

Assessing Student Performance in Digital Signal Processing (DSP) Subjects: A Comparative Study of Traditional and Online Learning Environments

Mohd Rizman Sultan Mohd, Juliana Johari, and Fazlina Ahmat Ruslan*

Abstract—This study compares traditional and online learning environments to evaluate students' performance in Digital Signal Processing (DSP). Online learning had become an option for the delivery of the subject since the COVID-19 pandemic. As one of the core subjects in the Electrical Engineering course, there is a need to investigate the impact of the traditional and online learning environment methods on student performance for the DSP. There is a total of 100 participants in the assessment involving undergraduates from Electrical Engineering who completed the subject. Based on the results, 70% of the students choose to take the subject using traditional methods compared with the online learning environment. This study suggests that the student prefer to take DSP subjects in traditional classroom learning compared to the online learning environment.

Index Terms—Digital signal processing, online learning environments, traditional learning environments.

I. INTRODUCTION

Digital Signal Processing (DSP) is a fundamental subject in many engineering disciplines, such as electrical, computer, and biomedical engineering. With the increasing importance of DSP in various applications, it is important to ensure that students have a strong foundation in DSP concepts and techniques [1]. Traditionally, DSP has been taught in a classroom setting, but recent advances in technology have enabled the use of online learning environments for teaching DSP [2]. The COVID-19 pandemic has accelerated the adoption of online learning for higher education. In response to the pandemic, many universities have shifted to online learning to minimize the risk of infection. This has created an urgent need to investigate the effectiveness of online learning for teaching DSP [3].

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*Corresponding author
Email address: fazlina419@uitm.edu.my

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Although there have been some studies that have compared the effectiveness of online learning and traditional classroom learning for teaching various subjects, there is still a lack of research on the factors that affect student performance in DSP. Based on previous study, there are various factors that may influence student performance in both traditional classroom learning and online learning environments [4]. J. Lee et al., [5] studied on the effectiveness of online learning environment and factors to improve the engagement of the student. The results show that there are six factors to improve student engagement in an e-learning environment including psychological motivation, peer collaboration, cognitive problem-solving, interaction with lecturers, community support, and learning environment management. Attendance is one of the main issues in online learning environment. A study by C. Lu and M. Cutumisu [6] explore the impact of attendance on the academic outcome based on online learning. The study shows that attendance does not give a direct impact on the outcome but has a significant effect on the engagement between students and lecturer. This mean that even the attendance is poor, the results of the test or exam is not affected at all which mean the student might take their own initiative to study to prepare for the test and exam rather than willing to spend time on online classes. This case may not be ideal for all subject because of the multiple approach on teaching and learning.

Acceptance by the student is also becoming one of the factors for the learning environment. The acceptance is directly related by student's perception which comes with the emotional engagement between lecturer and students. The study by K. Salta et al. [7] reports that student's emotional engagement is impacted by the transition from a traditional to an online learning environment. This is also supported in the study by J. Iqbal et al. [8] where emotional intelligence and study habits are examined in blended learning environments. The results show that cognitive engagement is needed to strengthen emotional intelligence and study habit. The study of students' perspectives on e-learning by Y. Lin and H. Nguyen [9] shows that e-learning must be well-prepared to avoid students' education being compromised. Engagement is among the other key to the effectiveness of online education delivery. The assessment of these key elements is needed to analyze the comparison between both learning environments.

This study aims to address this gap by comparing the effectiveness of traditional classroom learning and online learning environments for teaching DSP and investigating the relationship between student performance in DSP and various factors such as attendance, engagement, prior knowledge, and motivation. This study analyzed the student's performance results on the DSP subject and the assessment results based on the survey carried out for the students. There is total 100 numbers of students involved in this study. The findings established the statement on the justification of which teaching approach is the best for the students. In addition, results help the lecturers to identify the factor that affects the student's performance in this subject.

