Exploring the Quality of Course Deployment in Engineering Education: A Quantitative Assessment using Quality Function Deployment

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1 ABSTRACT

Due to the rapid changes of the industrial landscape, engineering education is becoming more dynamic in meeting the needs of the 21st century. Many industries may likely prefer special skills over traditional degrees, which necessitates the to keep updating our course curricula in response to the required skillsets. At the same time, it is very important to understand students' perceptions of this rapidly changing educational portfolio. This paper attempts to explore how our rapidly changing course curricula can develop students' skillsets while maintaining their expectations and adaptability. To do so, we conduct a well-organized anonymous student survey on the different aspects of a particular course and evaluate using the Quality Function Deployment (QFD) tool, subsequently. The course titled "Design for Manufacturability" (MFG 5311) is used as the case study in this study, where 17 students enrolled in this course were considered as the study population. The course was offered as one of the core courses of the Industrial, Manufacturing, and Systems Engineering (IMSE) department at the University of Texas at El Paso (UTEP) in the Spring 2021 Semester. From this study, we extract several key findings regarding curricular enhancement, students' expectations, and technical skillsets development from students' perspectives.

Keywords: Engineering Education; Quality Function Deployment; Curriculum Review; Design for Manufacturability

2 INTRODUCTION

The proliferation of computers and information technology changes the landscape in every sector ranging from industrial domain to federal/non-federal companies to societal issues [1-3]. Consequently, today's engineers are facing continuous challenges due to the rapid changes in the problem domain [4, 5]. Operational and production systems become dynamic, customer demands are shifting, systems parameters are changing, and cyber-physical systems are introduced in many systems. Together, it creates a new transformation of the industrial revolution and we are in the phase of industrial 4.0. The very nature of work is changing due to technological advances and rapidly evolving supply chains and customer needs. Most employers, nowadays, expect that their workforce should have skills and competencies with state-of-the-art technologies. According to the U.S. Bureau of Labor Statistics (BLS), the industry has begun adding more jobs in manufacturing after the economic recession of 2010. However, the nature of jobs has changed, with fewer jobs at the manual assembly line and more jobs running on computers or machines [6]. Obviously, the future generation needs to be smarter, more innovative, technologically sound, and efficient to cope with the entirely new environment of industries.

To develop smart and skilled next-generation students, there are no alternatives to providing good educational training with the latest concepts and technologies. This indicates the need for curricula adjustment and academic transformation to meet the educational goals and objectives.

Universities, usually, set different missions and visions to address the needs of the society and job market. Here, classroom teaching and training play a critical role, but the education contents should reflect the right needs. It is the instructors' role to ensure quality education through a proper course design. While designing the course, sometimes, the student needs and perceptions are overlooked. It is very necessary to align the instructor thinking with the students' opinions and societal needs to ensure quality education. However, the quality of education remains vague and subjective in most cases. In common practice, universities arrange the course evaluation at the end of the semester, which provides an overall rating about the course where the different aspects of course design are not justified.

Here, we attempted an approach using the quality function deployment (QFD) [7] tool to evaluate the quality of course design and delivery in the classroom setting. To do so, we consider the different aspects of the course design, perform a student survey, identify the technical requirements, and build a correlation matrix to understand the overall course quality and prioritize the technical needs. The rest of the paper is organized as follows: the detailed methodology is described in Section 3; Section 4 shows the development of the QFD matrix. The results and findings are reported in Section 5 with a thorough discussion. Section 6 concludes this paper with a summarized overview and future aspects.

3 METHODOLOGY

In this section, we describe the methodology for the quantitative analysis for course deployment in classroom settings. Quality function deployment (QFD) is used as the core methodology of this paper. QFD, also commonly known as house of quality (HOQ), is a basic tool used in many applications such as identification of customer satisfaction, product design and development, manufacturing, research and development, information technology, and many other quality functions [8-10]. The concept of QFD is considered more than a design tool. Thus, apart from the design function, QFD is also successfully used in academic environment to understand the classroom settings and improve the quality of education [11, 12]. In general, QFD is a structured approach to integrate the customer requirements, which are prioritized to expedite the design functions and reduce the design cycle. It includes five steps: 1) identifying and ranking the relative importance of customer requirements; 2) identifying design parameters (or engineering characteristics) that contribute to the customer requirements; 3) estimating the relationship between design parameters and customer requirements; 4) estimating the relationship among design parameters; and 5) setting target values for the design parameters to best satisfy customer requirements.

