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Implementation of Quality Function Deployment to Improve Online Learning and Teaching in Higher Education Institutes of Engineering in Oman

Jawaher Rashid Ahmed Al yaarubi and Amuthakkannan Rajakannu*
National University of Science and Technology
Muscat, Sultanate of Oman

Abstract. In this digital era, online learning and teaching is an essential platform for college and university students, and it requires many technical facilities and in-depth knowledge to have an effective learning process. During the COVID-19 pandemic, students and teachers in Higher Education Institutions (HEIs) were forced to grapple with the certainty of shifting to online classes due to large learning groups or the advantages of effective distance learning which is becoming an essential part in learning and teaching. In the case of Oman, there have been some efforts to integrate alternative learning mechanisms in the past, but they have not followed the scale in the post-pandemic world. This study sought to utilize the principles of Total Quality Management (TQM) by implementing Quality Function Deployment (QFD) to understand the experiences of Omani teachers and students from HEIs to enhance the quality of online learning and teaching. The perspectives of teachers and students were investigated and recorded. In this regard, 165 teaching staff and 355 students from HEIs of engineering participated in a survey. After the survey, a house of quality analysis was performed to analyze the requirements based on how strongly they relate to the standard learning outcomes expected from HEIs in Oman. The results of the house of quality show that "in-person attention is required as a technical requirement", with a high score of 164, and that student knowledge and competence need to improve as a customer requirement, with a high score of 45. This shows that more attention is required in online education in the Sultanate of Oman before it is implemented as a significant part of learning and teaching.

Keywords: higher education institutions; online learning and teaching; quality function deployment; total quality management; voice of the customer

* Corresponding author: *Amuthakkannan Rajakannu, amuthakkannan@nu.edu.om*

1. Introduction

The Sultanate of Oman, with a population of over 4.5 million, has a sustainable economic climate, outstanding infrastructure, and skilled human resources. The education and health sectors are critical in achieving economic strategy goals, including Oman Vision 2040 (2020). Oman has realized that educational reform, including curricula, teaching, and learning processes, is its pillar toward quality education. The sustainability of economic growth and human resources development through improving education technologies was essential to Oman Vision 2040 (Oman Vision 2040, 2020). The Ministry of Higher Education and scientific research and innovation institutions in Oman promote higher education in the public and private sectors as per Royal Decree number (2/1994) released in the Sultanate of Oman government document(NCSI,2020). As a result of population growth and the diversity of the different sectors, the number of HEIs has expanded in Oman, with a remarkable expansion witnessed following the year 2018. The geographical distribution of universities and colleges across governorates of the Sultanate is shown in Figure 1.

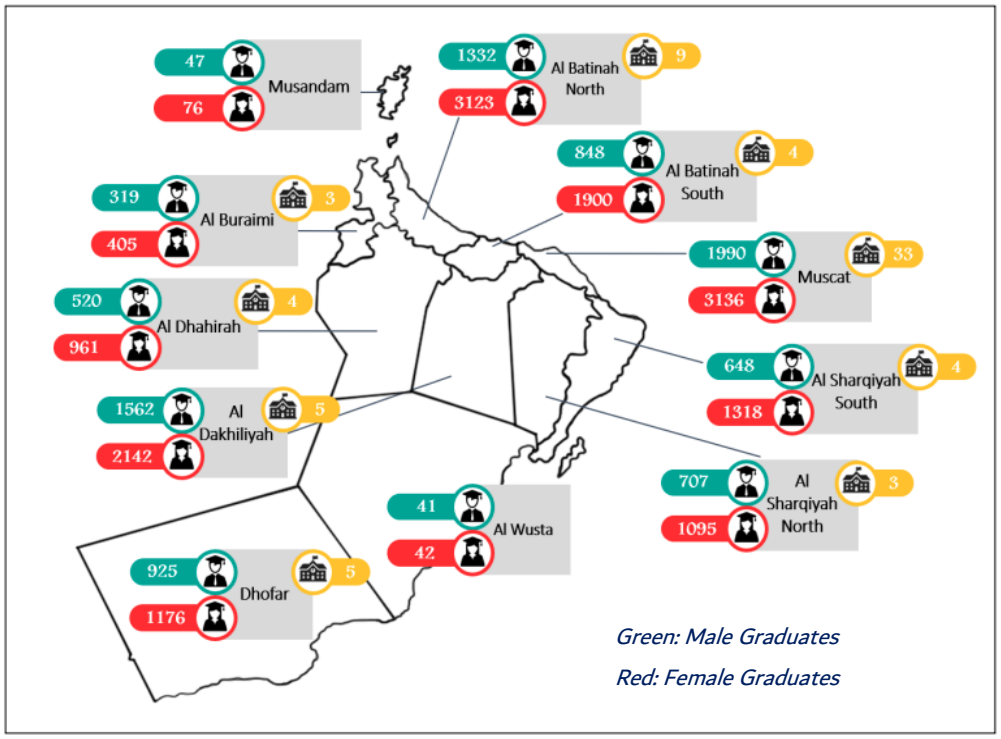

Figure 1: Geographical distribution of universities and colleges across governorates of the Sultanate of Oman and the passed-out graduates in 2017–2018 (NCSI, 2020)

Raza et al. (2022) researched the Blackboard learning system, an online platform designed for e-learning employed by many higher education institutes (HEIs). The study explored the acceptance and use of the Blackboard learning system in Pakistan. The study shows that the Blackboard system is highly suitable for online learning. Ali et al. (2018) examined university students' acceptance of e-learning systems in Pakistan. The results revealed that university students' acceptance of the e-learning system is reasonably good. Aslam, Akram et al. (2021) conducted research on online learning at a medical college in China. The study aimed to

investigate international medical students' online teaching experiences during the COVID-19 pandemic in China. More than half of the respondents reported their Internet connection quality as poor to average. The study concluded that online learning is not suitable for medical education because of the involvement of physical examination of the body in practical classes. Aslam, Saleem et al. (2021) discussed the challenges in implementing online learning during the pandemic, revealing various challenges in implementing online education in teaching and learning in developing countries.

These studies have shown positive feedback in implementing online teaching and learning. However, quality checking is essential in implementing an online education system. The researchers did not focus much on quality checking and quality improvement in online learning and teaching. Therefore, this paper set out to apply the principles of total quality management (TQM) in online learning through the use of quality function deployment (QFD) to identify the main hurdles and areas of improvement that need to be addressed in the case of HEIs in Oman. The novelty of this work is the implementation of QFD in assessing the quality of online learning and teaching. QFD is a structured and essential tool in TQM implementation that uses engineering and management charts to transform customer requirements into process characteristics. Since the educational world is moving toward digitalization, it is necessary to maintain the quality of education before implementing any digital techniques. In this paper, the hypothesis is set up to verify the quality of online education based on customer requirements. The aim of implementing QFD is to identify the exact technical requirements needed to satisfy the customer and stakeholder expectations.

This work sought to achieve the following objectives:

1. To use QFD in understanding the challenges that students from HEIs in Oman are facing in adopting and understanding coursework through online learning.
2. To leverage QFD to collect information from teachers in HEIs in Oman relating to their experience of delivering course material through online learning.
3. To identify the gaps in the current approach to online learning among HEIs in Oman to enhance quality.
4. To provide recommendations to HEIs in Oman toward improving online learning based on the outcome of the research using TQM principles.

2. Literature Review

The higher education sector of Oman is constantly evolving to achieve high-quality education. Therefore, it is essential to begin this review by providing more insight into the current state of higher education in Oman to better understand the nature of the improvements that will have to be undertaken based on the evaluation. As per the National Center for Statistics and Information (NCSI, 2021), the number of students enrolled and the number of teachers employed in HEIs in Oman from 2007 to 2018 are shown in Figures 2 and 3, respectively. The data in the figures indicate that the HEI sector of Oman has been expanding in the past years. While the number of students has more or less stabilized in the 120,000 to 130,000 range, more and more teachers have been employed in various HEIs to

support the sector's growth. As a part of technology, HEIs in Oman have introduced alternative learning modes focused on e-learning channels. Tawafak et al. (2019) examined the efficacy of using e-learning in coursework among Omani university students. Based on an evaluation of student and teacher experiences, the authors found that more variables had to be controlled to make e-learning effective.