II. LITERATURE REVIEW

Digital Signal Processing (DSP) is a fundamental course in electrical and computer engineering that requires students to master complex mathematical concepts and computational techniques. DSP teaching includes the hands-on of the Field Programmable Gate Array (FPGA) instruments. It involves the internal hardware blocks with programmable connections to execute a specific application customized by the user on a real-time based. FPGA is essential as the practical teaching of DSP involves programming with the FPGA instruments [10]. It has become increasingly important to understand how students perform in DSP courses and to identify effective teaching methods that can enhance their learning experience. In recent years, a growing body of literature has explored various approaches to teaching DSP and evaluated their effectiveness not only focusing on online learning but an effective way to deliver this subject.

A study conducted by B.H. Shraddha et al [11] investigate the use of flipped classroom approach. In this paper, the flipped classroom is introduced for the fundamental courses to enhance the learning capability with a creative facilitating process. There are several activities outlined to increase the two-way communication between lecturer and students. Based on the results, it is shown that there is a significant improvement in the student's performance in the fundamental courses.

A.M. Deshpande [12] investigate the project-based learning approach in DSP. In this paper, project-based learning is introduced to increase the student's cognitive and behavioral engagement in order to enhance their self-learning skills. Based on the results, it is shown that the approach is managed to enhance the student's engagement and interest in DSP subject. This led to a self-learning ability towards the practical applications of the DSP.

Another approach to teaching the DSP is merging the design-based and project-based lectures in the subjects [13]. The class is not based on one-way communication as the learning is mixed with practical activities involving the application of the DSP in certain areas. This experimental learning with theory delivery had proven to give a good impact on the student's ability to apply the concept learned in a practical problem.

While many approaches are taken to the improvement of the teaching style, J.T. Gomez et al. [14] introduce the liberal arts

in the DSP learning environment. The initial objective is to improve teaching effectiveness through a multisensory approach which is given by the liberal arts. The approach is taken a quantitative perspective rather than the traditional curriculum encompassing analytical and mathematical formulation. The study shows that the approach had increased the comprehension and memorization of the abstract concepts.

The multiple approaches to teaching the DSP had shown that the course is one of the toughest subjects in electrical engineering study. The teaching of DSP can be summarized as a collective approach of theory and practices [15]. In summary, the literature suggests that DSP education can be enhanced using active learning techniques, online learning environments, educational technology, and innovative assessment techniques [16]. These approaches can improve student engagement, motivation, collaboration, and understanding of DSP concepts. But due to the COVID-19 pandemic, the face-to-face learning environment is restricted [17] therefore, the DSP had to be delivered through online classes without a practical class.

W. Jing et al. [18] explore the potential of teaching DSP online. They present the application of various online platforms for lectures with additional multimedia features to enhance the learning experiences. This will help to fill the gap between traditional and online learning environments. X. Wang et al. [19] proposed the blended teaching practices for DSP using the combination of an online resource's platform and integration with the traditional classroom learning. Blended teaching practices are proven to be the ideal learning environment since the DSP requires both theory and practical applications. Although the results show there is no significant drop in the environmental changes for the DSP subject, further study must be performed.

The transition of traditional classroom learning to the online learning environment must be analyzed using both students' performance and students' feedback. J. Paul and F. Jefferson [20] perform a comparative analysis between online and face-to-face learning environments for science courses over a decade. They found that with a technological approach, online teaching is more practical compared to traditional classes. However, there is no significant difference in students' performance. This shows that the flexibility offered by online learning does not improve the student's performance.

The finding is aligned with the study by Tang Y.M. et al [21]. In this paper, they investigate the students' readiness in online learning environments for two groups of students; undergraduates and postgraduates. The results show that the level of acceptance is low for undergraduates compared with postgraduates. Students' acceptance is an important aspect of online learning environment implementation. The study by Tang T. et al. [22] shows that students were dissatisfied with the interaction, especially in the Q&A session in the online classes. This varies with the subjects. If the subject is fully based on theory, the consent is low. But if the subject has a practical and hands-on simulation, the student prefers to have a face-to-face class. That is why, the blended learning environment is preferable by most of the students [23].

