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Assessing Skills Gap in High Value Manufacturing: An Oil and Gas Industry Continuing Education Case Study*

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Prior research reveals that there is a gap in the skill set of new hires (especially in fresh college graduates) with respect to what is needed to perform advanced manufacturing jobs in industry. Several methods are being employed by both industry and academia to narrow the gap. Academic institutions are designing industry oriented and project-based curricula while industry is partnering with community colleges and universities in supporting capstone projects and developing short courses to meet their needs. This paper investigates the skills gap in high value manufacturing, especially in the energy industry. The research utilizes an energy industry focused continuing education case delivered to 53 participants as a tool to understand the current skill level of the participants and their self-beliefs about the preparedness of the new hires, particularly those who join fresh from higher education. A structured survey methodology is used to assess the program outcomes and investigate the skills gap in the current workforce. The paper also investigates if there are any significant differences in the perceived skills gaps in the current workforce and new hires based on gender, ethnicity, and education of the participants. The case study findings show that current and newly hired industry workforce lacked the needed skills in some key areas of high value manufacturing. The perception of the skills gap in new hires varies by age, gender, and education level of the participants. On the other hand, the case study analysis does not find any statistically significant difference in the skills of current workforce based on the participants' demographic data or the type of industry they work for. The study also finds a significant difference in perceived preparedness level between the type of HVM topics among all groups (participants themselves and current workforce and new hires in their industry).

Keywords: employee skill gap; high value manufacturing; self-assessment; continuing education

1. Introduction

The contribution of manufacturing towards the United States economy is significant and accounts for 11.2% of the total gross domestic product (GDP) [1]. It is estimated that a value of $1.37 is added back to the US economy for every dollar spent on manufacturing, thereby producing one of the highest multiplier effects among all the industry sectors [2]. Despite its economic contribution to GDP, the United States lost 5 million manufacturing jobs between January 2000 and December 2014 [3] due to high manufacturing imports from other parts of the world. Adding to this, Deloitte estimated that approximately 2.4 million jobs will be potentially unfilled between 2018 and 2028 due to the skills gap between industry requirements and talent in the job market. In a study that was done prior to COVID-19 pandemic, 89% of executives agree that there is a talent shortage in the manufacturing sector [4]. The study also shows that the talent shortage is due to the skills gap, which also highlights the lack of proper education or training to prepare a job-ready talent pool [4]. Further, the problem is expected to worsen in the coming decade as a result of the retirement of the baby boomer generation [4]. A recent study on "COVID-19 policy action plan recommendations" estimates that around 53.1% manufacturers anticipate a change in operations and 35.5% of manufacturers are facing supply chain disruptions [5]. On the other hand, even though the manufacturing industry lost 5 million jobs between 2000 and 2014, during the same period the number of workers with graduate degrees increased by 35% and the number of workers with associate degrees increased by 23%[6].

To narrow these skills gaps, several approaches are being considered by both educational institutions and industry including both formal career oriented education programs in high school and junior colleges and training programs in industry [7]. The educational programs include certifications, diplomas, associate, and bachelor's degrees targeted to bridge the skills gap of the workforce. Although it is recognized widely that proper need analysis helps develop a right program for the right

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job, prior literature suggests that it does not frequently take place and is often not done adequately in the organizations [8]. Research suggests oftentimes the training programs are developed without a rigorous need analysis. This leads to a risk of not attaining the objectives [9]. In order to close the skills gap, the business leaders are focused on multiple strategies including K-12 curriculum, postsecondary credentials and certifications, and upskilling the current workforce through training[10]. Turek and Perek-Bialas [11] suggest that the influence of age differences in the workforce increases the need for implementing a continuing education program in order to improve on the worker's productivity. The other factors impacting training and development activities as well as employee inclination to participate vary based on the size of a business [12–14] and gender and diversity [15]. Overall, several approaches have been in practice to improve workforce skills through various credit (degree program) and non-credit (continuing education) programs in engineering fields and others. However, there are very few prior studies available specific to high value manufacturing. Furthermore, prior studies also lack a quantitative assessment of workforce preparedness specially in the fields of high value manufacturing.

