact of online and in-person learning modes on the academic performance of students taking FTHA courses in one of the universities in the South Pacific Islands prior-to-and-during the COVID-19 era was investigated using a non-parametric statistical analysis. With regard to the findings of this study, the following conclusions are drawn:

1. Relying on the outcome of descriptive analysis, there was evidence suggesting that the online mode of instruction might influence better academic performance in FTHA courses in comparison with an in-person instructional approach.
2. The Mann-Whitney and the Kruskal-Wallis tests did not show evidence of better students' academic performance with the use of online learning mode. Notwithstanding, it can be inferred that the online learning mode does not yield a negative response in respect of the performance of students who offered all four mechanical engineering courses. Therefore, online is considered a reliable alternative to in-person or at least a suitable complement to in-person in the in-person-online blended mode during the ongoing COVID-19 era and other pandemic or inevitable constraints in the future.
3. The obtained data and overall outcome of this study can be utilized by the administrators of engineering colleges and education policymakers of universities for planning towards the development of improved digital infrastructures and effective strategies on adoption of wholly online or in-person-online blended modes for delivery of learning activities.

It is worth mentioning that the scope of this study was limited to only four mechanical engineering courses (Fluid Mechanics, Thermodynamics, Heat Transfer, and Advanced Thermofluids). This is not surprising since, as at the time of this study, there was a paucity of data on the performance of other critical mechanical engineering courses (such as Strength of Materials, Mechanical Vibration, Dynamics, Machine Design, Materials Science, and Fracture of Structural Materials) where online was used as a mode of instruction. A follow-up paper is planned in the near future to investigate the comparative impact of the online mode of instruction on some of the aforementioned mechanical courses in at least ten selected universities across the globe. Interested researchers are equally admonished to consider future studies in this regard in an attempt to further close the existing gap of information on documented research efforts on the effects of an online learning approach on students' academic performance in selected mechanical engineering courses.

6- Declarations

6-1- Author Contributions

Conceptualization, O.O.; methodology, O.O. and I.O.; software, I.O., O.O. and Y.O.; validation, I.O., O.O., O.A. and Y.O.; formal analysis, O.O., I.O., O.A. and Y.O.; investigation, O.O., I.O., O.A. and Y.O.; resources, O.O.; data curation, O.O. and Y.O.; writing—original draft preparation, O.O. and O.A.; writing—review and editing, O.O., I.O. and Y.O.; visualization, O.O. and Y.O.; supervision, O.O. and O.A.; project administration, O.O.; funding acquisition, O.O. All authors have read and agreed to the published version of the manuscript.

6-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6-3- Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6-4- Institutional Review Board Statement

Not applicable.

6-5- Informed Consent Statement

Not applicable.

6-6- Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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