In this paper, a comparative assessment is carried out based on students' performance and student's acceptance. There are a total number of 100 students participating in this study. This student is separated into two categories which are traditional classes and online classes. The online classes start from October 2020 until October 2021, while the traditional classes continue from March 2022 until October 2022. The same performance scale indicator and survey form are used for the students. The student's performance scale is based on a staggered learning period with the assessment based on the study's progress timeline. So, the performance is basically scanned through the full subject teaching and learning process in the semester. The survey form is handed out at the end of the DSP subject for the semester. While other studies are attempted to find the gap before and after the pandemic, this paper presents a comparative study based on the pandemic and post-pandemic situation.

III. METHODOLOGY

This study utilized a comparative design to assess the performance of students in Digital Signal Processing (DSP) under traditional and online learning environments. This study uses the students' performance and students' acceptance based on both traditional and online learning environments. Only one class is referred for this study. This class was conducted by the third author. The data used for this study cover a period of three academic years, with student data collected from both traditional and online classes. The online classes start from October 2020 until October 2021, while the traditional classes continue from March 2022 until October 2022. The methodology of this study starts with the data collection for students' performance analysis and students' feedback from the survey which was conducted at the end of the subject for each semester.

A. Student's Performance Data

The data for this study were collected from the final grades of students who had completed the DSP course in the academic semester of October 2020, March 2021, October 2021, March 2022, and October 2022. The grades were collected from the official academic records of the university. The data includes the carry marks and the final exam. Carry marks is the cumulative sum from quizzes and tests. The assessment's structure remains constant for all academic semesters. The tabulation of the data is shown in Table I.

TABLE I. STUDENT'S GRADES ALLOCATION FOR THE SUBJECT

Assessment	Frequent	% of Final Marks
Quiz	10	10
Test	2	30
Final Exam	1	60

Table I shows the allocation of the subject with the quizzes and the test carry marks with a total of 40% and the remaining 60% will be the final exam. From the 40% marks, the student must score through 10 quizzes and 2 tests. Each of the quizzes is based on topics while tests are based on several topics. The final exam composes of entire topics in the subject. The number of students enrolled in the DSP subject for the class is shown in Table II.

TABLE II. STATISTICS OF STUDENT IN CLASS

Semester	Male	Female	Total
October 2020	8	16	24
March 2021	12	6	18
October 2021	3	18	21
March 2022	12	3	15
October 2022	14	8	22

Based on Table II, the highest number of students enrolled in the class is in the semester of October 2020 with 24 students, and the lowest number of students enrolled in the class is in the semester of March 2022 with only 15 students. The survey is distributed to this student at the end of the class for that semester. There is a total of 100 students in the class from October 2020 until October 2022.

B. Survey Preparation

To prepare for the survey, there are certain measures to be taken. This study tries to uncover the student acceptance of the online learning environment approach on DSP while getting an insight view of the most preferable option for this subject to be taught. To develop the survey, a series of questions is needed. This requires a depth understanding of what to be modeled based on their answers. The easiest way to deliver the survey is by using multiple-choice questions rather than open-ended questions. This will ease the data collection and will give a better view of their perception.

Based on the findings from the literature review, the set of questions can be divided into general questions, attendance, engagement, prior knowledge, and motivation as listed below:

a) General:

- Which learning environment do you find more conducive to understand DSP concepts?
- Do you believe online classes for DSP adequately provide hands-on practical experience?
- Would you prefer online classes or traditional classes for DSP?
- How would you rate the overall experience with online classes?

b) Attendance:

- How satisfied are you with your attendance in online class for DSP?
- How important do you think attendance is for your learning experience in DSP?