The objective of this paper is to investigate the preparedness of current and future workforces in the area of high value manufacturing, especially in the oil and gas industry. It provides a quantitative assessment of preparedness of the current workforce and new hires in high value manufacturing. This study utilizes a series of continuing education sessions as an assessment tool that allows participants to self-evaluate on certain topics related to high value manufacturing. The continuing education sessions expose the industry participants to a few key HVM topics thereby providing them with an opportunity to self-evaluate their current skill level in those specific topics. In addition, the assessment tool also asks the participants to provide a general assessment of their current colleagues and new hires in their companies with respect to HVM topics under discussion. It may be noted that skill levels of future hires are indirectly measured through the assessment of skills of "new hires" who joined the company fresh out of college just like the future hires who would be joining the workforce from similar academic programs. The proposed continuing education-based approach provides topic specific data which allows hiring managers and workforce training developers to gain perspectives on future training needs and hiring strategies. Unlike a generic survey that only provides a list of skills set, the unique benefit of using continuing education environment for assessing workforce preparedness is, in this case, the participants know the actual content of a topic therefore can provide a more accurate response. Further, the present study also analyzes the perceived skills gap in the current and future workforce (or new hires) with respect to the selected HVM topics based on demographic variables such as gender, diversity, and education of the participants, and the type of employer such as size of their employers to understand if there are significant differences in the skills set of various population groups.

The remaining sections of the paper is organized as follows: Section 2 provides an overview of related literature. In section 3, the research methodology is described including research design, the survey instrument, and the data collection method. Data along with the analysis results are presented in section 4. Section 5 discusses managerial implications of findings of this research. Lastly, in section 6, the key findings of this research are summarized along with ideas for future work.

2. Literature Review

Following World War II, in the 1950's and 60's, people in the United States were able to secure jobs with middle-class wages in the manufacturing industry even with a high school diploma [16]. However, that trend has changed in the subsequent decades because of the increased demand for workers with the education of high school diploma or more. According to a Georgetown university report, globalization, automation, upskilling, and job shift (across industries) are the major reasons for increased emphasis on postsecondary education to get a good manufacturing job which pays a median of $65,000. Automation itself, in the last two decades, replaced around 5.7 million manufacturing jobs in the United States[16]. Globalization is making the current skills obsolete and creating a need to update skills with new manufacturing competencies across the world [17]. As a result of globalization and automation, employers are demanding high skill workers with post-secondary education. Below are some of the post-secondary education options and efforts undertaken to bridge the skill gap.

2.1 *Efforts to Bridge Gaps through Educational Attainments/Degrees*

Professional education and certifications play a crucial role in supplying the skilled workforce to the ever-demanding manufacturing industry. Though the number of degrees awarded in the U.S. is increasing year on year, some companies are concerned that the new college graduates do not yet have the proper skills to start working in the manufacturing industry [18]. There seems to be a major disconnect between educational institutions and industry, i.e. the universities are not able to match the pace of the technological advancements in the industry [19]. One way of bridging this skill gap is through continuing education of current students as per industry needs [20], i.e., organizing professional development sessions for the students where they get to learn the skills (knowledge) required for the industry. For teaching math intensive engineering courses, problem-based learning methodologies can be employed to expose students to industrial problems [21].The active learning methodology is beneficial in increasing student's engagement in the classroom for undergraduates [22] and yields better academic results compared to conventional teaching [23]. Literature suggests that in order to gain maximize the student learning during industry internship, the program should be properly structured, and likewise, the academic courses should include industry components such as industry oriented projects [24, 25].