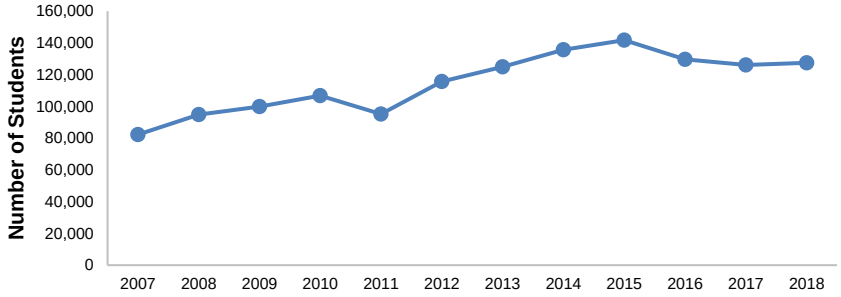

Figure 2: Number of enrolled students in HEIs in Oman from 2007 to 2018 (NCSI, 2021)

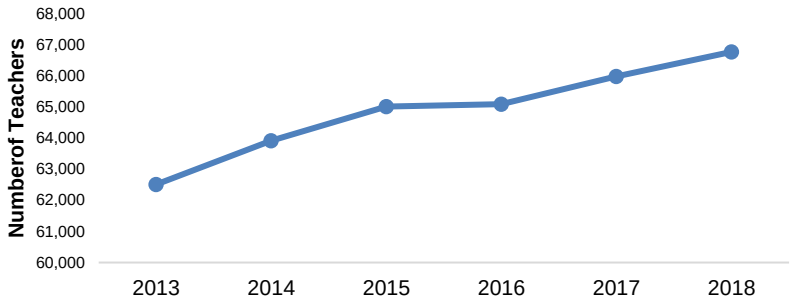

Figure 3: Number of employed teachers in HEIs in Oman from 2013 to 2018 (NCSI, 2021)

Sarrab et al. (2016) evaluated the factors influencing mobile and online learning adoption among students in HEIs in Oman. They found that students were more critical of the ease of use of online learning platforms and the ability of educators to engage in this alternative channel. In 1970, the sultanate moved toward a rapid and extensive overhaul of the country's educational system. This was initiated with the growing recognition of the importance of higher education in Oman's economic viability (Hakro & Mathew, 2020). This is exemplified by the fact that the continued improvement of standards related to higher education has been a core issue pushed in the Oman Council since the 1980s (Al Najar, 2016). The hurdles are highlighted in three issues: funding, access, and quality. Modern technologies such as wireless technology, digital innovation, and artificial intelligence are expanding Oman's learning platforms to improve the education sector's effectiveness (Al-Emran & Shaalan, 2017).

Gawande (2015) evaluated blended learning, a learning mode in which students are exposed to online and in-person instruction. The author emphasizes that students must first understand the value of online education as a method and see

it as a viable way to aid them in understanding their course material. Regarding achieving greater buy-in, Al-Emran et al. (2016) sought to investigate the attitudes of university students in Oman toward mobile and online learning. They identified that younger students are typically more open to these learning mechanisms because of their affinity for digital solutions. Slimi (2020) undertook a case study on the situation in HEIs in Oman and found that learners and teachers have been able to adjust to the online setting. Still, the author identified negative online learning experiences, namely Internet connectivity problems and the technological infrastructure students have access to. In addition, Slimi (2020) mentioned the inability of some instructors to translate their methods into the online setting. All these findings show that work is still needed to improve the quality of online learning in Oman.

TQM is a quality management framework that seeks to capitalize on leveraging all aspects of the organization to holistically and comprehensively meet standards of quality aligned with the needs and expectations of a firm's customers (Abbas, 2020). Pambreni et al. (2019) considered the case of small and medium enterprises in Malaysia and found that using TQM helps firms improve overall performance because of its focus on customer satisfaction. Shams (2017) showed that TQM is an adequate paradigm for improving higher education outcomes, especially emphasizing its applicability to numerous national and cultural settings. Al-Qayoudhi et al. (2017) more directly looked into TQM's use in Oman by undertaking a case study on a university, with findings confirming the conclusions made by Shams (2017). Regarding QFD, Sagnak et al. (2017) found that it is more effective in improving quality, particularly in business schools. Al-Bashir (2016) determined that the tool helps to support the efforts of various universities in the Gulf area in bolstering the educational experience. These studies ultimately point to the fact that QFD and TQM have a place in the education sector. Both can be leveraged to aid HEIs in the continued transition and improvement of online learning implementation.

Nasim et al. (2020) emphasized that several studies have repeatedly shown that TQM can be used to evaluate and adjust teaching styles to suit student needs better. Furthermore, TQM can be used to understand the various aspects of the experience of the student to adapt curriculum and pedagogy and to ensure that the coursework and course material provided to students are up to par with national and international standards. In considering the experiences of HEI staff members in Iran, Aminbeidokhti et al. (2016) found that TQM helped to support organizational learning. The authors noted that applying the principles of TQM made HEI faculty and staff more conscious about issues in teaching styles and course material. Psomas and Antony (2017) conducted a survey on the implementation of TQM in 15 private HEIs operating in Greece to determine which aspects of TQM are used in these organizations and the main focus areas they sought to improve. Nadim and Al-Hinai (2016) set out to identify the critical success factors of TQM in the context of higher education. The study is especially relevant as data were collected from an HEI in Oman. According to the authors, successful TQM was predicated on employee involvement and stakeholder focus.

Nadim and Al-Hinai (2016) noted the importance of stakeholder focus, meaning that the student's experience is paramount in using TQM in HEIs.

QFD is a method through which companies can listen to their customers' voices and opinions to move toward addressing the core needs of the group (Kiran, 2017) Since TQM is highly customer-driven and geared toward ensuring satisfaction, QFD provides a means to better identify and understand customer needs. It allows the company to carry out the most effective actions (Erdil & Arani, 2019). QFD is a tool that is deployed when undertaking TQM. It allows organizations to understand customer requirements for a given product or service and, thus, effectively organize engineering specifications that can meet these requirements (Lam & Bai, 2016). Therefore, QFD responds to the customer-centric nature of the TQM framework by creating a concrete path for the organization (Puglieri et al., 2020). As mentioned, QFD guides the design process during product development. Using a case study focused on a ceramic tile-making company, Erdil and Arani (2019) developed a framework that utilized QFD as a quality improvement tool focused on identifying corrective actions and technical limitations to current products. In taking this approach, Erdil and Arani (2019) found that the company improved customer satisfaction and service quality, as evidenced by reduced complaints. This shows that QFD can be used to support quality improvement and not just to chart product definition.

The voice of the customer is a core and central theme of QFD. The voice of the customer, as the name implies, refers to all the customer's needs and requirements explicitly and implicitly (Gangurde & Patil, 2018). According to the study by Iqbal and Girgg (2020), if QFD is appropriately implemented, it can emphasize the customer's voice, leading to prioritization on the part of the company. One of the primary tools QFD applies is creating a house of quality. This is the fundamental design tool employed in QFD that visualizes the customer requirements and their level of importance against the product features to determine the strength of association across these aspects of the product or service. Amuthakkannan et al. (2018) proposed a new methodology for blending the customer's voice with a novel concept of the "red green chart (RGC)" to build the house of quality and improve the effectiveness of component selection for design changes. In this research work, the QFD is applied to predict the appropriate technical requirements in each stage of product development in the area of mechatronics system design.