- c) Engagement:
 - How would you rate your overall experience with online classes?
 - In your opinion, which mode of learning provides better interaction and engagement opportunities?
 - How would you rate the quality of instruction in online classes compared to traditional classes?
 - Are you able to effectively communicate and collaborate with your peers in online classes for DSP?
 - How would you rate the level of engagement and active participation in online classes for DSP?
 - How comfortable do you feel asking questions and seeking clarifications in online classes for DSP?
 - How satisfied are you with the level of student-lecturer interaction in online classes for DSP?
- d) Prior Knowledge:
 - How would you rate your level of understanding of DSP concepts after attending online classes?
 - How effective are online classes upon your prior knowledge of DSP?
- e) Motivation:
 - Which mode of learning do you prefer for the DSP?
 - How satisfied are you with the overall organization and structure of the online classes for DSP?
 - How satisfied are you with the availability and accessibility of learning resources in online classes for DSP?
 - How important do you think student-lecturer interaction in online classes for DSP?

The answer sheet for this question is ranging from two to five answer options. The results will show the ranks for this selection and will be used to calculate the most selected answer by the students.

IV. RESULTS AND DISCUSSIONS

The results of this study are based on two parts consists of students' performance analysis results and students' acceptance in the feedback survey conducted at the end of the semester.

A. Student's Performance Analysis

The performance of the students in DSP subjects for each semester are shown in Table III.

TABLE III. STATISTICS OF STUDENT'S PERFORMANCE

Semester	Number of Students	% of Student Passed
October 2020	24	100
March 2021	18	67
October 2021	21	67
March 2022	15	60
October 2022	22	86

Based on Table III, the percentage of students passing the subject is inclined from 100 to nearly half during the online classes and began to increase during the traditional physical classes. It is generally shown that the percentage of students passes the subject is declined from the start of online class implementation for the DSP. The percentage rose again at the start of the traditional class after post-pandemic situations. The most percentage of students who passed the DSP is in the semester of October 2020 while the most percentage of students who failed the DSP is in the semester of March 2022. The average of quizzes, tests, and final exam results for each semester is shown in Table IV.

TABLE IV. AVERAGE MARKS FOR QUIZZES, TESTS, AND FINAL EXAM

Semester	Quizzes (10%)	Tests (30%)	Final Exam (60%)
October 2020	9.34	22.07	45.26
March 2021	9.36	20.39	23.45
October 2021	7.42	22.23	26.9
March 2022	6.03	20.74	30.72
October 2022	7.5	20.37	35.29

Based on Table IV, October 2020 recorded the highest average marks for final exam, followed by October 2022. March 2021 recorded the highest average marks for quizzes and October 2021 recorded the highest average mark for tests.

During the pandemic, the classes are taught online which brings the assessment are also carried out online. Quizzes are made based on each chapter taught in one session while tests are a combination of more than one chapter. The final exam question basically consists of the entire chapter on that subject. Based on Table IV, the biggest contribution to the marks is the final exam, followed by tests, and quizzes. On average, students manage to score more on quizzes and tests compared to final exams.

Based on the trends reported, it can be concluded that there are several acceptable opinions that had been raised. At the beginning of online learning, students are facing a new norm where they adapt the long-distance learning through online interaction. Malaysia at that time was facing a major shutdown and people are restricted to staying at home. This made the students focus on the online learning environment. When everything starts to cool down and people are given permission to move freely, the students were no longer attached to online learning. However, further analysis must be carried out to find the real answer to this resulting trend.

B. Student's Feedback Analysis

Students' feedback analysis is based on a survey form that consists of multiple-choice questions. 100 students participated in this survey and the feedback is shown in graph format for each of the categories. Table V shows the response distribution from the survey.