About a quarter of the high wage jobs available in the market require candidates with an associate degree [16] which are evolving with time and technology, and are being transformed from a monotonous job to problem-solving jobs requiring good interpersonal skills [18]. In the last decade, the manufacturing industry has shown a great need for workers with an associate degree (a shift from regular high school diplomas) emphasizing the requirement of a highly-skilled workforce to tackle evolving high technology manufacturing [6]. Workers with STEM associate degrees earn \$21,000 more than their counterparts from non-STEM backgrounds. Bridging the skill gaps of these workers is crucial in maintaining the supply of the high skilled manufacturing workforce. The two-year community colleges provide an option to students to either join the industry with an associate degree or transfer into a university for a 4-year undergraduate degree [26]. It is important to have effective communication between the institution and the respective industries so that the curriculum will be up to date to match the skill demands of the relevant industries [27]. Triki, Gupta, Wamuziri and Rafik [28] decry the lack of collaboration between industry and those developing vocational education programs. Yousef and Eaglin [29] used the Quality Function Deployment (QFD) framework to translate the needs of industry to the curriculum of associate degree institutions via surveys. Further, introducing career pathways through multiple entry/exit options in the associate degree program enables students to continue their education even after interruptions [30]. A significant number of students continue their education after graduating from an associate degree program, however in most cases, the transfer to a four-year university is inefficient due to the lack of uniformity in requirements by universities [31]. Yang [32] notes that continuing education is that which is done after formal education and that such education should be practical and aimed at problem solving. Ladeji-Osias et al. 2010 [31] propose an outcome-based associate degree rather than course by course comparison to improve the transfer process. One innovative program resulted from a collaboration between the Commonwealth of Pennsylvania and the nanofabrication industry to train technicians [33]. Another program aimed to train those that received liberal arts degrees for work in advanced manufacturing; the key, again, was to provide a program that met industry needs [34]. Similarly, apprenticeship programs provide an low expenditure option since the workers undergo an "on the job" training program [35]. Lerman [36] defines the apprenticeship as "a program of courses, work-based learning and productive employment in which workers achieve occupational mastery and industry-recognized credentials". However, the apprenticeship programs in the United States are less active in comparison to developed European economies such as Austria, Germany, and Switzerland [36]. The main advantage of the apprenticeships program to industry is the continuous supply of a skilled workforce with hands-on experience in a real industry setting. Given the high retention rate of apprentices (as high as 91%), this solution is very beneficial in creating a high skill workforce (Labor employment and Training administration) [37]. Although it is easy for large organizations to launch and recruit for the apprenticeship program, it is difficult for the medium and small-scale industries because of limited resources [38]. To combat this, small and medium manufacturers in Ohio partnered together and adopted the same one-year program credential from the National Institute for Metalworking Skills or the American Welding Society for the participants [38].

2.2 Effect of Demographics, Job Roles, and Enterprise Scale on Manufacturing Skills Gap

There have been few studies focusing on the skills gap with respect to the demographic aspects of employees. A study carried out by Carrone and Castello [39] reported that by 2050 the number of workers over 55 years old is expected to increase by 60%. One of the contributing factors to that is the current open positions in the industries due to the skill gaps. This increasing skills gap will gradually decrease the proportion of young workers joining the workplace [40] and also result in an increase in the number of people working past their traditional retirement ages [41, 42]. Another study carried out by Turek and Perek-Bialas [11] suggests that there is a requirement for effective continuing education training and development in the modern workplace as per the age and experience in order to improve on their productivity and close the skill gaps. Also, these training and development programs are influenced by businesses of different sizes and enterprise scales [12]. Moreover, studies in UK have observed that there is a positive perception, and the propensity to undertake formal training and development increases, with the size of employing organization [13, 14]. One study in which the skill differences with respect to writing capabilities were assessed among different ethnic groups found better ratings for white and Hispanic/Latino groups [43]. Other studies have observed that the learning, technological capabilities, conceptions of readiness, and motivation are affected by ethnicity [44–46]. Moreover, Olivetti and Petrongolo [15] observed the gender attribute affects the wage and skill gap across different countries and also skill groups within countries and observed a positive cross-country correlation between unskilled to skilled gender employability in industries.

Lastly, while the extant literature discusses the efforts to bridge the skill gaps through academic programs, apprenticeships, and continuing education programs, the inclusion of industrial projects in academic courses, case-studies, outcome-based curriculum plan, and planning of on-the job trainings are also mentioned as effective solutions to close the current skill gaps. However, to our knowledge, prior research has very little or no coverage of cross-sectional analysis of workforce preparedness on high value manufacturing topics, nor have we found any study by variables such demographics or industry type. We believe that such a study can help create a diverse pool of future workforce in manufacturing.

3. Proposed Research Methodology: A Case Study from High Value Manufacturing Industry

This paper uses a case study approach involving continuing education to quantitatively examine the preparedness of current industry professionals and new hires (fresh out of college). The proposed approach was adopted in an effort to gather as specific data as possible so that the hiring managers and human resources personnel can develop appropriate training programs and hiring strategies. Since the participants are exposed a relatively detailed content in each topic before they are asked to evaluate their self-skill level as well as that of their colleagues, they would have a better sense as to what is being asked in the survey. It is widely accepted method in workforce development literature to use case study to evaluate training program for professional development efforts. For example, Albyati [47] used case study research to evaluate a training program in construction industry. Other examples include: examination of motivation of participants to adopt "game-based learning" [48], and investigation of effect of training and development program on employee satisfaction [49] . Similarly, a self-assessment approach to measure workforce preparedness has been used in Kerby et al. [50].