Several studies have highlighted the use of QFD in higher education. The research of Sagnak et al. (2017) emphasizes how QFD supports quality improvement in the higher education sector. Matorera and Fraser (2016) took a broader view of the topic, responding to the larger question of whether QFD can genuinely serve as a way to evaluate and assess the quality of instruction in higher education settings. From data collected in business schools in South Africa, it was concluded that QFD indeed has a place in higher education and is an effective tool for pursuing quality improvement. Mesuwini (2024) conducted a pilot study on the perceptions of South African technical and vocational education and training (TVET) students of their online learning experiences and challenges. It was found

that some students failed to attend online classes due to a shortage of smartphones/laptops and data, a lack of communication from tutors, and poor connectivity. Yousef (2024) discussed challenges and opportunities in the prevalence of the internationalization of higher education in the Middle East and North Africa. As per this research, in terms of internationalization, Qatar is at the highest level, while Egypt is at a low level. The research gap in the above literature is the implementation of QFD for online learning and teaching and its quality assessment. There is no research on the voice of the customer and building a house of quality in relation to the quality assessment of online learning or hybrid modes of teaching.

3. Methodological Framework

3.1 Research Strategies

A survey questionnaire facilitated the quantitative approach adopted in this research. The research required respondents to provide recommendations for online learning among HEIs. As such, the teachers and students in the sample had to come from Omani HEIs. Data were collected from the College of Engineering, National University of Science and Technology, Oman to focus on data collection and reduce logistical issues. This may have introduced some bias into this study as it is a private institution and the students are from an engineering-related course.

To determine the sample size, Slovin's formula ($n = \frac{N}{1+Ne^2}$) was utilized. This equation computes the suggested sample size (n) from a population (N) given the statistical significance (e) selected for the study (Adam, 2020). Convenience sampling was implemented in the respondent selection process. From this broad recruitment strategy, 422 students and 187 teachers agreed to participate. From this initial pool, 355 students and 165 teachers were randomly selected as part of the final sample. Any respondent who withdrew their intention to join after this final selection was replaced by, once again, another respondent randomly selected from the larger group. Note that all respondents were duly briefed and asked to provide consent to participate before any data collection was conducted to adhere to ethical practices.

Two sets of questionnaires, one for each group, were created with two sections each. The first section of the questionnaire is geared toward collecting information on the respondents. On the part of the teachers, the first section covered their gender, age group, current teaching position, the online platform they use, and years of experience with online instruction. On the other hand, the first part of the questionnaire for the students collects data on their gender, age group, the department they are a part of in the College of Engineering, the online learning platforms they use, and the time they have spent attending online classes. The second part of the questionnaires is the same for both groups, as this is where their customer voice is evaluated. The questionnaire falls within four product attributes: technical, financial, operational, and functional. These were determined to be the key categories that any product or service should consider, including online learning. The respondents were provided a link to a Google form where they were asked to provide the information asked of them. The first part of

data analysis involved computing the descriptive statistics and frequencies of the data collected in the initial part of the questionnaire for both groups.

3.2 Analysis of the Voice of the Customer

The second aspect of analysis entailed understanding the voice of the customer. To do this, the mean score of each questionnaire was computed for the students and the teachers. Since students are central to the online learning process, a final inclusion score for the items was computed by weighting the student score by 70% and the teacher score by 30%. From this, the six most pertinent items were deemed to be the critical technical requirements that an effective online learning scheme must be able to capture. This represents a preliminary step required to develop the house of quality diagram used in QFD. In addition to looking at the scores to finalize the technical requirements, inferential statistical analysis was also conducted to determine trends and differences in the responses of the teachers and students.

3.3 Creating a House of Quality

The third part of data analysis was the core analysis centered on creating a house of quality for online learning, representing the needs of both teachers and students. This is a diagrammatic tool implemented as part of QFD, and the goal here is to determine the main areas of improvement that should be prioritized to meet the customer's needs. Figure 4 shows a diagrammatic representation of the house of quality and how it can be analyzed.

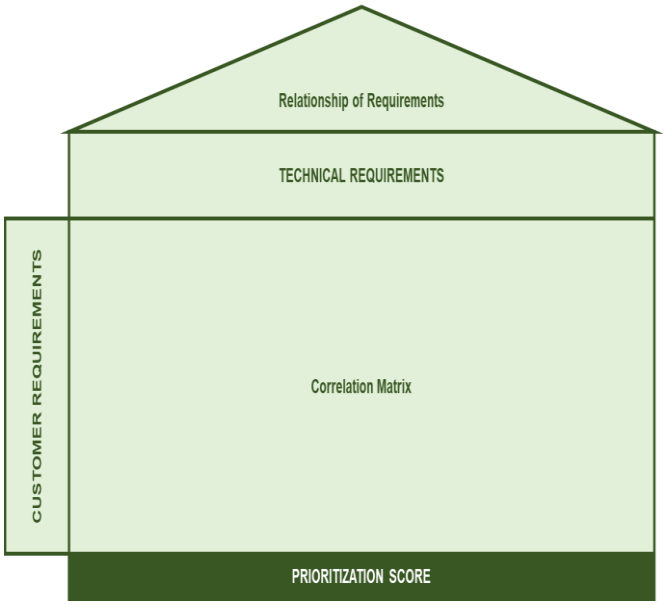

Figure 4: House of quality framework

Four parts need to be considered in the house of quality. The two major ones are the customer requirements and the technical requirements. The other two parts are determining relationship requirements and preparing a correlation matrix. The house of quality is established with the two main parts, and the rest can be constructed around the two main parts. The correlation matrix evaluates how each customer requirement relates to the technical specifications. The rule of

thumb is to score high correlations with 9, mid correlations with 5, low correlations with 1, and aspects with no correlation are scored 0. To fill up the matrix, the correlation score is multiplied by the importance score of each item. The scores across each column are then added to determine the priority core of the various technical requirements. The roof or apex of the house of quality represents the relationship of each requirement. This can range from a strong positive to a strong negative correlation. In this study, this was determined by carrying out a bivariate analysis of the scores of each of the items based on data from the students and the teachers.

4. Analysis of the Study Sample

4.1 Teacher Respondents

The first group of respondents in this study was the teachers. The study considered the teachers' key characteristics. Based on the sample size determination, 165 teacher respondents were appropriate to produce a statistically significant sample size at the 0.05 significance level. The gender distribution is the first aspect of the data highlighted for this category, with the results displayed in Figure 5.

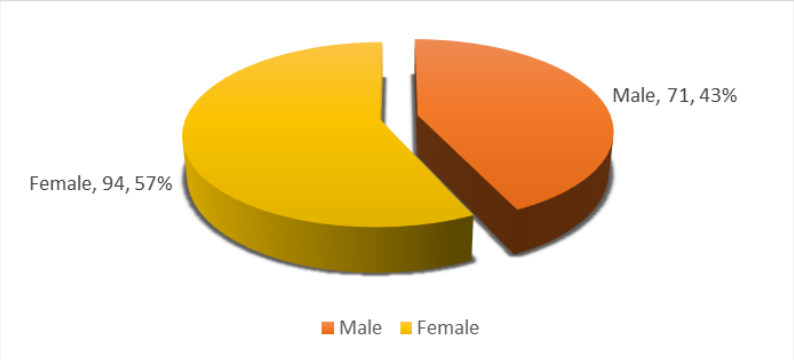

Figure 5: Distribution of the teacher respondents by gender

As shown in Figure 5, the data indicate that most of the teachers surveyed in this study were female, as they composed 57% (n = 94) of the sample, whereas only 43% (n = 71) were male. In addition to asking respondents what their gender is, the questionnaire also inquired about their age, and the data for this are shown in Figure 6.