Although there are various ways to conduct the QFD, the voice of the customer is the first most necessary input in this process. In this paper, our objective is the identify the quality of course curricula design from student perspective and today's needs engineering education. Therefore, our customers are the students who enrolled for the course and we need to collect student's voices. To accomplish the objective, first, we conduct an anonymous survey and then convert the survey data into the QFD requirements. The details of the data collection through survey procedure and quality function deployment are illustrated in the following Subsections.

3.1 Survey procedure and data collection

In order to collect students' (customers) voices, a thorough survey was created for the Design of Manufacturability (MFG 5311) and System Engineering Process (SE 5347) courses. These two courses are cross-listed and offered as one of the core courses for the Industrial, Manufacturing and Systems Engineering (IMSE) Department at The University of Texas at El Paso (UTEP). The course is offered in every Spring Semester in Face-to-Face (F2F) format. However, due to the COVID-19 pandemic, the course was offered online in 2020, which necessitated identifying the students' satisfaction in course delivery. As part of this opportunity, we develop a compressive survey using QuestionPro and conduct the survey anonymously. The QuestionPro is a web-based survey platform that provides an efficient mechanism to collect, summarize, and visualize data without revealing responder information. The survey consists of 18 questions to understand the students' background, motivation, and course needs from the student's perspective. The survey questions are listed below.

1. What is your major i.e., Industrial Engineering, Manufacturing Engineering, and Systems Engineering?
2. Are you currently doing any part-time or full-time jobs? If so, is your job responsibility aligns with the field of your major?
3. How many hours (approximately) you can spend (weekly) for your study purpose?
4. Are you familiar with the course curriculum of your major field?
5. Are you familiar with the course curriculum for the course "Design of Manufacturability/System Engineering Processes"?
6. What is the reason you are enrolled in "Design of Manufacturability/System Engineering Processes"?
7. Are you comfortable with the class time? (6.00 – 8.50 PM)
8. Are you getting enough exposure to industrial, real-life problems in this course?
9. Are you getting enough exposure to software tools (Lindo/Lingo, Visio, Excel, etc.)?
10. Are you getting enough to expose to the methodologies taught in this course?
11. Based on your perception of the classroom setting, please rank the following (1-10) criteria in the order of importance (1 being the least important and 10 being the most important)
    a. Interactive class sessions
    b. Interaction with students
    c. HomeWorks and Class projects
    d. Leaning state-of-the-art-contents in manufacturing and systems engineering field
    e. Flexibility in classroom activities
    f. Exposure to real problems
    g. Opportunity to practice/apply knowledge
    h. Enhancing subject matter problem-solving skills
    i. Developing software skills
    j. Accessibility of the course content through the online platform
    k. Face-to-Face classrooms
    l. Online class sessions
    m. Hybrid class sessions

12. Apart from the above list, what other requirements do you want to include or see in this course based on your expectations? Please provide the importance in the parenthesis on a scale of 1 to 10.
13. How satisfied are you with the following existing course setting? Please provide your rating on a scale of 1 to 5 (1 being not satisfied at all and 5 being very satisfied)
    a. Lecture materials
    b. Examples in lectures
    c. Homework/Assignments
    d. Class projects
    e. Online learning
    f. Theoretical knowledge
    g. Instructors' office hour sessions and problem-solving
    h. PowerPoint presentation
    i. Contents availability on BlackBoard
    j. Audio/Video quality during the online class sessions
    k. Class recordings
    l. Using Lingo/Lindo/Excel
14. Please rate your course instructor based on the following criteria (on the scale of 1 to 5, where 1 indicate low performance and 5 indicates the best performance)
    a. Clear explanation
    b. Adequate examples in the topic area
    c. Accessibility
    d. Flexibility/Understanding
    e. Explain students' questions/concerns clearly
    f. Approachable
    g. Knowledge in the subject matter field
15. Are you getting enough resources/guidelines to be a success in this course?
16. Do you think the graduate courses should improve their curriculum?
17. If there are two things you can change about this course, what you would like to change?
18. Do you have any other comments/suggestions about this course curricula?