3.1 Case Study Background

As a part of a National Science Foundation Advanced Technological Education (ATE) project, two professional development sessions were offered in 2018 and 2019 in the Houston metropolitan area of Texas. Each session was two days long. Of those two sessions, the first focused manufacturing operations excellence program and second session focused on manufacturing quality excellence program. These programs were developed with inputs from an industry advisory panel. The following sections describe each session in detail along with assessment results.

3.1.1 Manufacturing Operations Excellence program

This two-day short course focused on hands-on exercises and techniques that can be applied immediately to improve the financial bottom lines of manufacturing operations. The delivery of the course was divided into three modules: inventory management best practices, manufacturing operations management, and quality management best practices as shown in Table 1.

3.1.2 Quality Excellence program

The quality excellence program was also offered as a two-day course and focused on defining and measuring quality, non-destructive evaluations, and statistical process control. Table 2 shows the different topics covered under the three modules of the quality excellence program. The key outcomes of the program were designed to understand and implement effective quality tools and techniques and defining the role of quality in different fields of manufacturing. Both of these programs were developed by focusing on oil and gas industry applications.

3.2 Research Design

A trained workforce is critical for the advanced manufacturing industry. To contribute effectively,

Table 1. Topics covered in Operations Excellence Program

Module	Topics
Inventory Management Best Practices	Inventory classification Inventory costs and economic order quantity Re-order point and safety stock
Manufacturing Operations Management	Production cost-assessment and management Materials requirements planning Minimizing manufacturing waste and non-value-added time
Quality Management Best Practices	Assessing supplier quality Assessing the cost of poor quality (COPQ)

Table 2. Topics covered in Quality Excellence Program

Module	Topics
Defining and Measuring Quality	Inventory classification Basics of Quality Cost of poor-quality during measurement and analysis
Non-Destructive Evaluation	Identifications of manufacturing defects Types and selection of appropriate NDE methods Analysis and interpretation of data
Statistical Process Control	Statistical Process Control Process Capability Analysis

the workforce must be continuously trained in the latest technologies and best practices [51]. Additionally, studies show that employee training is positively correlated to the worker motivation [52]. Furthermore, a motivated workforce improves the productivity of the organization [53]. To design a professional education or training program, identification of the relevant skill needs of the organization must be performed and such assessment of the skills gap should be done on a periodic basis to be current with newer technologies and best practices [54]. Motivated by these facts from the extant literature, the research design used in this paper is centered on the two-professional development (or continuing education) sessions on manufacturing quality and manufacturing operations. The industry participants who were all employed at the time of the continuing education formed the samples for this research. The survey questions were designed to elicit self-assessment of participants with respect to their skill level on high value manufacturing topics covered in the continuing education sessions. The survey questions not only included their self-assessment, but also assessment of their colleagues (current workforce) and new hires (future workforce) who join the industry right out of college. Multiple research questions were developed (described in the following section) to assess the current workforce gap and preparedness of new hires. The research design includes a cross sectional analysis of responses by various population groups such as gender, ethnicity, age (as an indirect representation of employee's experience), education, and the size of employer. In addition, the survey instrument also includes general assessment of the programs with respect to design and organization of learning materials, course delivery/learning experience, relevancy of topics, and future interest in similar continuing education programs.

As stated earlier, the main objective of the research is to assess preparedness of current and future workforce in high value manufacturing. To that end, research questions are designed and developed to examine any gap in the skill set of current workforces and their perception of the skills level of new hires. In addition to exploring any correlation between the skill level and demographic variables such as age, ethnicity, job roles, gender and diversity, and education backgrounds, the research also explores any underlying relationship between the preparedness of workforce and size of the employer. The assumption here being a large employer would invest more in training of its employees therefore would have more prepared workforce than the employees of small-scale companies. Table 3 shows the list of research questions, population groups examined, and workforce assessment metrics.

4. Data Collection and Analysis

The survey instrument developed for this research was distributed at the end of each module in both sessions. There programs were offered in 2018 and 2019 and were attended by about 70 industry participants. Of those 70, only 59 participants had completed the survey and thus are included in this study.