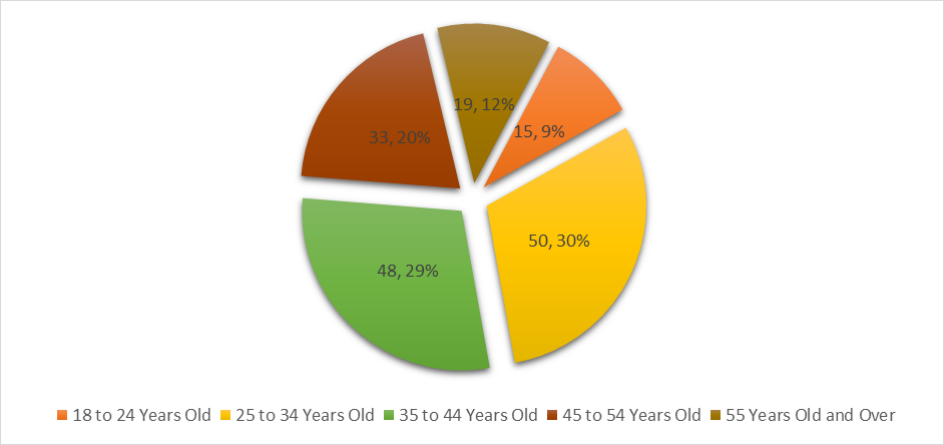

Figure 6: Distribution of teacher respondents by age group

The data visualized in Figure 6 indicate that most of the teachers in this study fell within the 25 to 34-year and 35 to 44-year age groups, as these composed 30.30% (n = 50) and 29.09% (n = 48) of the sample, respectively. The lowest representation came from either end of the age spectrum, as those in the 18 to 24-year group comprised only 9.09% (n = 15) and those 55 years old and over composed only 11.52% (N = 19) of all teachers in the sample. In addition to personal information, data were also collected on respondents' work and experience. The first aspect related to respondents' current work designation, as shown in Figure 7.

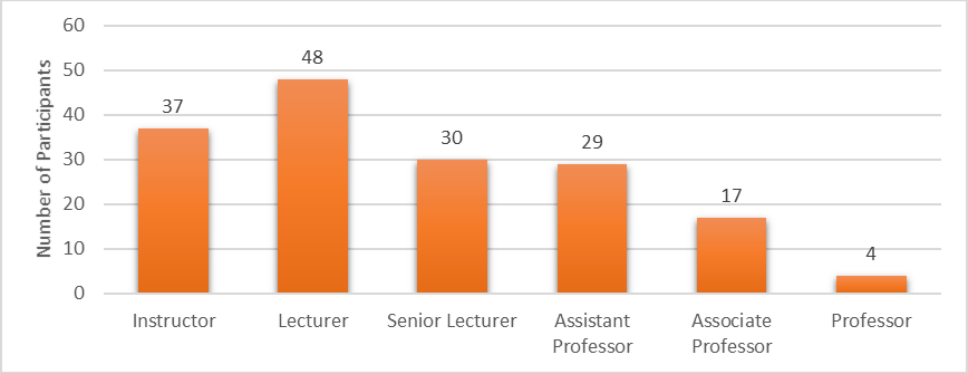

Figure 7: Distribution of teacher respondents by work designation

The teachers who completed the survey tended to be teachers who fell within the lower designation ranks. This is apparent, as 22.42% (n = 37) of the respondents were instructors and 29.09% (n = 48) were lecturers. On the other hand, only 2.42% (n = 4) of the teacher sample had the designation of professor. The next aspect considered is the department the teacher respondents belonged to in the college. The results are shown in Figure 8.

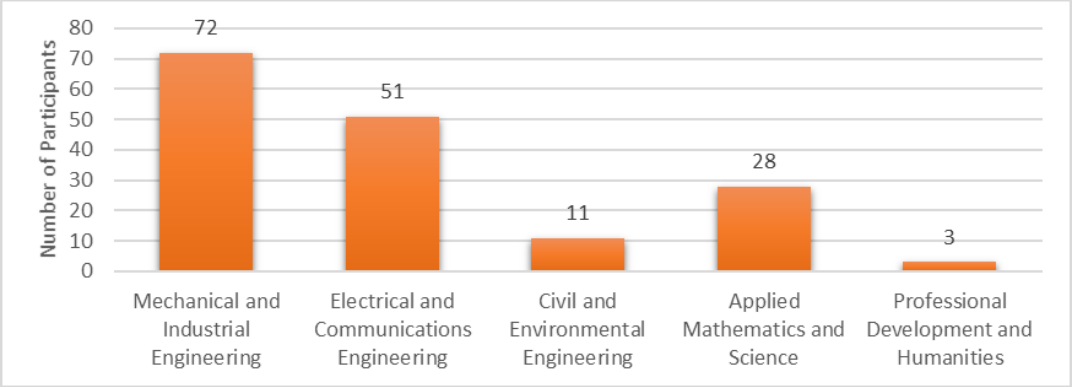

Figure 8: Distribution of teacher respondents by department

Almost half of the teacher respondents, that is, 43.64% (n = 72), came from the Mechanical and Industrial Engineering Department. This is closely followed by those from the Electrical and Communications Engineering Department, with 30.91% (n = 51). The lowest representation came from the Professional Development and Humanities Department, with only 1.82% (n = 3) of the teacher respondents belonging to this department. Focusing now on aspects of online learning, the respondents were asked about the number of months of experience they had with this medium of instruction. The results in this regard are illustrated in Figure 9.

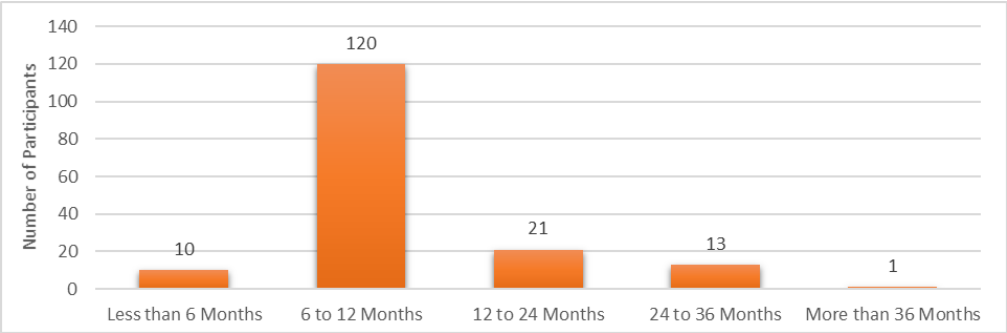

Figure 9: Distribution of teacher respondents by months of experience with online learning

Figure 9 shows that most of the teacher respondents had experience with online learning of only 6 to 12 months, representing 72.73% (n = 120) of the teacher sample. These results show that most respondents were thrust into online courses with little time to learn how to manage the setting. It makes sense, therefore, that even teachers were struggling to cope with the complexities of connecting with students remotely and trying to communicate the complex subject matter. This further highlights the need for a more concerted effort to improve the online learning experience, which, as this study argues, can be facilitated by TQM by implementing QFD.

The last aspect of information asked of the teachers concerning their online classes was related to the platform they most frequently utilized. Note that this does not mean that this was the only one they used. Instead, their response indicates the

platform they preferred using, among other options, during their time using the online setting. The results are shown in Figure 10.

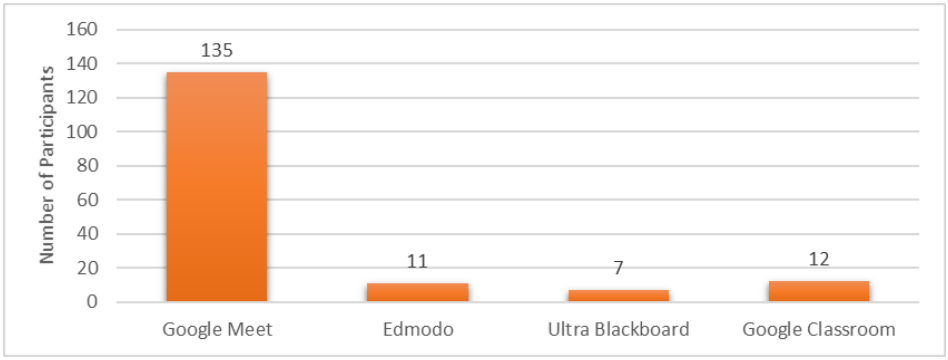

Figure 10: Distribution of teacher respondents by preferred online platform

The data in Figure 10 make it apparent that the teacher respondents generally tended toward using Google Meet for their online classes, as this accounted for 81.82% (n = 135) of all responses. The rest of the respondents were more or less split between the three other platform options in the questionnaire.

