Teaching mathematics in an EFL context at higher education; before, during and after the COVID-19 pandemic: a comparative study

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Abstract

Purpose – This study was done to compare the modes of teaching mathematics in higher education in the United Arab Emirates (UAE). The three teaching methods were used as follow: before, during and after the COVID-19 pandemic. The three teaching methods are: (1). Normal on-campus face-to-face teaching and learning activity before the COVID-19 pandemic. (2). Full online teaching and learning activity during the COVID-19 pandemic. (3). Blended teaching and learning activity after the COVID-19 pandemic.

Design/methodology/approach – Over the last few years, there has been a considerable amount of literature investigating the efficacy of the various delivery modes: on-campus delivery (face-to-face), online delivery and blended learning (hybrid), in helping college students improve their mathematical skills. However, the extent to which one learner learns best has been hotly debated among the researchers. Therefore, this study aims to compare the efficacy of implementing three teaching and learning delivery modes before, while, and after the COVID-19 pandemic: on-campus delivery (face-to-face), online delivery and blended learning (hybrid) on academic achievement in mathematics at a higher education institution in the UAE. The main research question explores whether there is a statistically significant difference (p = 0.05) in students’ academic based on the delivery methods: on-campus face-to-face, online and blended learning. The participants in the study were students from one of the largest higher education institutions in the UAE, and all of them studied the same mathematics course before, during and after the COVID-19 pandemic. Student scores in the three academic semesters were thoroughly compared and analyzed using the ANOVA test to check if there is a significant difference between the three groups followed by a Tukey test to identify the significant difference in favor of which group. The results showed that there were significant differences in the mean scores in the students’ achievement in the mathematics courses favoring the blended learning delivery mode. The findings also show that the students’ achievement in mathematics using the on-campus face-to-face teaching and learning was better than the students’ achievement in mathematics using online teaching and learning delivery modes.

Findings – The main study question was: is there a statistical significant difference at the significance level (α = 0.05) in students’ achievements in mathematics courses at higher education in the UAE, which can be attributed to the method of teaching? The descriptive statistics reveal that the average student’s score in the final exam after the COVID-19 pandemic is 65.7 with a standard deviation of 16.65, which are higher than the average student’s score in the final exam before the COVID-19 pandemic of 58.7 with a standard deviation 20.53, and both are higher than the average students’ score in the final exam during the COVID-19 pandemic 51.8 with standard deviation 21.48. Then, the ANOVA test reveals that there is a statistically significant difference between the three groups in the final exam marks. The researchers used the multiple comparison tests (Tukey test) to determine the difference. The Tukey test reveals that there is a statistically significant difference between the average students’ score in the final exam after the COVID-19 pandemic and the average students’ score in the final exam during the COVID-19 pandemic, where p = 0.015 < 0.05 as well as there is a statically significant difference between the average students’ score in the final exam after the COVID-19 pandemic and the average students’ score in the final exam before the COVID-19 pandemic, where p = 0.000 < 0.05 in favor of the average students’ score in the final exam after the COVID-19 pandemic. On the other hand, there is a statistically significant difference between the average students’ score in the final exam before the COVID-19 pandemic and the average students’ score in the final exam during the COVID-19 pandemic, where p = 0.016 < 0.05 in favor of the average students’ score in the final exam before the COVID-19 pandemic.

Research limitations/implications – There are several limitations that may reduce the possibility of generalizing the expected results of the current study to students outside the study population: (1) The study is limited to students of a federally funded postsecondary education institution in the UAE, in which most
students are studying in their non-native language. (2) The study is limited to the mathematics courses. (3) The achievement test used in the study is a standardized test developed by the college as a cross-campus summative assessment.