Notice that questions 1 to 10 are identified to understand student's background, motivation, and basic perception about the course. Questions 11 and 12 are designed to get student priority about the classroom settings, whereas question 13 determines the students' satisfaction on various parameters of the existing course design. Question 14 identifies the overall performance of the course instructor. The purpose of questions 15 to 18 is to understand students' feelings about the course improvement and seek additional comments or suggestions. The response of this survey provides the voice of the student body who were enrolled in the MFG-5311/SE-5347 courses. Once collected, we convert this response into the QFD.

3.2 Quality Function Deployment

As shown in Figure 2, to perform the QFD analysis we need to identify the six key components: 1) customer requirement (What); 2) Technical requirements (How); 3) correlation among technical requirements; 4) relationship matrix between "What" and "How"; 5) competitor comparison; and

6) technical assessment. To obtain the quantitative assessment of the curricula deployment, we performed the necessary analysis for each of the QFD components. The description of the QFD component analysis is given below.

Identifying the customer requirement and priorities (WHAT):

The customer requirements or the "voice of customer (VOC)" are lists of customers' needs or expectations that they to have for their products or services. Usually, the customer requirements are identified through several approaches such as focused group interviews, one-to-one interviews, observing the use, collecting email responses, or survey [13]. Here, for our purpose, we have conducted a web-based survey using QuestionPro as described in Section 2.1. 17 students, who were enrolled for the MFG 5311/SE 5347 course, participated in the survey to provide their feedback. We collected the students' voices through Questions 11 and 12 (see Section 2.1). The responses of Questions 11 and 12 come with students' priorities on different parameters of the existing course design. Once collected, we summarized the students' requirements based on priorities and calculate the weights (w_i) for each of the VOC. Students' rating for the VOC is shown in Figure *1*.

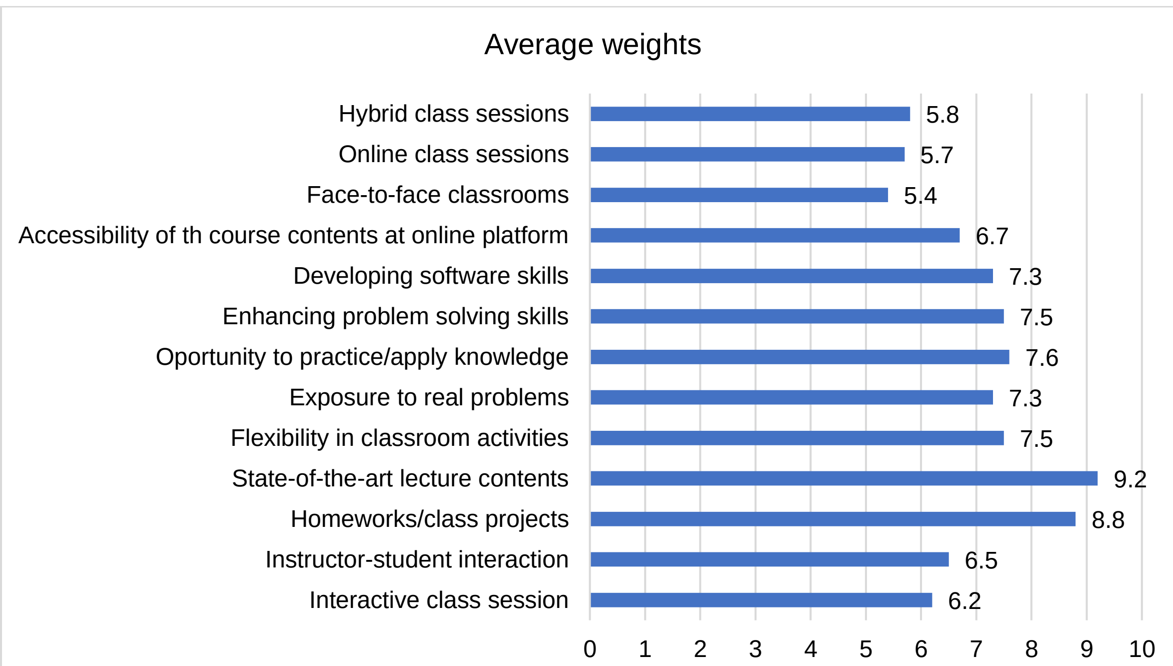

Figure 1. Average weights of students' requirement (VOC)