4.2 Student Respondents

The second group of respondents in this study was the students, of which 355 were included in the final group to ascertain statistical relevance. Mainly, the same information asked of the teacher respondents was asked of these student respondents, starting with gender. The results are shown in Figure 11.

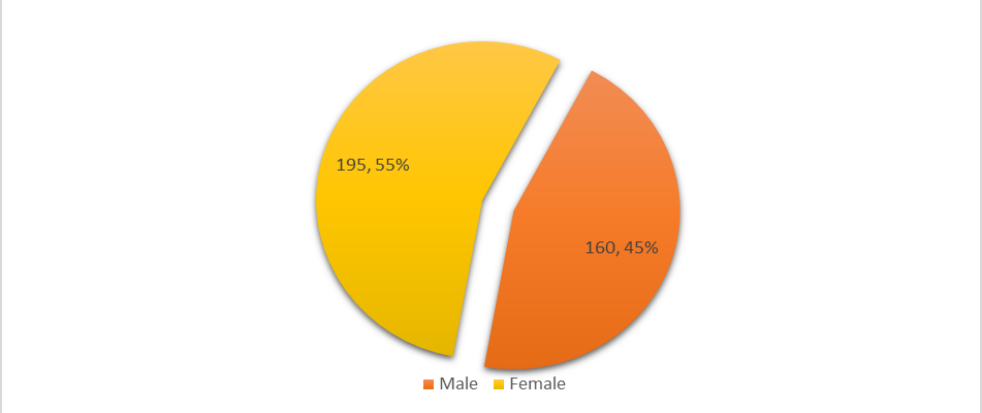

Figure 11: Distribution of student respondents by gender

Just as in the case of the teacher respondents, most of the student respondents were also female, representing 54.93% (n = 195) of the sample, while the male students comprised 45.07% (n = 160). However, in terms of the gap in gender representation, the case for the students is far more balanced when compared to the teachers. In addition to gender, the student respondents were also asked about their age, and the data are illustrated in Figure 12.

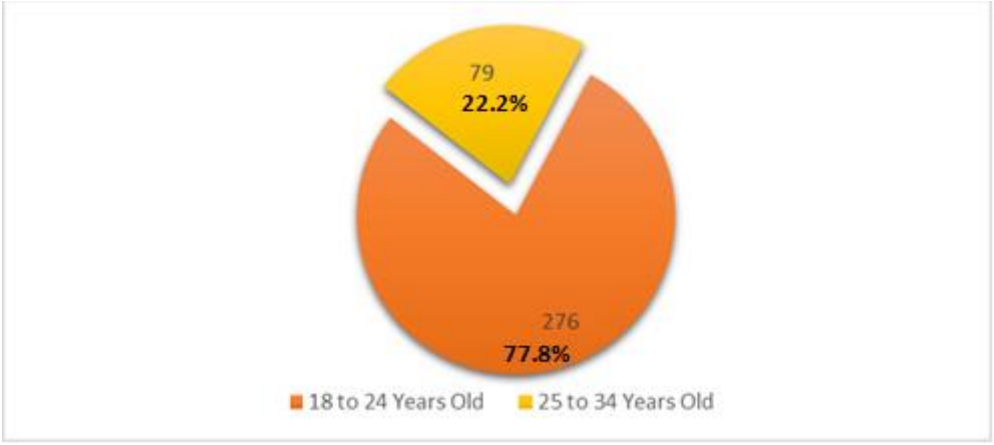

Figure 12: Distribution of student respondents by age group

Compared to the teacher respondents, who had representation across all the age groups covered in the questionnaire, the student respondents only fell within two groups. This is not surprising, as these covered the gamut of all student designations, from undergraduate students to those currently pursuing further studies. Among these two groups, most student respondents were in the 18 to 24-year-old age range, with 77.75% (n = 276), while the rest were in the 25 to 34-year-old age range, with 22.25% (n = 79). Moving away from the personal information, the questionnaire also posed questions about students' education. The first aspect was related to their department in the College of Engineering. The distribution is shown in Figure 13.

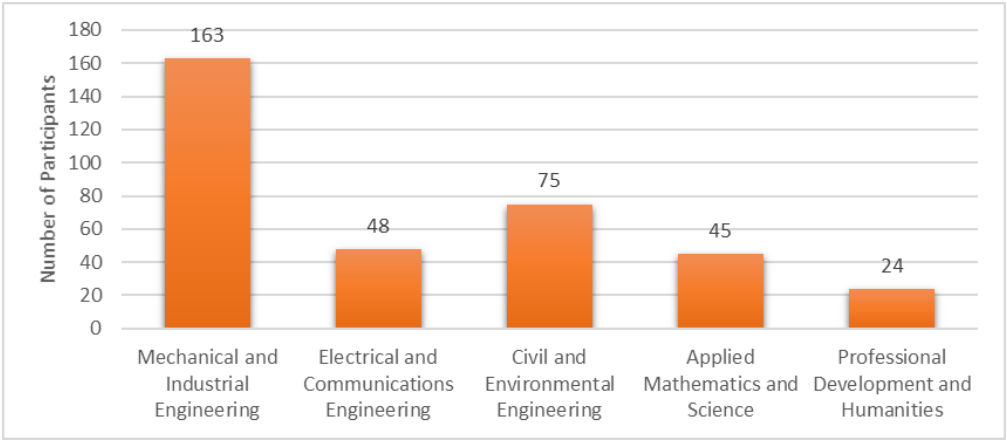

Figure 13: Distribution of student respondents by college department

Interestingly, the distribution across the various departments is similar to that of the teacher respondents. That is, as with the teacher respondents, most student respondents were from the Mechanical and Industrial Engineering Department, representing 45.92% (n = 163) of the sample, followed by the Civil and Environmental Engineering group, with 21.13% (n = 75). The lowest representation, on the other hand, as was the case for the teacher sample, was for the Professional Development and Humanities Department, which only covered 6.76% (n = 24) of the student sample. The following two questions revolved around information on the student respondents' online learning experience.

Respondents were first asked about the number of months they spent with this setup, considering both experiences before, during, and after the pandemic. The distribution of their responses is shown in Figure 14.

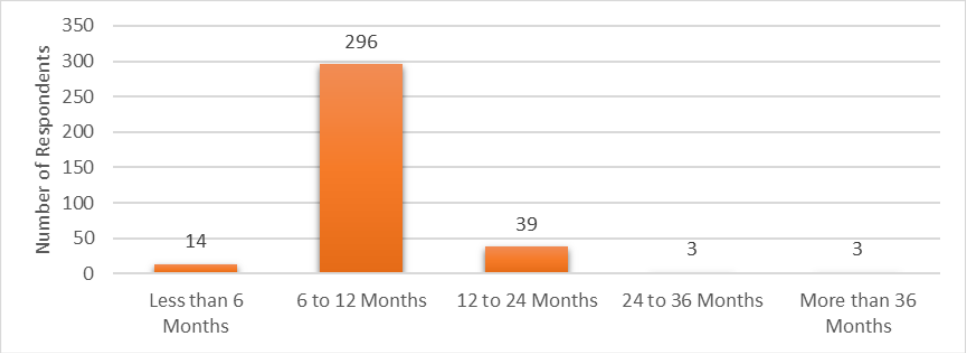

Figure 14: Distribution of students by time spent with online learning

The results are staggeringly skewed toward the 6 to 12-month horizon, equivalent to the time when in-person classes were suspended because of various issues, such as abnormal weather conditions, less attendance due to traffic issues, etc. Most of the student respondents, that is, 83.38% (n = 296), fell in this category. This shows that, just as in the case of the teachers, the students were thrust into an educational setup foreign to them. They had to adjust as they went along, which would inevitably affect their education quality. The final question asked to the student respondents in this part of the questionnaire related to the most frequently used platform for their online classes. The results are shown in Figure 15.