Practical implications – The hybrid education model, also known as blended learning, combines traditional face-to-face instruction with online learning components. When applied to teaching mathematics in higher education, this approach can have several implications and benefits. Here are some key points supported by references: (1) Enhanced Accessibility and Flexibility: hybrid models offer flexibility in learning, allowing students to access course materials, lectures and resources online. This flexibility can accommodate diverse learning styles and preferences. A study by Means et al. (2013) in “Evaluation of Evidence-Based Practices in Online Learning” highlights how blended learning can improve accessibility and engagement for students in higher education. (2) Personalized Learning Experience: by incorporating online resources, instructors can create a more personalized learning experience. Adaptive learning platforms and online quizzes can provide tailored feedback and adaptive content based on individual student needs (Freeman et al., 2017). This individualization can improve student performance and understanding of mathematical concepts. (3) Increased Student Engagement: the integration of online components, such as interactive simulations, videos and discussion forums, can enhance student engagement and participation (Bonk and Graham, 2012). Engaged students tend to have better learning outcomes in mathematics. (4) Improved Assessment and Feedback Mechanisms: hybrid models allow for the implementation of various assessment tools, including online quizzes, instant feedback mechanisms and data analytics, which can aid instructors in monitoring students’ progress more effectively (Means et al., 2013). This timely feedback loop can help students identify areas needing improvement and reinforce their understanding of mathematical concepts. (5) Cost-Effectiveness and Resource Optimization: integrating online materials can potentially reduce overall instructional costs by optimizing resources and enabling efficient use of classroom time (Graham, 2013). (6) Challenges and Considerations: despite the benefits, challenges such as technological barriers, designing effective online materials and ensuring equitable access for all students need to be addressed (Garrison and Vaughan, 2014). It requires thoughtful course design and continuous support for both students and instructors. When implementing a hybrid education model in teaching mathematics, instructors should consider pedagogical strategies, technological infrastructure and ongoing support mechanisms for students and faculty.

Originality/value – The research is the first research in the UAE to discuss the difference in teaching mathematics in higher education before, during and after the COVID-19 pandemic.

Keywords Online learning, Blended learning, Mathematics education, Face-to-face learning

Paper type Research paper

Introduction

There has been a major shift in education delivery and instruction modes in recent years. Many educational institutions globally have increasingly adopted either fully online learning or blended learning modes rather than the traditional face-to-face instructional model. This shift in the delivery approach has blossomed due to massive technological advancements. In other words, easy access to the Internet, the World Wide Web and computer technology have provided a plethora of opportunities for asynchronous learning. Here lies the conundrum: has the shift from entirely traditional face-to-face instruction to fully online instruction and/or even the instructional method in between (blended and hybrid learning) been effective? The face-to-face instruction methods used in the traditional classroom settings were notable for sharing course material and supporting materials with students during real-time interactions between students and their teachers (Snart, 2010). In contrast to face-to-face education is online learning, where learning involves interactions that are mediated through the use of digital, typically internet-based, technology (Greenhow et al., 2022). The third mode, a mix of online and face-to-face instruction, is known as blended or hybrid learning. According to Bonk and Graham (2012), blended learning refers to an instructional delivery that combines both face-to-face instruction and online learning.

Overall, as can be seen in Figure 1 blended learning mode usually involves aspects from the face-to-face learning mode and online delivery mode – it is a combination of both human and technology-mediated aspects (Anthony et al., 2022).

While many researchers have offered various opinions of the efficacy of these three delivery modes: face-to-face, online and blended, the research results failed to agree on a
definitive ruling on the value of learning mathematics online and through blended learning relative to face-to-face mathematics learning. That is to say, many studies on how college students feel about these learning modes have produced a variety of findings. For instance, in their study, Gecer and Dag (2012) reported that students in a mathematics department found that the blended learning environment encouraged their active participation in the course activities and that they found it helpful to follow the course material, homework and projects online. On the other hand, Ashby et al.’s (2011) results demonstrated that learning environments differed significantly, with students in blended classes performing the least successfully in algebra courses compared to those in face-to-face and online learning environments. Similarly, Krishnan (2018) investigated the two learning modes: the face-to-face learning mode and the online learning mode, in hybrid mathematics course and found out that students prefer the face-to-face traditional method in mathematics teaching and learning.

In addition, a more recent study was conducted to investigate whether the instructional delivery methods such as online, hybrid, blended learning and face-to-face delivery methods influenced students’ grades when teaching mathematics to English language learners in higher education institutions in the United Arab Emirates, Brashear (2020) has concluded that students in the online method had a significantly higher grade with a large to very large effect size compared to other methods – the more online teaching took place, the better students’ grades were. This study revealed that students with the online method scored best, followed by the hybrid method and in third position is the blended method. Similarly, in a comprehensive study that was also conducted in one of the higher education institutions in the United Arab Emirate, Ayob et al. (2023) reported that blended learning which merges e-learning with traditional education offered more flexibility in education as it makes the educational process easier for learners to learn at their own pace anywhere and anytime while having contact with their teachers as well. They stated that; “... With blended learning, education has become a more effective interactive process than traditional classes.” Acknowledging the fact that the flipped learning mode seems challenging for students to understand the learning abstract mathematical concepts, an interactive e-book approach was used to support flipped learning and was found to facilitate and bridge out-of-class and in-class learning by providing support for interactive learning contents presented on mobile devices (Hwang and Lai, 2017). They reported that
this approach not only promoted the students’ self-efficacy for learning mathematics but also improved students’ achievement.