4.1 Participants Summary

A summary of descriptive statistics on participants is provided in Table 4. As shown in Table 4, the

Table 3. Research Questions

Research Question	Survey Population Group	Workforce Assessment Metric
RQ1: What is the general perception of industry professionals with respect to their skills and those of others with respect to HVM topics?	Overall	Self-skill level Current workforce skill level New hires skill level
RQ2: Are there significant differences in perceived skills based on gender?	Male vs. female	
RQ3: Are there any significant differences in perceived skills based on age or experience?	35 and under Vs. Over 35 years old	
RQ4 Are there any significant differences in perceived skills based on ethnicity?	URM vs Non URM	
RQ5: Are there any significant differences in perceived skills based on education level of participants?	Associate or Under Vs. Bachelor or higher	
RQ6: Are there any significant differences in perceived skills based on firm size?	Big company vs Small-medium size company	
RQ7: Are there any significant differences in perceived skills based on role of participants?	Supervisory role vs Non-supervisory role	
RQ8: Can differences in perceived skills be attributed to nature of the topic?	Managerial (less technical) topics vs Moderately technical topics Managerial (less technical) topics vs Highly technical topic Moderately technical topics vs Highly technical topics	

program participants comprised of 63% of male and 37% of female. It may be noted here that the median ages and education levels of the participants varied between the programs. For example, ages of respondents of the manufacturing operations excellence program ranged from 23 to 63 with a median value of 37 years and the quality excellence program ranged from 23 to 60 with a median of 45.5 years. Therefore, for analysis purposes, the *Age group 1* consisted of the survey participants age less than or equal to 40 and the *Age group 2* consisted of the participants with age greater than 40 years of age. Similarly, education of the participants is also divided into two groups with the first group representing those with a Bachelor's degree or higher, and the second group with less than Bachelor's degree. With respect to diversity of the participants, the programs observed that 36% of the participants identified themselves as white, 42% of the population as Hispanic or Latino, 8% as Asian and 15% as American Indian/ Alaska Native, Black/ African American or others.

Table 4. Participants Summary

Survey Population Group (n = 53)		
Age group	Below Age 40	38%
	Above age 40	62%
Gender based group	Male	63%
	Female	37%
Ethnicity based group	URM	21%
	Non-URM	79%
Education Group	Bachelor's degree or higher	40%
	Below Bachelor's degree	60%
Industry Scale	Small/Medium	32%
	Large	68%
Job Role	Supervisory	38%
	Non-Supervisory	62%

4.2 Data Analysis

The data analysis consists of assessment of the continuing education program and evaluation of participants' preparedness with respect to the topics covered in the program. The participants' preparedness is analyzed by dividing the population into various groups by gender, education level, ethnicity, age, and type of employer. The analysis uses non-parametric Wilcoxon Signed Rank test due to smaller sample size of some population groups [49].

The statistical test was conducted at 95% significance level.

4.2.1 Program Assessment

The program assessment metrics included course design and organization, course relevance and hand-on learning, participant learning experience, and participant's interest in similar sessions in future. Fig. 1 shows that participants had very positive views of both manufacturing operations and quality programs with respect to all four metrics. Only one metric (course relevance and hands-on learning) was below 4.0 for the quality module. That may be due to a session in that module that covered non-destructive evaluation of quality which was a very technical topic compared to some of the others. The target scores for all four metrics were 3.5/5 which was met across all the modules in both sessions.

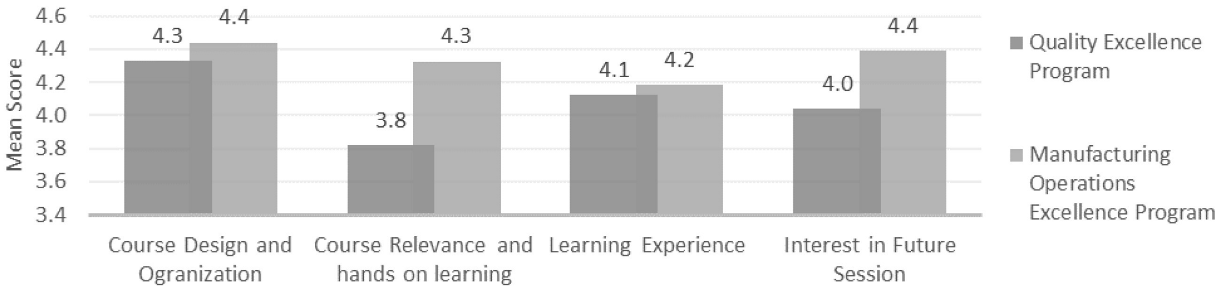

Fig. 1. Course Learning survey scores for program modules.