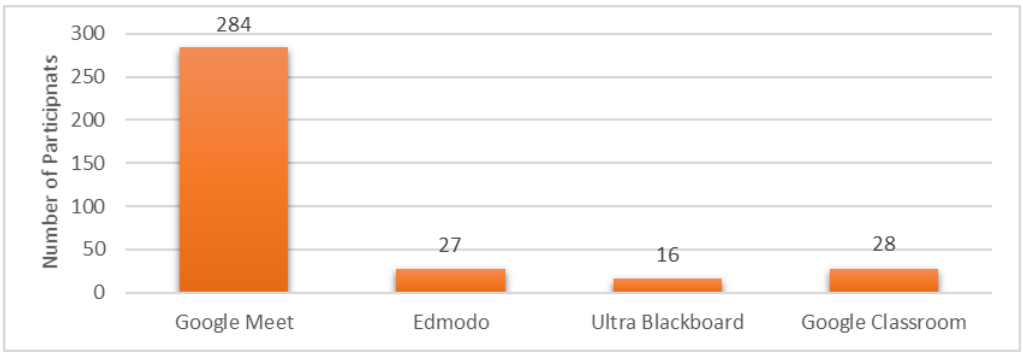

Figure 15: Distribution of students by preferred online platform

Unsurprisingly, the teacher respondents' responses to this question paralleled those of the student respondents, as the platforms used by the teacher group would be similar to the ones in the student group, given that they are at the same institution. Figure 15 shows that most students used Google Meet, with 80% (n = 284) indicating thus. The rest are closely distributed among the other options.

4.3 Understanding the Voice of the Customer

To better understand and identify the nuances in the customer's voice, three primary levels of analysis were carried out in this research. The first is to show the main trends in how the teachers and the students responded to the various

items of the questionnaire. The second is to evaluate if there are discernible and statistically significant differences in the responses of the two groups. The third level of analysis would highlight the priority technical areas of online learning by aggregating the results of the two groups using the weighted scoring of 70% on student responses and 30 on teacher responses. To this end, Figure 16 shows the average score of each item for both the students and the teachers. The results show that the two groups have apparent differences of opinion. From this, there are several items on which the students scored higher and some that garnered a more robust response from the teachers. This shows that the two groups are not monolithic.

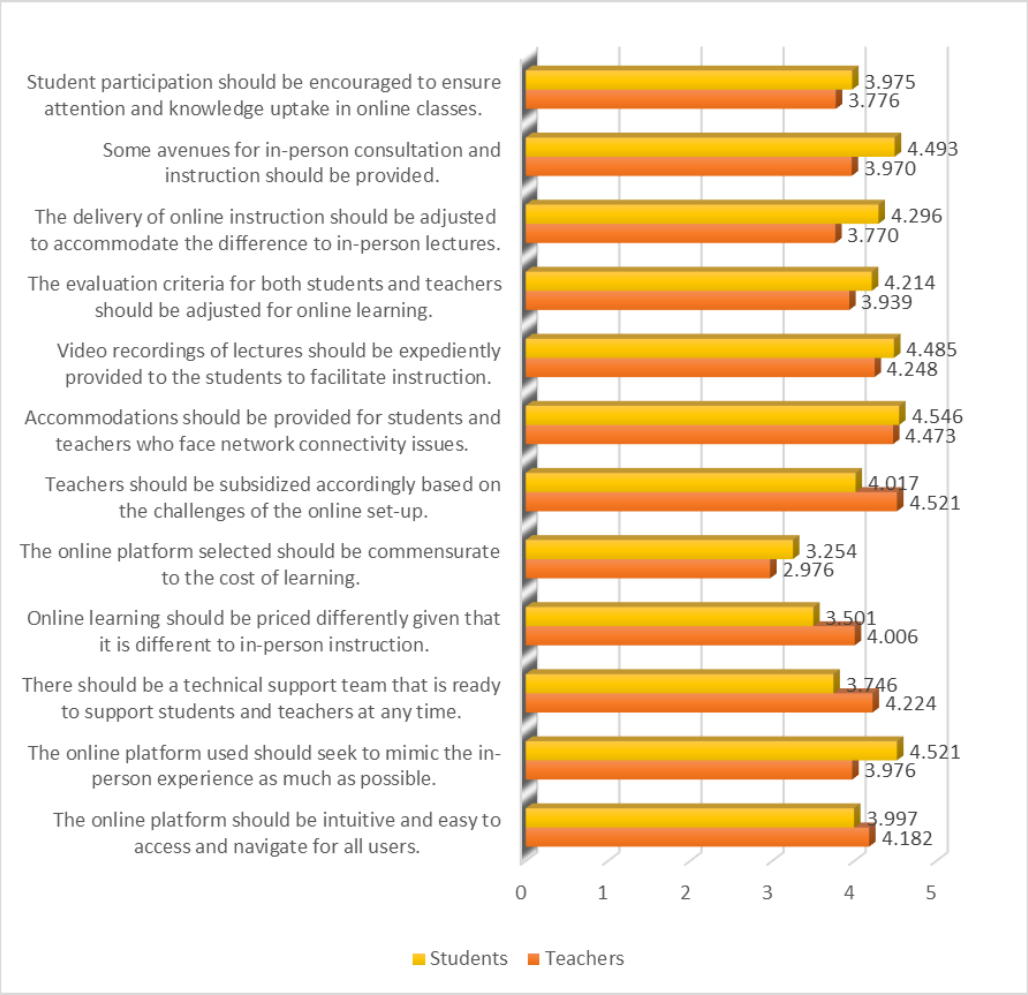

Figure 16: Summary of responses of teachers and students in relation to the technical requirements of online learning

With the overall results now presented, the second level of analysis involves researching more profoundly into the disparity in the opinions of the two groups. Figure 17 presents a visualization of the gap in the scores of the teachers against that of the students. Figure 17 provides a clearer view of the differences in the scores of the two sample groups. Positive values indicate that the teachers scored the items higher, while negative values mean the converse is true.

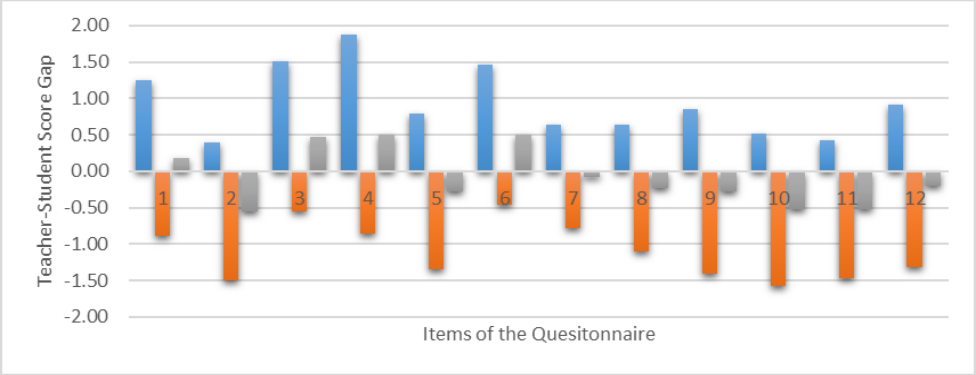

Figure 17: Visual representation of the differences in scores given by teachers and students for each of the items

There were two items on which the teachers scored much higher than the students. The first was the need to have a technical team that is constantly on standby to support teachers and students. This makes sense, because it is typically the teachers who struggle more with the technical aspect of online learning. The data show that many teacher respondents were older than 35, which may mean a steeper learning curve for utilizing these online platforms. The other item emphasizes how the teacher respondents felt more burdened because of the new setup. The students scored much higher on adjusting the delivery in online classes, given that they differ from in-person lessons, and the need to provide in-person courses to provide a mix of experiences.