To further explore the efficacy of the teaching modes, Taley (2022) stated that regarding the mode of interactions, the study showed that students taught with only asynchronous modes experienced less teaching presence than students taught through either the synchronous or blended modes yet, students who study via a blended learning mode showed superior conceptual comprehension because they could always access learning materials and review difficult mathematical concepts. Overall, the results of this study could not confirm that asynchronous learning environments attract more students to online learning, instead, it was confirmed that if there was dynamic real-time discourse as it related to traditional face-to-face classroom education, the presence of mathematics teaching was maximized.

Finally, it is evident that the efficacy of face-to-face, online and blended delivery modes has been the subject of much debate among researchers, but no clear consensus emerged from the research findings regarding the relative merits of online and blended learning in comparison to face-to-face mathematics instructions.

Methodology
This study was done to compare the modes of teaching mathematics in higher education in the UAE. The three teaching methods were used: before, during and after the COVID-19 pandemic.

(1) Normal on-campus face-to-face teaching and learning activity before the COVID-19 pandemic.

(2) Full online teaching and learning activity during the COVID-19 pandemic.

(3) Blended teaching and learning activity after the COVID-19 pandemic.

The below Figure 2 represents the three teaching modes:

To achieve this goal, this study attempts to answer the following main question:

Is there a statistically significant difference at the significance level \( \alpha \leq 0.05 \) in students’ achievements in mathematics courses at higher education in the UAE, which can be attributed to the methods of teaching?

To answer the study question, the researchers compared the students’ achievements in mathematics during the three semesters before, during and after the COVID-19 pandemic (Spring 2019, Spring 2021 and Spring 2022).

Hypotheses
The null hypothesis was considered for the research question. There is no statistically significant difference at \( \alpha \leq 0.05 \) between the mean scores in the student’s achievement test between the experimental groups who were taught using the three teaching methods:

(1) Experimental group one was taught using on-campus face-to-face classes through synchronous activities (before the COVID-19 pandemic).

(2) Experimental group two taught using online classes and online content through asynchronous activities (during the COVID-19 pandemic).

(3) Experimental group three taught using on-campus face-to-face classes and online content with both synchronous and asynchronous activities (after the COVID-19 pandemic).
Limitations
There are several limitations that may reduce the possibility of generalizing the expected results of the current study to students outside the study population:

1. The study is limited to students of a federally funded postsecondary education institution in the UAE in which most students are studying in their non-native language.
2. The study is limited to the mathematics courses.
3. The achievement test used in the study is a standardized test developed by the college as a cross-campus summative assessment.

Procedure
The research methodology applied is the comparative research approach because the research aims to make comparisons across different teaching modes at different times. Three phases were carried out as follow: the first was before the COVID-19 pandemic when teachers taught the course on-campus through face-to-face classes with synchronous activities. The second was during the COVID-19 pandemic when teachers taught the course through online classes and online content with asynchronous activities. The third one was after the COVID-19 pandemic when teachers taught using on-campus face-to-face classes and online content with both synchronous and asynchronous activities.

Phases one, two and three of the study occurred during the spring semesters (from January to May) in the academic years 2019, 2021 and 2022, respectively. Each academic year,
there were always four sections for students to register for the mathematics: two for male students and two for female students. Registered students had mixed-level abilities and they came from different program majors “for instance, the department of Business, computer and information sciences, and health science”. Each course had only one teacher, so the same teacher taught all the four sections. The aim of each of these phases in this study was to examine students’ achievement in the mathematics courses in the General Studies division in one of the higher education institutions in the UAE.

In the academic year 2019 (phase one), the mathematic course was delivered face-to-face where teachers and students met for four hours two days a week. Teachers used to teach the course content using the same procedures and instructions in all of the face-to-face classes. At the end of the unit, the instructors administer a unit test. Each unit test was completed in class, then graded and returned to students the following class session. No online materials were provided to students and no part of their grades required the use of online technology.