TABLE V. STUDENT'S FEEDBACK RESULTS

Category	Question	Response Distribution
General	1	Online = 30 Traditional = 70
	2	Yes = 70 No = 30
	3	Online = 30 Traditional = 70
	4	Excellent = 10 Good = 30 Average = 40 Poor = 20
Attendance	1	Very Satisfied = 40 Satisfied = 30 Neutral = 20 Dissatisfied = 5 Very Dissatisfied = 5
	2	Very Important = 50 Important = 35 Neutral = 10 Not Important = 5
Engagement	1	Excellent = 20 Good = 40 Average = 10 Poor = 5
	2	Online = 45 Traditional = 55
	3	Better in Online Classes = 40 Better in Traditional Classes = 30 Same in Both = 30
	4	Yes = 70 No = 20 Not Applicable = 10
	5	High = 40 Moderate = 35 Low = 25
	6	Very Comfortable = 45 Comfortable = 35 Neutral = 10 Uncomfortable = 5 Very Uncomfortable = 5
	7	Very Satisfied = 35 Satisfied = 40 Neutral = 15 Dissatisfied = 5 Very Dissatisfied = 5
Prior Knowledge	1	Excellent = 30 Good = 40 Average = 20 Poor = 10
	2	Highly Effective = 40 Effective = 35 Neutral = 15 Ineffective = 5 Highly Ineffective = 5
Motivation	1	Online = 35 Traditional = 65
	2	Very Satisfied = 40 Satisfied = 40 Neutral = 10 Dissatisfied = 5 Very Dissatisfied = 5
	3	Very Satisfied = 35 Satisfied = 40 Neutral = 15 Dissatisfied = 5 Very Dissatisfied = 5
	4	Important = 85 Neutral = 10 Not Important = 5

For the general section, most students choose to have DRP classes using a traditional learning environment compared to online learning. Even though they can catch up with the course taught online, they consider the online class an average choice compared to the physical classroom environment.

For the attendance section, the majority of students choose high satisfaction with their attendance online and they consider attendance as a very important aspect of an online class. Based on the survey there are still a few students who are not satisfied with their attendance. This is due to several issues which are the availability of internet services and the online teaching platform provides by the institution.

For the engagement section, the majority of the student has a good experience in online classes but when comes to choosing between online and traditional classes, they still prefer to have a physical class compared to online classes. Flexibility in online classes also had given a good impression on the student because the engagement between lecturer and student can become more effective. Unlike traditional classes, online classes had made students closer to lecturers and they tend to get attention easily. Overall, most of the students were satisfied with the engagement aspect of online classes.

For the prior knowledge category, the majority of student thinks that having prior knowledge of the course is essential and could help them in understanding the subject better. The on-screen delivery of the content is more effective than the traditional way of teaching using a physical projector or slides.

Lastly for motivation, again most of the student are preferred to have traditional classes compared with online classes. This is because of the importance of student-lecturer interaction in delivering the subject.

Based on the response distribution for all five categories in Table V, most students find that traditional classroom learning is more conducive to understanding DSP compared to online classes. Around 70% of students believe that online classes do not adequately provide hands-on practical experience. That is why they prefer to have traditional classroom learning compared to online classes for DSP.

While 70% of students are satisfied with their online classes, attendance is considered an important aspect of their learning experience in DSP. However, the quality of instruction and engagement opportunities in online classes received mixed responses with 40% suggesting that online classes are better while 30% choose traditional classes. Most students felt that they were able to effectively communicate and collaborate with their peers in online classes. This also applies the same with student-lecturer interaction. 70% of students rated their level of understanding of DSP in online classes as good. Lastly, most of the students perceived student-lecturer interaction as an important aspect of online classes for DSP.

Overall, most of the students did not have any problem learning DSP through an online platform. But when given an option between traditional classroom learning and an online learning environment, most of the students choose to have DSP subjects in traditional rather than online learning. This can conclude that the blended learning environment can be applied to the DSP subject in the future.

C. Individual vs Combined Effects

The survey findings provide valuable insights into the individual and combined effects that influence students' preferences and experiences within the subject of DSP learning. Examining a comprehensive array of questions across distinct categories, these results shed light on the multifaceted factors that guide students in choosing between traditional classroom learning and online instruction for DSP subjects. Individually, these responses reveal notable trends and attitudes. For instance, a significant proportion of students, constituting 70%, express a clear preference for traditional classroom settings, emphasizing their inclination toward face-to-face learning. Conversely, a sizable number, again at 70%, harbor doubts about the ability of online classes to deliver hands-on practical experience, signaling common concerns within the student body. These individual effects provide a detailed understanding of students' standalone viewpoints.