4.2.2 Assessment of Workforce Preparedness

Table 5 presents the overall preparedness scores for all six modules offered in the two continuing education sessions. The preparedness scores include self-assessment of the participants' skills level, and their assessment of their current colleagues skills level, and also their assessment of new hires skills level. It may be noted the new hires assessment scores represent the participant's view on newly joined employees who enter the workforce right out of higher education. It can be observed that while there is not much variation between the participants 'self-assessment scores and that of their current collogues, they have a very different perceptions of the preparedness of new hires. In other words, the participants felt that there were skills gaps among new hires across the board on all topics related to high value manufacturing topics discussed during the continuing education sessions. We believe that this is not unusual as colleges and universities tend to focus more on concepts and principles than one any specific industry applications. Therefore, new hires are put under management trainee programs by many employers that tend to rotate the new employees around various departments to improve their understanding of industry and company business practices. In addition, in some technical topics like non-destructive evaluation, participants also felt a lack of preparedness among their current co-workers. It may be noted that the preparedness (or skill levels) is measured in a 1–5 scale with 5 being the ideal and1 being the zero skills. What is striking here is if we considered 3.5/5 (70%) as a proficient score, there were many topics in which the participant felt lack of preparedness not just the new hires but also participants themselves and their current co-workers.

4.2.3 Analysis of Workforce Preparedness by Participant's Demographic Attributes

Table 6 presents results of p-values of two value t-tests that were performed to analyze the difference in mean preparedness scores between different participant population groups. As shown in the Table 5, for the majority of the modules there was no statistically significant difference in preparedness among different population groups. However, with respect to the statistical process control module (which was part of manufacturing quality excellence program), there were significant differences between more experience (40 years or older) and less experience (below 40 years old), male and female participants. Unexpected was the difference in preparedness in statistical process control found across all employees (participants themselves, their current colleagues, and new hires). There were also differences in perception as to how male and female employees evaluated the preparedness (or the skill levels) of their current colleagues and new hires.

Table 5. Overall average skills level score for all participants

Manufacturing and Operations Excellence Program			
Modules	**Self-skill**	**Skill level of current workforce**	**Skill level of new hires**
Inventory management best practices	3.43	3.33	2.95
Skill level of current workforce	3.82	3.73	3.18
Skill level of incoming workforce	3.79	3.74	3.32
Quality Excellence Program			
Modules	**Self-skill**	**Skill level of current workforce**	**Skill level of new hires**
Defining and measuring quality	3.68	3.55	3
Non-destructive evaluation	3.16	2.87	2.74
Quality management best practices	3.78	3.41	3

Table 6. Summary of two value t-test (p-values) on difference between mean preparedness scores between different participant population groups

Modules	**Age group (Below 40 vs 40 and above) (n1 = 33, n2 = 22)**			**Male vs Female (n1 = 33, n2 = 20)**			**URM vs Non-URM Ethnicity based groups (n1 = 11, n2 = 42)**			**With a Bachelor's degree vs without bachelor's degree (n1 = 21, n2 = 32?)**		
Workforce Preparedness Metrics	**Self-skill level**	**Current work-force skill level**	**New Hire skill level**	**Self-skill level**	**Current work-force skill level**	**New Hire skill level**	**Self-skill level**	**Current work-force skill level**	**New Hire skill level**	**Self-skill level**	**Current work-force skill level**	**New Hire skill level**
Inventory Management best practices	0.87	0.87	0.4	0.36	0.11	0.285	0.76	0.57	0.42	0.23	0.45	0.17
Manufacturing Operations management	0.2	1	0.6	**0.027***	0.26	0.94	0.08	0.93	0.78	0.82	0.056	0.83
Quality management best practices	0.52	0.78	0.74	0.837	0.73	0.943	0.87	0.24	0.55	0.74	0.76	0.77
Defining and Measuring Quality	0.91	0.41	0.09	0.47	0.88	0.73	**0.02***	0.43	1	0.31	0.2	**0.03***
Non-destructive evaluation	0.91	0.69	0.49	0.16	0.43	0.63	0.72	0.81	0.56	0.88	0.27	0.39
Statistical Process Control	**0.035***	**0.035***	**0.035***	0.72	**0.004***	**0.05***	0.09	0.76	1	0.8	0.16	**0.02***

Note: bold type and * indicate statistically significant at 95% confidence level.

4.2.4 Effect of Participant's Employer Size and Job Role on the Assessment of Skills Gap

To analyze any potential effect of employer and employee's job role, the participants were divided into various subgroups and their mean skills level scores were compared by using *t*-tests. For example, to examine the effect of job role, the participants were divided into two: managerial and non-managerial roles. Lastly, the enterprise size based on the revenues and profit may also impact the employee skills owing to their ability to invest in internal training and development activities. The company type was divided into two groups: large corporations that have $1B or more in annual revenues and small corporations which have less than $1B in annual revenues. The similar division was made in [55]. Table 7 provides a summary of results of the T-tests on difference between the mean skills level scores between various participant population groups.