In the academic year 2021 (phase two), many educational institutions had to shift from traditional face-to-face classroom instructions to online instructions because of the COVID-19 pandemic. Due to COVID-19, schools and universities were temporarily shuttered. Students enrolled in the online mathematics course accessed all materials through the course management system (Blackboard Learn). They never had face-to-face meetings with their instructors. The online materials on Blackboard Learn were organized in weekly folders. The weekly folders have various resources to help students study at their own pace and to prepare for their upcoming online classes. For instance, students watched interactive videos and used self-paced Nearpod lessons, where interactive activities and concept check quizzes were embedded to test students’ takeaways.

During the academic year 2022 (phase three – post-COVID-19), the General Studies studies adopted the Blended Learning Model (GSBLM), which is a combination of face-to-face classroom-based or online instruction and flipped sessions (online sessions). The mathematics flipped sessions consisted of self-access and self-paced sessions with video recordings, interactive materials or other instructional media simulating the lecture portion of classroom-based lessons. The mathematics classroom-based sessions were reserved for applied and interactive activities with students and teachers engaged in the teaching and learning process. The alternation between classroom-based instruction, online instruction and flipped classrooms occurred at regular intervals every week – that is two hours for covering the flipped (online) materials and two hours for the classroom-based sessions.

It is important to note that since the data collected and analyzed in this study are gathered from archival data (existing data); the researchers were under no obligation to obtain consent from participants.

Figure 3 represents the research design.

Results
The research question was addressed by analyzing final comprehensive exam scores as the measure of summative achievement. Statistical analysis tools such as mean, passing rate and ANOVA test were used in the analysis. The research question sought to determine the difference between the three teaching modes: before, during and after the COVID-19 pandemic (see Tables 1–3).

Summary findings and discussion
The main study question was: is there a statistically significant difference at the significance-level ($\alpha \leq 0.05$) in students’ achievements in mathematics courses at higher education in the UAE, which can be attributed to the method of teaching?
The descriptive statistics reveal that the average student’s score in the final exam after the COVID-19 pandemic is 65.7 with a standard deviation of 16.65, which are higher than the average student’s score in the final exam before the COVID-19 pandemic of 58.7 with a standard deviation of 20.53.

<table>
<thead>
<tr>
<th>Time</th>
<th>Phase one during Spring 2019</th>
<th>Teachers taught on-campus face-to-face classes with synchronous activities.</th>
<th>Phase two during spring 2021</th>
<th>Teachers taught using online classes and online content with asynchronous activities.</th>
<th>Phase three during spring 2022</th>
<th>Teachers taught using On-Campus face-to-face Classes and online content with both synchronous and asynchronous activities.</th>
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<tbody>
<tr>
<td>January 2019</td>
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<td>May 2019</td>
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<tr>
<td>January 2021</td>
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<td>May 2021</td>
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<td>January 2022</td>
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<td>May 2022</td>
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</tbody>
</table>

**Source(s):** Authors’ own creation

**Table 1.** Descriptive statistics

<table>
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<th>Description</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
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<tbody>
<tr>
<td>Before COVID-19 pandemic</td>
<td>123</td>
<td>58.7175</td>
<td>20.53291</td>
</tr>
<tr>
<td>During COVID-19 pandemic</td>
<td>123</td>
<td>65.7093</td>
<td>21.47686</td>
</tr>
<tr>
<td>After COVID-19 pandemic</td>
<td>123</td>
<td>65.7093</td>
<td>16.65705</td>
</tr>
<tr>
<td>Total</td>
<td>369</td>
<td>58.7290</td>
<td>20.42549</td>
</tr>
</tbody>
</table>

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The descriptive statistics reveal that the average student’s score in the final exam after the COVID-19 pandemic is 65.7 with a standard deviation of 16.65, which are higher than the average student’s score in the final exam before the COVID-19 pandemic of 58.7 with a standard deviation of 20.53.
standard deviation 20.53, and both are higher than the average students’ score in the final exam during the COVID-19 pandemic 51.8 with standard deviation 21.48.

Then, the ANOVA test reveals that there is a statistically significant difference between the three groups in the final exam marks. The researchers used the multiple comparison tests (Tukey test) to determine the difference.