Identifying the Technical Requirements (HOW)

The technical requirements provide the solution approaches to the customer requirements. Hence, the technical requirements need to be identified carefully to meet all of the customer requirements properly. This task needs expert involvement having sound knowledge about the different characteristics of the customer needs. As the objective of this paper is to get finding in an academic environment, the course instructors are considered as the experts for this purpose. However, given the students' needs and priorities, we discussed with other faculty inside and outside of UTEP, and education experts from the Department of Education to get the appropriate solutions and avoid any biases. Table *1* shows the 15 technical requirements to fulfill the students' needs. For example, updating the lecture materials at a certain time period can provide the opportunity to the state-of-the-art learning contents into the course design. Similarly, incorporating group assignments or mini lab sessions may help to make the classroom more interactive and provide a practical learning opportunity. Notice that the individual expert rating is collected from 6 faculty and later averaged to get the overall rating for each of the technical requirements.

Table 1. Technical characteristics to meet the course needs

No.	Technical requirement description	Expert rating
1	Updating lecture materials at a certain time period	8.35
2	Incorporating group assignments or mini-projects	6.97
3	Adding optional mini-lab sessions	5.80
4	Instructor's office hour	7.2
5	One-to-one tutoring hours with TA	6.86
6	Specific problem-solving examples from each learning module	7.62
7	Use of discussion board on BlackBoard platform	6.35
8	Hands-on activity sessions	7.56
9	Individual projects	6.67
10	Software tutorial sessions/lectures	7.13
11	Add supplementary reading/activity materials	5.75
12	Use of interactive technology for an online class such as Wacom devices	8.20
13	Use of audio/visual contents in lecture materials	7.98
14	Real-world case integration and analysis	7.23
15	Class recording and make it available on BlackBoard	8.10

Correlation among technical requirements and competitor comparison

Since all the technical characteristics are affected positively by each other, we did not consider the correlation matrix among the technical requirements. In addition, as course curricula design mostly depends on the instructors derived from geographical, societal, and workforce needs, there are no set, of course, design/activities that can be considered as standard or competitor. Hence, we did not consider the analysis for the competitor comparison component.

Relationship matrix between "What" and "How"

The relationship matrix provides the quantitative indication of how the customer requirements related to the technical requirements. According to the QFD guidelines, we used a three-scale rating for each of the pair-wise relations between WHAT and HOW. The relationships are ranked as strong (●), medium (⊕), and weak (▲) with the numeric value of 9, 3, and 1, respectively. We evaluate each pair of WHAT-HOW relationships and fill that corresponding cell with an appropriate notation. For example, the technical requirement of “Instructor’s office hour/one-to-one tutoring hours” is very much related to increasing the interaction with students, thus their relationship has been determined as “strong”. On the other hand, “updating lecture material” (HOW) has a very little relation with “interaction with students” (WHAT), which makes this pair a weak relation. If there is no relation between any pair of WHAT-HOW, the cell is left blank and we consider zero for that cell value. For example, updating the lecture materials has no relation with the class flexibility or accessibility of the course contents. Thus, we fill all the cell (r_{ij}) of the relationship matrix, which is later used for technical assessment.

Technical Assessment:

The technical assessment measures how well each of the technical requirements fulfills the needs the customer requirements. In our case, we determine the appropriateness of the course design (activities) in response to the students’ needs. Following this step, the course activities can be prioritized based on the normalized score (ns_j) obtained from the QFD tool. The score of each technical requirement (s_j) is calculated using Equation 1. Later, the scores are normalized according to Equation *2*.

$$s_j = \sum_{i}^{n} (w_i * r_{ij}) \tag{1}$$

$$ns_j = \frac{s_j}{\sum_j^m s_j} \tag{2}$$

where, m and n indicate the number of technical requirements and customers’ requirements, while i represents their corresponding index, respectively.