As shown in Table 7, there were significant differences in mean preparedness score of new hires as perceived by the participants with a B.S. degree and those without a B.S. degree with respect to two quality related modules (namely "defining and measuring quality" and "statistical process control"). Furthermore, while difference in mean preparedness score for "non-destructive evaluation", another quality related module was not significant at 95% confidence level for any particular group, it was significant at 90% confidence level with respect to corporation types on preparedness of current workforce and new hires. One explanation for this could be the larger companies can develop inhouse training program for current and new hires therefore would not feel the same level of skills gap compared to that by the smaller companies which may not have same level of resources to offer the training to their employees. Likewise, employees with no 4-year degree could feel less prepared when it comes to some quality related topics (see Table 7) if they have not been exposed to

Table 7. Summary for the p-values of two value t-test for employer size and job role-based participant groups

Workforce Preparedness Analysis						
Modules	**Large corporation Vs. Small corporation (n1 = 36, n2 = 17)**			**Managerial role vs Non-Managerial Role (n1 = 20, n2 = 33)**		
Workforce Preparedness Metrics	**Self-skill level**	**Current workforce skill level**	**New Hire skill level**	**Self-skill level**	**Current workforce skill level**	**New Hire skill level**
Inventory Management best practices	0.42	0.17	0.42	0.39	0.23	0.7
Manufacturing Operations management	0.73	0.91	0.25	0.69	0.12	0.44
Quality management best practices	0.26	0.56	0.3	0.27	0.06	0.67
Defining and Measuring Quality	0.62	0.57	0.13	0.19	0.31	0.27
Non-destructive evaluation	0.15	0.1	0.07	0.18	0.89	0.56
Statistical Process Control	0.26	0.98	0.6	0.54	0.6	0.28

Table 8. Summary for the p-values of Wilcoxon signed rank tests

	Workforce Preparedness Metrics		
Modules Compared	**Self-skill level**	**Current workforce skill level**	**New Hire skill level**
Inventory Management best practices vs Manufacturing operations	0.052	**0.032***	0.206
Manufacturing Operations management vs Quality management best practices	0.763	1	0.429
Inventory Management best practices vs Quality management best practices	0.293	0.156	0.34
Defining and Measuring Quality vs Non-destructive Evaluation	**0.009***	**0.003***	0.096
Non-destructive evaluation vs Statistical process control	0.012	**0.011***	0.366
Defining and Measuring Quality vs Statistical Process Control	0.527	0.658	**0.048***

Note: bold type and * indicate statistically significant at 95% confidence level.

those, and also would not have adequate knowledge about whether or not the new hires would have those skill sets. On the other hand, there were no significant differences with respect to the remaining modules for both manufacturing operations and quality programs.

4.2.5 Effect of Technicality of the Topic on Participants' Assessment of Skills Gap

The modules of both the continuing education programs had introductory, intermediate level, and advanced level topics. To determine the perceptions and preparedness of the manufacturing industry employees, Wilcoxon signed-rank tests were performed on the survey scores. For analysis purpose, overall average preparedness score for self-skills level, current workforce level, and new hires were calculated for all six topics of the continuing education programs. Thereafter, the difference in mean score for analyzed using Wilcoxon signed-rank test for each pair of topics as shown in Table 8. Since each observation refers to the score of different modules by the same respondents, these data are not independent but in fact, correlated. Wilcoxon signed rank test is a non-parametric test suited for correlated data. Hence, it was used over the competing techniques like two value t-tests and Mann-Whitney test [56]. Our study has found that the level of preparedness of participants varied significantly between the topics, especially in the topics of manufacturing quality programs. Among these differences, our study finds that the level of technical difficulty of topic was inversely correlated with perceived preparedness of the participants and their colleagues. The manufacturing operations excellence coursework had 22 participants and Quality excellence program had 31 participants.

5. Discussion of Results and Managerial Implication

The program assessment results showed that there was almost a unanimous agreement among the participants with respect to the application, organization, and delivery of the content. The participants expressed interest in learning further about advanced topics, and also in some cases, suggested improvements to make the sessions more interactive, include more breakout sessions as the part of continuous improvement of the program. Overall, the participants agreed on the importance of the continuing education topics. In addition, the case study data showed that the current workforce lacked certain HVM skills that were presented during the continuing education programs. This could be a very important piece of information for engineering managers and human resources departments in developing the training programs needed to upskill the current workforce and also work with institutions of higher education to develop industry-oriented curricula.