Delving even deeper into the results, the differences were assessed for statistical significance using the independent samples *t*-test. The results indicate that all the items show a statistically significant difference in the mean scores provided by the respondents. This shows the distinct paradigms through which teachers and students go through online learning. While there may be disparities, a final aggregated priority score was computed from the two groups, and the ratings are shown in Figure 18. Among these, the six highest scores will be considered for the house of quality construction to represent the customer's voice. Based on the scores in Figure 18, the six critical items deemed the highest priority are isolated in Figure 19. The data visualized in the graph indicate the aggregate score along with the individual ratings by the teachers and students.

Among the six items of highest priority, the top two came from operational factors: the need to provide practical delivery of video recordings, and accommodations and considerations when network connectivity issues affect students and teachers. One technical and one financial factor were also covered in these priorities. The technical factor was the importance of choosing an online platform, whereas the financial factor touched upon the need to subsidize teachers better based on the challenges of the online setup. The last two priorities were functional. These were the need to include opportunities for in-person consultation to supplement the online classes, and the importance of adjusting learning methods to account for the difference in the online experience.

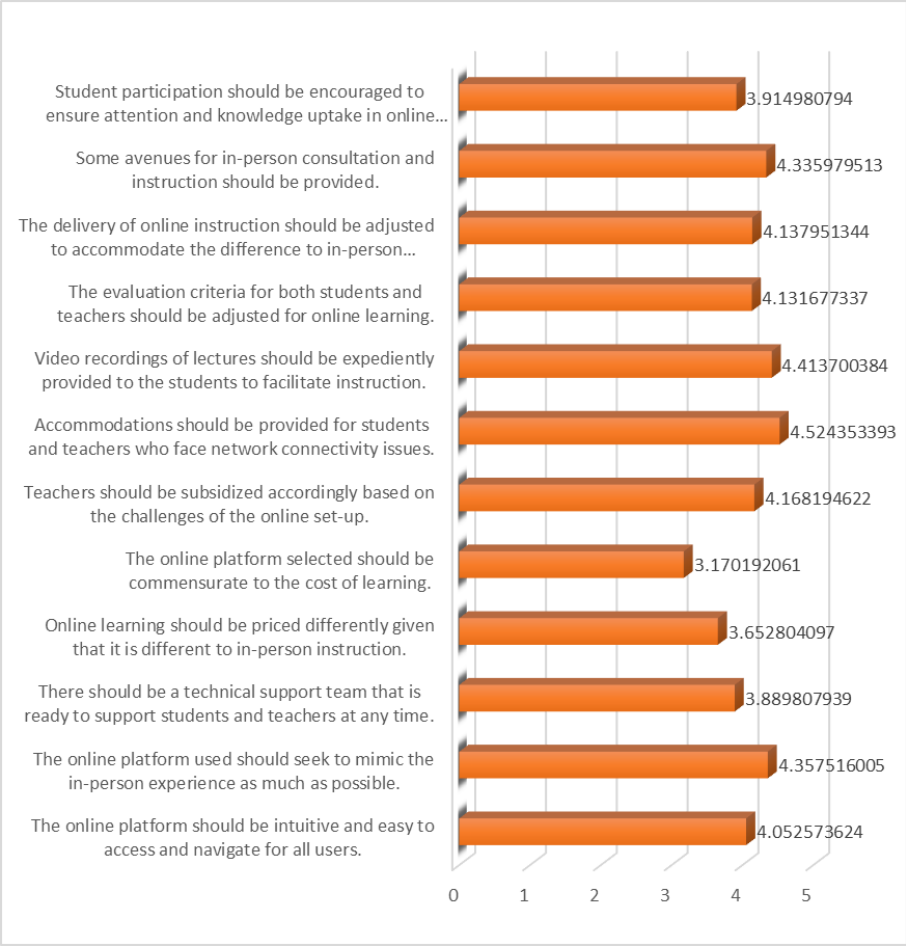

Figure 18: Aggregated scores for each of the items in the questionnaire

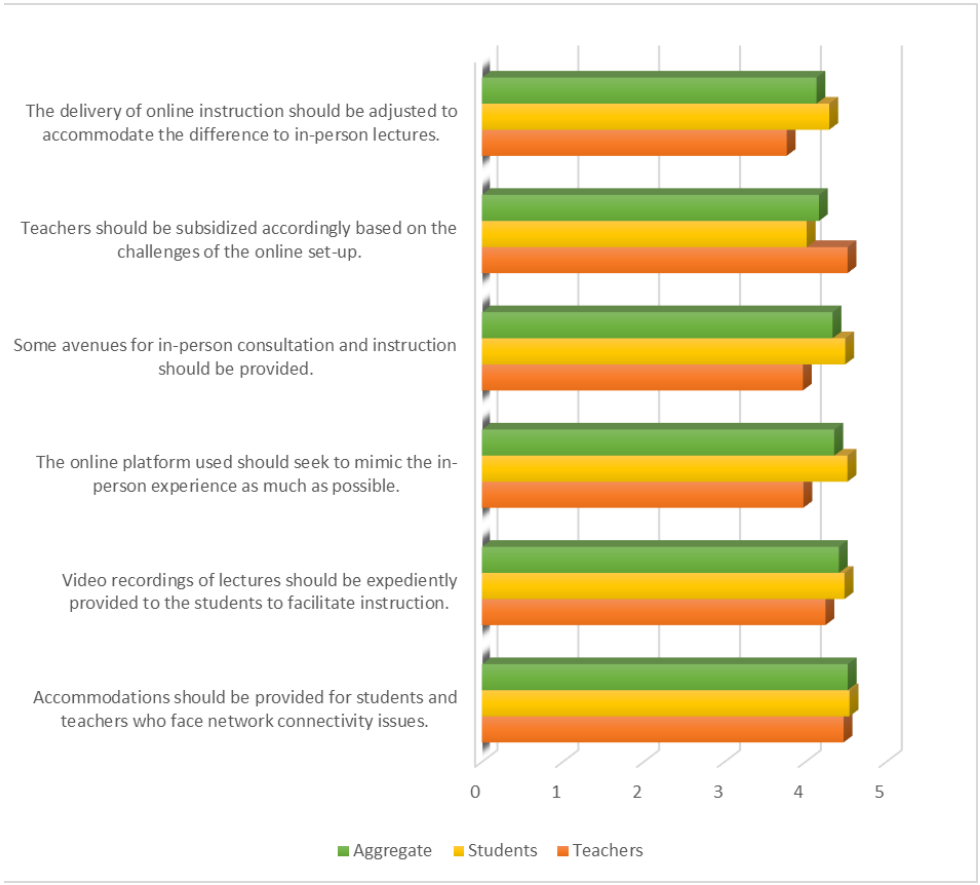

Figure 19: Highest priority items based on computed aggregate scores

5. Constructing the House of Quality for Online Learning

Three main aspects needed to be added to the house of quality: the relationship between the customer and technical requirements from the customer's voice, the target direction of each requirement, and the correlation between requirements. These are all shown in Figure 20 and discussed accordingly.