4 DEVELOPMENT OF THE QFD MATRIX

The quality function deployment matrix is shown in Figure *2*. The right of the matrix shows the students’ needs (VOC) along with their respective weights, which are directly obtained from the student survey. The technical requirements, at the top of the QFD matrix, are identified to meet the students’ needs as discussed in the above section. Notice that we did not consider the top roof of QFD, correlation among the technical requirements, as all the technical characteristics positively affect each other. As this QFD is for course evaluation and considering the fact that all courses have their distinction, we did not compare it with any other courses. Hence, we avoid the competitor assessment component of the QFD. In the middle, the relationship matrix is filled with the notation to represent the strong, medium, and weak relationship for each pair of WHAT-HOW. The relationships are identified through careful observation and intensive discussion with students and faculty. At the bottom of the QFD matrix, we show the technical assessment with score and relative importance, which are calculated using Equation 1 and Equation *2*. Later, the technical requirements are ranked according to their relative importance.

Students' Need (VOC) \ Technical Requirements	Weights in the scale of 1 to 10	Weight in percentage (%)	Updating lecture materials at every two years	Incorporating group assignements or mini-projects	Adding optioanl mini-lab	Instructor's office hour	One-to-one tutoring hours with TA	Solved example problem from related learning module	Use of discussion board on BlackBoard platform	Hands-on activity sessions	Individaul projects	Software tutorial sessions/lectures	Add supplementary reading/activity material	Use of interactive technology for online class such as wacom devices	Use of audio/visual contents in lecture materials	Real-world use case integration and analysis	Class recording and make it available on BlackBoard
Interactive class session	6.2	6.8	⊕	⊕	●			●	▲	●	1	▲	▲	●	●	⊕	
Instrauctor-Student interaction	6.5	7.1	▲	●	●	●		⊕	⊕	⊕	⊕	▲	▲	●	⊕	▲	
Homeworks/class projects	8.8	9.6	●	●	⊕	●	●	●	⊕	⊕	●	⊕	▲	▲		▲	
State-of-the-art lecture contents	9.2	10.1	●	●	⊕	▲	▲	▲	▲	▲	⊕	⊕	⊕			▲	
Flexibility in classroom activities	7.5	8.2			▲	⊕	⊕	⊕	⊕	▲	⊕	▲	⊕	▲	▲	⊕	●
Exprosure to real problems	7.3	8.0	⊕	⊕	▲		▲	⊕		●	●	▲	▲			●	
Opportunity to practice/apply knowledge	7.6	8.3	⊕	●	⊕		▲	⊕		●	●	⊕	▲			●	
Enhancing subject matter problem solving skills	7.5	8.2	●	⊕	⊕	▲	●	●	▲	●	●	▲	▲			⊕	
Developing software skills	7.3	8.0	⊕	⊕	●	▲	⊕	▲		⊕	⊕	●	▲			▲	
Accessibility of the course content through online platform	6.7	7.3							▲				⊕				●
Face-to-face classrooms	5.4	5.9			▲				●	●	▲	▲	▲	▲	⊕		⊕
Online class sessions	5.7	6.2			▲				●	⊕	▲	▲	⊕	●	●		●
Hybrid class sessions	5.8	6.4			▲				●	⊕	▲	▲	⊕	●	●		●
	91	100															
Score			414	471	413	217	267	397	323	539	499	269	253	262	248	298	282
Relative importance			8	9.1	8	4.2	5.2	7.7	6.3	11	9.7	5.2	4.9	5.1	4.8	5.8	5.5
Ranking			4	3	5	15	11	6	7	1	2	10	13	12	14	8	9

Figure 2. The QFD matrix for quantitative evaluation of course deployment

5 RESULTS AND FINDINGS

Overall, we perceived three key findings from the students' survey and QFD analysis. The first important result is from the survey is that about 53.75% of students expressed their satisfaction with the existing design of the MFG 5311/SE 5347 course. On the other hand, 37.35% of students feel that the existing course curricula should be restructured to improve, while 8.9% of students showed their neutral opinion. Assuming that this 8.9% of students vote for course restricting, we have a large portion (46.25%) of the student group who want to see changes in the existing curricula. This finding helps the instructors to understand students' overall perception of the course and realize the importance to changes the curricula to meet student needs. Given this necessity, we find a way of changing through the QFD analysis, which is obtained in the second and third findings.