Simultaneously, the survey exposes combined effects that showcase the intricate interplay of various factors. For instance, when it comes to the crucial aspect of engagement, 55% of students prefer traditional classes for better interaction and engagement opportunities, while 45% lean toward online classes. This combined effect highlights the dynamic nature of student preferences and underscores the importance of engagement in shaping their choice of learning mode. Additionally, in terms of motivation, while a majority (65%) express a preference for traditional classes, most (80%) express contentment with the organization and structure of online classes, providing a glimpse into how individual motivations can sometimes diverge from overall satisfaction with online learning.

These individual and combined effects within the survey results offer educators and institutions crucial insights into the complex landscape of student preferences, allowing for more tailored and responsive approaches to DSP education. The following table presents a comprehensive overview of these effects based on the survey responses.

TABLE VI. INDIVIDUAL VS COMBINED EFFECTS

Category	Question	Effects
General	1	Individual
	2	Individual
	3	Individual
	4	Individual
Attendance	1	Individual
	2	Individual
Engagement	1	Individual
	2	Combined
	3	Individual
	4	Individual
	5	Combined
	6	Individual
	7	Individual
Prior Knowledge	1	Individual
	2	Individual
Motivation	1	Individual
	2	Individual
	3	Individual
	4	Individual

Based on Table VI, individual effects indicate a strong preference for traditional classroom learning (70%), concerns about hands-on practical experience in online classes (70%), and varied perceptions of online class experiences. The combined effects reveal the interplay of factors, with 55% favoring traditional classes for interaction and engagement, while 45% prefer online classes. Additionally, the data highlights a generally positive view of online instruction, effective communication, and collaboration (70%), and the impact of engagement levels on experiences. These findings offer insights into the intricate dynamics of student choices and attitudes within the DSP education landscape.

V. CONCLUSION

The survey results offer critical insights into the landscape of DSP education, allowing for the formulation of valuable future recommendations. The first step involves a comprehensive discussion of the findings, focusing on both individual and combined effects presented in the survey results. This in-depth analysis will help establish a solid connection between the data and existing literature in the field, shedding light on how these findings either corroborate or diverge from prior research.

For educators, the implications of the survey results are substantial. The strong student preference for traditional classroom learning and concerns about the adequacy of hands-on practical experience in online classes should prompt instructors to consider how to optimize their teaching methods. This may involve adapting course content, integrating technology more effectively, and fostering a more interactive learning environment.

Institutions should also heed the recommendations arising from the survey. They must evaluate their course offerings, technology infrastructure, and student support services to better align with student preferences. Flexibility in course delivery methods and investment in resources that enhance the online learning experience are crucial. Furthermore, continuous professional development for educators, focusing on online pedagogy and technology utilization, can enhance the overall quality of education. The availability and accessibility of learning resources, both in traditional and online settings, should be a focal point for institutions. Keeping digital libraries up-to-date and ensuring that online platforms facilitate easy access to course materials is imperative.

In line with student-teacher interaction being a key driver of motivation, institutions should prioritize platforms and tools that enable meaningful and regular interactions between students and instructors. The importance of ongoing data collection and analysis cannot be understated. By continually gauging student satisfaction and adapting teaching methods and delivery modes accordingly, institutions can remain agile and responsive to the evolving needs and preferences of their students.

As for the conclusion, this study has conducted a comprehensive evaluation of DSP subjects in both traditional classroom and online learning environments, with a focus on students' performance and their acceptance of these modes of

instruction. Among the 100 participating students, it is evident that the shift from online learning to traditional classroom settings has a discernible impact on their academic performance. Furthermore, the analysis of student acceptance, as indicated by survey data, reveals a prevailing preference for traditional classroom instruction over online classes. However, it is essential to delve deeper into the findings and relate them to the existing body of literature on this subject. The implications of these results for educators and institutions are noteworthy. While many students have adapted to online learning, the study demonstrates that they still value face-to-face interaction for a better grasp of DSP concepts. Therefore, this paper underscores the importance of delivering DSP subjects through traditional classroom learning as opposed to online methods.

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