Customer Requirements	Priority Rating	The online platform used should seek to mimic the in-person experience as much as possible.	Teachers should be subsidized accordingly based on the challenges of the online set-up.	Accommodations should be provided for students and teachers who face network connectivity issues.	Video recordings of lectures should be expediently provided to the students to facilitate instruction.	The delivery of online instruction should be adjusted to accommodate the difference to in-person lectures.	Some avenues for in-person consultation and instruction should be provided.
		Technical Requirements from VOC					
Create an environment of effective learning and instruction for students and teachers.	5	45	45	45	25	45	25
Ensure that students are able to attain knowledge and gain competence.	5	45	5	45	25	45	45
Develop the innate curiosity of the students and make them life-long learners.	4	36	0	4	20	20	20
Inculcate the importance of ethical practice to the students.	4	20	20	4	4	20	4
Make the students confident in their skills and capable of adapting to situations.	3	15	0	3	3	15	3
Emphasize the importance of entrepreneurship and responsive citizenship.	3	3	0	3	3	3	3
Provide an education that is cost-effective.	1	0	9	1	1	0	1
Total Priority Score		164	79	105	81	148	101

Figure 20: House of quality for online learning based on the survey data

The first element that needed to be included in the house of quality is the relationship between the technical requirements of the voice of the customer and the established customer requirements for online learning. In the customer requirements, creating an environment of practical knowledge for students is the first requirement, which was shown to have a sufficiently strong relationship with four of the technical requirements. The first technical requirement is the need to have an online platform that best mimics in-person learning. This makes sense as it would improve the learning context of those involved.

The second technical requirement concerns teachers having to be subsidized better for the challenges of online learning. In this regard, the strong relationship is based on the importance of making teachers feel better about their role in online learning, and this would extend to how well they carry out their roles. The two other requirements also have a strong relationship, which is related to network problems during online learning and the importance of adjusting instructional delivery to the needs of the new method. The second customer requirement of ensuring that students gain knowledge and competence is highly connected to the former. The former is strongly related to selecting an online learning platform that translates the needs of in-person learning virtually, extending accommodations in case of connectivity issues, and the value of adjusting the mode of instruction and delivery to leverage the new learning environment. In addition to these, it is highly recommended to provide avenues for in-person consultation for better understanding and to enhance knowledge. This would allow improved competence to be developed due to the additional time spent with the student. Developing the student's innate curiosity was the only factor highly related to an effective learning platform, as this would lead to uninterrupted learning, and the student can focus on their pursuit of new knowledge. Helping students gain a favorable understanding of ethics and ethical practice also had no strong relationships, but this was somewhat related to choosing the right platform, subsidizing teachers properly, and ensuring delivery is appropriate. The requirement to make the student more confident and adaptable had no solid correlation with technical specifications. Still, a minor relationship was found on the ones that underscored seamless instruction. The same could be said for the customer requirement, which involves developing strong and active citizens among the students and cultivating the entrepreneurial spirit. The last requirement considered was ensuring that the education provided is cost-effective. This was the only factor strongly related to paying the teachers more due to the hassles of online learning, as this was the sole financial aspect considered. With all the relationships established, the technical requirements drawn from the customer's voice can be given a final prioritization score, as shown in Figure 19.

Another aspect of the house of quality is deciding the target direction of each requirement. This was evaluated based on whether they needed to be increased or decreased or if a specific amount was to be prescribed. Apart from this, correlations between the requirements were also identified. This was done by carrying out a bivariate analysis of the scores the teachers and students gave. Those found to have a positive correlation that was statistically significant at the 0.05 level were deemed to have a weak positive correlation. In comparison, those significant at the 0.001 level were considered vital. A similar nomenclature was followed for negative correlations. The item pairs with no statistically significant correlation were noted as having no relationship between factors.

6. Main Findings and Analysis related to QFD Implementation in HEIs

In looking at the prioritization scores computed in Figure 20, two technical requirements scored notably higher than the rest. The first is the need to choose an online platform that aligns well with students and teachers and best imitates

the nuances of in-person instruction (score 164). The second is the need to adjust instruction delivery to raise the challenges and complexities of online communication (score 148). Both factors align with the main challenge for students and teachers to improve the delivery of coursework and course material in the online setup. As such, universities should seek to evaluate platforms that can help bridge the virtual disconnect in these classes while also supporting teachers by giving them workshops and similar training and development opportunities that would give them a better handle on online teaching. The data show that most teachers were thrust into this setup without prior experience, so this study was necessary. The other four requirements scored well in priority (scores 105, 101, 81, and 79) but were relatively similar in the final assessment. This is not to say that these are unnecessary to fortify the online learning experience. Instead, a better analysis would be that they should be pursued after the top two priorities from the house of quality have finally been addressed and covered by the relevant organizations.

As stated in the introduction section, four objectives were adopted to execute this case study in the HEIs in the Sultanate of Oman. The first two were to utilize QFD to understand the issues better and to solve complexities that students and teachers faced, respectively. This led to an evaluation of the voice of the customer buoyed by the principles of QFD, and from this, the six main requirements for improved online learning were identified. In addition, the house of quality analysis was implemented in the study to refine the consideration of these six main requirements by evaluating how they relate to the standard requirements. Among these, two main requirements were determined to be the most pertinent: selecting an appropriate online learning platform that translates the nuances of in-person instruction into the virtual setting, and making changes and adjustments in the delivery of course material. This was regarding the identification of gaps in the current approach to online learning in Omani HEIs. Moreover, the entire analysis, in relation to using QFD as driven by principles of TQM, was geared toward meeting the fourth objective of the case study, namely to provide recommendations to HEIs for enhancing the online learning experience.

7. Conclusion

The data revealed that students and teachers are relatively new to the online learning setup, as many have only had experience with online learning during the shift due to the digital transformation. The implication is two-fold. First, the students are still adjusting to this new learning style, and second, the teachers are still grappling with the challenges of translating instruction virtually. From this challenging context, it was found that the two groups have different priorities regarding improving online learning. The students focused more on the learning experience and how they would better understand the course material. On the other hand, the teachers emphasized the logistical challenges of the setup and how they need better support. Ultimately, the study identified six requirements that address the needs of both groups, allowing for recommendations for improvement to be made. However, the study has helped to expand the body of knowledge relating to the use of TQM and QFD in the higher education setting,

and more so in online learning. In addition, the case study has also provided much-needed insight into the implications of the educational experiences of students and teachers in HEIs, which is essential as researchers begin to grapple more holistically with the effects of Industry 4.0.

In the implementation of online learning, there are many managerial implications related to institutional leadership, changing organizational structure, financial commitment, staff training, and creating a smooth learning and teaching environment. Among these factors, the decision of the institution's leader on whether to adopt or not adopt the new technology-based learning is more important. An institutional leader is responsible for implementing and testing new strategies in learning and teaching, including online education. Similarly, the finance manager's role is equally important in realizing the importance of new methodologies and securing money to procure digital devices and relevant software related to online teaching.

8. Limitations and Future Work

The study's limitations are the sample size and group of students. This study was done in HEIs that conduct engineering-related programs. There may be a chance of deviation if the survey is conducted in institutes concentrating on arts and science curricula. Even though the online mode will be an essential learning methodology in the future, the outcome or prediction may vary slightly for regions but not significantly. However, it can be concluded that QFD is an excellent tool to assess the effectiveness of the online learning methodology.

Some recommendations for future work are provided as a final area of discussion. The first is methodological recommendations, which are improvements to the current data collection and analysis approach adopted in this study that can be applied in new iterations of the research. Next, research can be done to extend and expand the insights developed in this work. Regarding the methodological recommendations, the most pertinent is the need to expand the study sample. This work is more closely related to a case study, given that the sample was strictly from a single college or a university. For a better understanding of HEIs in Oman, a good mix of public and private institutions should be included in future work. Another methodological improvement would be the potential of triangulating the data collected by including qualitative research, specifically semi-structured interviews with students and teachers, to help elaborate upon the data. This study took a broad approach to online learning, hence a deeper dive would undoubtedly be productive. Similarly, it would be interesting to evaluate how different online learning setups (e.g., purely virtual, mix of in-person and virtual, etc.) affect the overall learning outcomes of students in HEIs based on academic achievement and their evaluation of their educational development. This would provide a necessary nuance to the entire online learning discussion and lend insight into its effects on students' academic growth.

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