Given the above needs, we have the findings to understand the customer/student requirement, as shown in Figure 1. The results produced a priority and rank of the student requirements focused on this specific MFG 5312/SE 5347 course. These results yielded insight into the students' expectations and needs. It is good to know that most of the students are interested in learning the latest topic and concepts in their field of education and thus provide high weights to the requirement of state-of-the-art content in manufacturing and system engineering. Students provide the second most importance for the homework and class projects. Students are also very positive to be exposed to a real-world problem and enhancing their skill sets in problem-solving, thus getting the third priority on this requirement. Together, these requirements deal with the content design and structuring of the course. Therefore, the students have a high expectation of getting relevant course content and being able to put the learning into practice with their homework, assignments, and class projects. Surprisingly, our finding reveals that students are not too much concerned about the way of course delivery i.e., F2F, online, and hybrid method. This is good that student feels positive as long as they can learn the desired knowledge from the course.

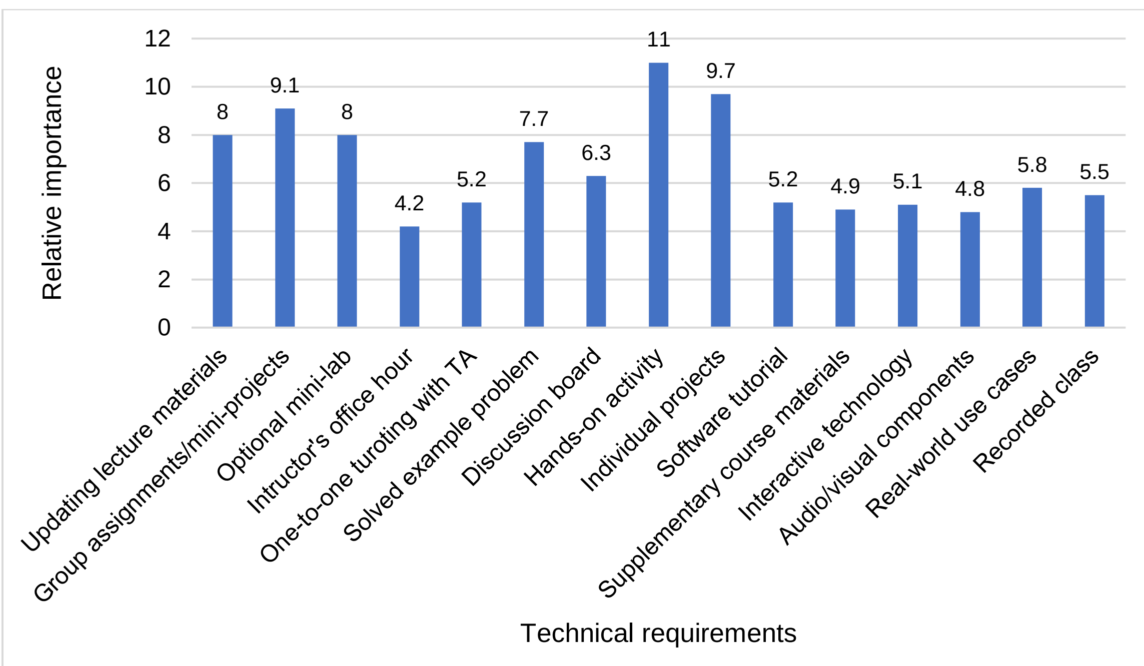

Figure 3. Relative weights of technical requirements

In the third finding, we determined and prioritize the technical requirements to improve the course design. As shown in Figure *3*, the requirement of hands-on activity gets the highest importance. This suggests that we need to design the course curricula with more hands-on activities. Having more hands-on activities can make the classroom more interactive, enhance teacher-student interaction, develop students' capability of problem-solving skills with great exposure to real-world problems. Obviously, the students want more interactive class sessions rather than reading or watching visual presentations in the classroom. While designing the course, the instructor should be careful to have curricula components like individual projects, group assignments/min-project, several short lab sessions. The instructor also should update the lecture material after a certain period of time and include the latest contents and concepts in the respective field of study. Thus, we can improve the course curricula and meet the students' satisfaction in shaping their future academic or career goals.