The Tukey test reveals that there is a statistically significant difference between the average students’ score in the final exam after the COVID-19 pandemic and the average students’ score in the final exam during the COVID-19 pandemic, where \( p = 0.015 < 0.05 \) as well as there is a statistically significant difference between the average students’ score in the final exam after the COVID-19 pandemic and the average students’ score in the final exam before the COVID-19 pandemic, where \( p = 0.000 < 0.05 \) in favor of the average students’ score in the final exam after the COVID-19 pandemic. On the other hand, there is a statistically significant difference between the average students’ score in the final exam before the COVID-19 pandemic and the average students’ score in the final exam during the COVID-19 pandemic, where \( p = 0.016 < 0.05 \) in favor of the average students’ score in the final exam before the COVID-19 pandemic.

Implications of using the hybrid education model in teaching mathematics in higher education

The hybrid education model, also known as blended learning, combines traditional face-to-face instruction with online learning components. When applied to teaching mathematics in higher education, this approach can have several implications and benefits.

Here are some key points supported by references:

1. **Enhanced Accessibility and Flexibility**: Hybrid models offer flexibility in learning, allowing students to access course materials, lectures and resources online. This flexibility can accommodate diverse learning styles and preferences. A study by

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### Table 2. ANOVA test

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### Table 3. Tukey HSD

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Means et al. (2013) in “Evaluation of Evidence-Based Practices in Online Learning” highlights how blended learning can improve accessibility and engagement for students in higher education.

(2) Personalized Learning Experience: By incorporating online resources, instructors can create a more personalized learning experience. Adaptive learning platforms and online quizzes can provide tailored feedback and adaptive content based on individual student needs (Freeman et al., 2017). This individualization can improve student performance and understanding of mathematical concepts.

(3) Increased Student Engagement: The integration of online components, such as interactive simulations, videos and discussion forums, can enhance student engagement and participation (Bonk and Graham, 2012). Engaged students tend to have better learning outcomes in mathematics.

(4) Improved Assessment and Feedback Mechanisms: Hybrid models allow for the implementation of various assessment tools, including online quizzes, instant feedback mechanisms and data analytics, which can aid instructors in monitoring student progress more effectively (Means et al., 2013). This timely feedback loop can help students identify areas needing improvement and reinforce their understanding of mathematical concepts.

(5) Cost-Effectiveness and Resource Optimization: Integrating online materials can potentially reduce overall instructional costs by optimizing resources and enabling efficient use of classroom time (Graham, 2013).

(6) Challenges and Considerations: Despite the benefits, challenges such as technological barriers, designing effective online materials and ensuring equitable access for all students need to be addressed (Garrison and Vaughan, 2014). It requires thoughtful course design and continuous support for both students and instructors.

When implementing a hybrid education model in teaching mathematics, the instructors should consider pedagogical strategies, technological infrastructure and ongoing support mechanisms for students and faculty.

Conclusion
It is essential to know that each of the three teaching and learning modes has a set of characteristics, tools, methods and educational methods that distinguish it from other types, as there is a wide range of basic differences between both e-learning and on-campus face-to-face teaching and learning, and these differences are represented through the following:

(1) On-campus face-to-face teaching and learning seeks to attend to students’ needs daily within the walls of the classroom environment, while e-learning is based on providing learning through the Internet and various means of communication.

(2) On-campus face-to-face teaching and learning is based on presenting academic content in the form of printed books and curricula, while e-learning is based on presenting content in the form of books, electronic study materials, websites and a range of multiple electronic sources such as video and audio.

(3) The role of students in on-campus face-to-face teaching and learning is not positive, as it does not participate in the process of transferring learning, while in e-learning the student participates in the learning process and exchanges knowledge among them.
E-learning depends on synchronous and asynchronous learning, while in on-campus face-to-face teaching and learning students can only get their learning through synchronous learning and with the actual presence of the student within the classroom environment, where the teacher and the students are present at the same time and place.

On-campus face-to-face teaching and learning is based on the use of traditional tools such as wooden boards and chalk, while e-learning is based on the use of smart boards and devices.

In conclusion, the outcomes of this research have provided insight into the efficacy of the various delivery modes: on-campus delivery (face-to-face), online delivery and blended learning (hybrid), in helping college students improve their mathematical skills. The research results reveal that the on-campus face-to-face teaching and learning model is better than e-learning in teaching mathematics. However, the results also reveal that combining both methods – the face-to-face method and the e-learning – in a blended learning environment better improves students' achievement in mathematics in higher education. Moreover, the results should be interpreted with caution due to the limitations of the current research.

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