On the other hand, according to the surveyed participants (which represented a cross section of the oil and gas industry including OEMs, equipment manufacturers, refiners, chemical manufacturers, and distributors), there was not any significant difference in perceived skills level among the different participants groups for most of the topics except for statistical process control which saw some variations between different age groups and different gender (see Table 9). More specifically, gender and age were contributing factors in terms of above-mentioned difference in self-assessment scores of skill levels of the participants as well as their perceived assessment of new hires. These differences can be attributed to the disparities in the industry structure having varying labor demand differences i.e., varying skills set requirements for different gender groups and thus creating a perception difference as well as actual skills set differences [15]. The age or experience factor plays an important role in determining its effect with respect to skills, competencies, learning and preparedness. The literature suggests that there are better learning capabilities and performances in older workers [57]. The analysis performed on the ethnicity construct showed that the self-skill level survey ratings for the URM population are sig-

Table 9. Significant differences in the mean scores for the participant groups (*Group having significantly higher mean score*)

Modules Compared	**Workforce Preparedness Metrics**		
	Self-skill level	**Current workforce skill level**	**New Hire skill level**
Inventory Management best practices	x	x	x
Manufacturing Operations management	Gender (*Female*)	x	x
Quality management best practices	x	x	x
Defining and Measuring Quality	Ethnicity (*URM*)	x	Education (*Bachelor's degree or higher*)
Non-destructive evaluation	x	x	x
Statistical Process Control	Age (*Age 40+*)	Gender (*Female*) and, Age (*Age40+*)	Gender (*Female*), Age (*Age 40+*), and Education (*Bachelor's degree or higher*)

nificantly higher than Non-URM for the DMQ module. Although some literature finds that differences among ethnicities in perceived learning and technological capabilities [44], conceptions of readiness [45], and motivation [46], because of limited samples in the quality sessions, this research question needs further investigation. For example, the majority of URM participants in the continuing education program did not have a Bachelor's degree. It was also found that the participants with higher education (Bachelors or above) thought that their new hires did not have sufficient skills level in HVM topics compared to the scores assigned by the lower education level group.

In addition to the demographic attributes mentioned earlier, the analysis performed on the population groups based on employer size and the job role showed no statistical differences in the perception of skill assessment ratings. The Wilcoxon-signed rank test performed on the program module's/ difficulty (or technicality) level showed that a significant difference observed for the perception of skills level in all three metrics (current workforce preparedness, self-skills level, preparedness of new hires. As stated earlier, the findings from this study can be beneficial in terms training, planning to upskill the current workforce, and the design of management training for new hires. That said, it is also important to note that it was a cross sectional analysis meaning the employee's skills level can be improved over time if they are provided with an appropriate training opportunity.

6. Conclusions and Future Work

The recent shift in manufacturing technologies has resulted into a gap in the skills (or preparedness) of the current and future workforce. Through a case study of multiple sessions of a continuing education program in high value manufacturing, this paper has presented an assessment of workforce preparedness (both current and future) in manufacturing, especially in oil and gas industry. The paper assessed the skills level of participants, their current colleagues, and new hires which represent current employees who joined the workforce fresh out of college without any prior experience. Two types of evaluations were conducted during the continuing education sessions. First evaluation was focused on the program assessment with respect to its organization and content. Our results showed that the participants rated both programs highly with respect to all four metrics.

The second evaluation consisted of analyses examining the difference in mean preparedness scores between various participants groups with respect to preparedness of current and future workforce in HVM related topics. As discussed earlier in the paper, our results showed that the level of preparedness with respect to quality modules varied significantly among different age, gender, education, and ethnic groups. We believe that further research is necessary before these findings can be fully generalized. More specifically, difference in level of preparedness based on gender and ethnicity is hard to explain. Such differences might have been influenced by other co-variates such as education, age, and type of employer (e.g., availability of training opportunity). Therefore, further study involving the interaction between these variables are necessary. That being said, the overall results from this case study can be very valuable for manufacturing and human resources managers in terms of developing new hiring strategies and training plans to mitigate the impact of skills gap in the current and future employees.

Lastly, the findings of this study could also be found limited because of the number of companies represented in the sample size. For example, while there was adequate diversity among the participants by any category (age, gender, ethnicity, education, industry type and job roles) the majority of the participants were from large companies. Therefore, another extension of this study would be to expand the industry base in the sample.

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