6 CONCLUSION

In this work, we tried to understand students' perceptions of existing engineering courses and used the quality function deployment to obtain a quantitative assessment to improve the course curricula. The paper revealed that about 53.75% are satisfied with the existing curricula while the rest of the students (including 8.9% with neural opinion) feel the necessity to improve the course. With this observation, we identified that besides the regular class lecture, adding the hands-on activity, designing individual class projects, group assignments, short-lab sessions, updating course contents would be effective in meeting students' needs and making their learning process more interesting and effective. However, this study had several limitations including short survey time, limited expert opinion, and sometimes students being reluctant to provide their comments and suggestion. Another major, limitation is that these findings are obtained based on the student groups from a single course and single semester. However, the survey with other students' groups with multiple engineering courses at different semesters would generate a more generalized and comprehensive quantitative evaluation and judgment. With that motivation, in the future, we plan to conduct a more intensive and wide survey across UTEP's college of engineering with multiple courses and a longer time frame.

7 ACKNOWLEDGMENTS

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8 REFERENCES

[1] D. W. Jorgenson and K. J. Stiroh, "Information technology and growth," *American Economic Review,* vol. 89, no. 2, pp. 109-115, 1999.

[2] J. Dedrick, V. Gurbaxani, and K. L. Kraemer, "Information technology and economic performance: A critical review of the empirical evidence," *ACM Computing Surveys (CSUR),* vol. 35, no. 1, pp. 1-28, 2003.

[3] M.-C. Boudreau and D. Robey, "Enacting integrated information technology: A human agency perspective," *Organization Science*, vol. 16, no. 1, pp. 3-18, 2005.

[4] J. T. Edwards and G. T. Woo, "An Organized Approach: Challenges Faced by Today's New Engineers in the Petroleum Industry," in *SPE Annual Technical Conference and Exhibition*, 2006: OnePetro.

[5] S. Kumar and J. K. Hsiao, "Engineers learn “soft skills the hard way”: Planting a seed of leadership in engineering classes," *Leadership and management in engineering*, vol. 7, no. 1, pp. 18-23, 2007.

[6] Torpey, Elka, “GotSkills? Think Manufacturing: Career Outlook.” U.S. Bureau of Labor Statistics, U.S. Bureau of Labor Statistics, available at: https://www.bls.gov/careeroutlook/2014/article/manufacturing.htm?cid=20&pnum=76

[7] L.-K. Chan and M.-L. Wu, "Quality function deployment: a comprehensive review of its concepts and methods," *Quality Engineering*, vol. 15, no. 1, pp. 23-35, 2002.

[8] H. H. Tee, "Quality Function Deployment in Product Design and Development: A Case Study," Nanyang Technological University, School of Mechanical and Production, 2005.

[9] A. Costa, M. Dekker, and W. Jongen, "Quality function deployment in the food industry: a review," *Trends in food science & Technology*, vol. 11, no. 9-10, pp. 306-314, 2000.

[10] K. Tan, M. Xie, and E. Chia, "Quality function deployment and its use in designing information technology systems," *International Journal of Quality & Reliability Management*, 1998.

[11] K. Lam and X. Zhao, "An application of quality function deployment to improve the quality of teaching," *International Journal of Quality & Reliability Management*, 1998.

[12] A. Aytac and V. Deniz, "Quality function deployment in education: a curriculum review," *Quality and Quantity*, vol. 39, no. 4, pp. 507-514, 2005.

[13] G. Placzkowski, "Acquiring, Processing and Deploying Voice of the Customer," *Quality Progress*, vol. 34, no. 7, p. 151, 2001.