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DOMAIN KNOWLEDGE GAP AND SIMPLE SOLUTIONS TO EMPLOYABILITY OF MECHANICAL ENGINEERING GRADUATES IN INDIA

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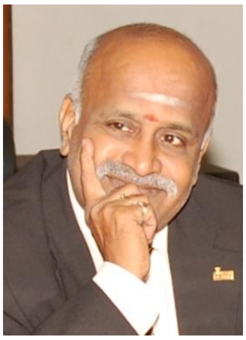

L RAMANAN

ABSTRACT

'Make in India' as an Initiative lead by the Government of India has started attracting Industries across all segments and from all nations across the global pole. Conducive atmosphere of governmental support for growth of industries in large, medium and small scale sectors provides a huge opportunity for employment of engineering graduates. However, industries find that most of the produce of Engineering Colleges is not employable due to many factors. This work is related to employer perception of Mechanical Engineering Graduates and their employability with a focus on 'domain skills', while the effects due to other factors are discussed in detail in the publications appeared in the IJOER journal. This work discusses the factors considered as important by the employers relating to mechanical engineering domain of engineering graduates. This research study is a portion from the research work on lower employability of mechanical engineering graduates in India.

Keywords: Domain Knowledge Gap,Make in India**,** Skill Development**,** Employability of Mechanical Engineering Graduates, ANOVA, Regression, QFD

I. INTRODUCTION

Industrial growth of India in the last few years is not only due to perceived least cost of work-force, but also due to governmental support with initiatives like 'Make in India' has attracted many MNCs (Multi-National Companies), thus providing many opportunities in employment across sectors. However, the demand and supply of skilled work force from engineering institutions is a concern for the employers, as they find employable engineering graduates are very low in percentage[1 to 3]. Ramanan et.al [4] have brought-out the factors that are considered as important in enhancing employability of engineering graduates which was followed by a survey across regions and industrial sectors of India [5]. This research work relates to one of the five factors [4] and its attributes related to domain skills. The other skills and their related attributes are covered in [6, 7 and 8].

It has been observed in the latest employability report brought-out by Aspiring Minds [9] in 2016 that the employability of mechanical engineering graduates is very low and is at 5.55%. It has also been reported in [9] that "*there is no significant improvement in employability in the last four years*". This observation is found to be in correlation with the findings of the research work as reported by the authors in their earlier work [5, 6, 7 and 8] that the employability issue is complex interaction of many factors and their attributes and cannot be addressed by focusing only on soft skills as practiced currently. Further the authors have stated [3] that this complex issue needs a solution with an multi-pronged approach.

It was observed from the employers' opinion on the lower employability of engineering graduates and mechanical engineering in particular, through the interviews and survey conducted for this research work, most of the employers are satisfied with theoretical curriculum of the engineering graduate studies, but largely found a gap in 'application of theoretical knowledge to practice'. This gap has a large influence on the employability of engineering graduates.

Abdul Kalam et. al [10] have stated that the "*the difficult state of availability of skilled manpower can be largely attributed to Indian education system, which does not focus on training students in employability skills. The Indian education system's focus has been more on theory and less on practical training, which helps in developing employable skills. Equally important is upgrading skills. Today, a large section of India's labour force carries out tasks with outdated skills*". This research work is a portion of finding-out need of industries in application knowledge, thus helping academia to improve the employability.

This paper is dedicated to the fond memory of Dr.A.P.J Abdul Kalam, Honorable past President of India and Mentor for Millions of Indians.

II RESEARCH METHODOLOGY

Samples, Size, Distribution and Approach

Six Sigma quality management approach demonstrated with derived benefits and success by the industry has been leveraged in this research work. Details of respondents like, industry segments and regions of India are as detailed in [5].

Survey Design and Instrument

Self-Administered research questionnaire covers the attributes taking into account, literatures and the opinions expressed during initial survey [4] as expressed by the employers. Gap in domain skills towards practical application is a concern for employers, though most of them are convinced with the theoretical knowledge of the fresh engineering graduates. The survey questionnaire structured relating to the domain skills is similar to earlier ones [5, 6, 7 and 8] and has two components 1) rating on the importance and need and 2) ranking based on the skillsfor practical applicationsfromfresh mechanical engineering undergraduates relating to the domain. The dependent and Independent variables are as in Table 1 and the simplified questionnaire is as Table 2.

Table 1. Dependent and Independent Variable

Independent Variable	Dependent Variable
Design of Subsystem, Components (DK-1)	Domain Specific Skill – Application of theory to practice (DK)
Measurement system knowledge (DK-2)	
Manufacturing Process to Practice (DK-3)	
Knowledge on adjacent Domain (DK-4)	
Modern Tools to Design (DK-5)	
Virtual Product Testing (DK-6)	
Modern Tools to Manufacturing (DK-7)	
Predictive Design (DK-8)	

Research Hypothesis

Following research hypothesis (null-hypothesis) were developed for the research questions related to the domain skills and consequent knowledge on practical applications.

- $H_0$33: Knowledge gap in design of systems, sub-systems and components do not have an effect on domain knowledge gap in applying theory to practice. $H_0$34: Measurement system knowledge gap does not have an effect on domain knowledge gap in applying theory to practice.
- $H_0$35: Knowledge gap in applying various manufacturing process to practice do not have an effect on domain knowledge gap in applying theory to practice.

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- $H_0$36: Knowledge gap on adjacent domain do not have an effect on domain knowledge gap in applying theory to practice.
- $H_0$37: Knowledge gap in usage of modern tools to design, do not have an effect on domain knowledge gap in applying theory to practice.
- $H_0$38: Knowledge gap in virtual product testing do not have an effect on domain knowledge gap in applying theory to practice.
- $H_0$39: Knowledge gap in usage of modern tools to manufacturing do not have an effect on domain knowledge gap in applying theory to practice .
- $H_0$40: Knowledge gap in predictive design do not have an effect on domain knowledge gap in applying theory to practice.

III RESEARCH FINDINGS

Data collected from the respondents are used in commuting the gap as an employer perception. Statistical analysis was carried-out using the multipurpose commercial statistical algorithm Minitab version 17 [11].

Gap Analysis on Domain Skills

The study is consistent with the findings of Varwandakaret. al [12], Rajeev [13] and the exploratory research done for this work, that the employability of mechanical engineering graduates is affected by the applied knowledge gap, though employers are satisfied with theoretical knowledge, but finds a gap in the knowledge of applying theory to practice.

Majority of the respondents (88%) recognise that there exists a gap in the domain knowledge of applying theory to practical needs as seen in Fig.1. Significant portion of the respondents to the tune of 11% perceive that their expectations are met with the availability of skills on domain knowledge with mechanical engineering graduates and hence there is no gap. A very small portion of respondents (~2%) expressed the availability of domain skills exceeds their expectations.

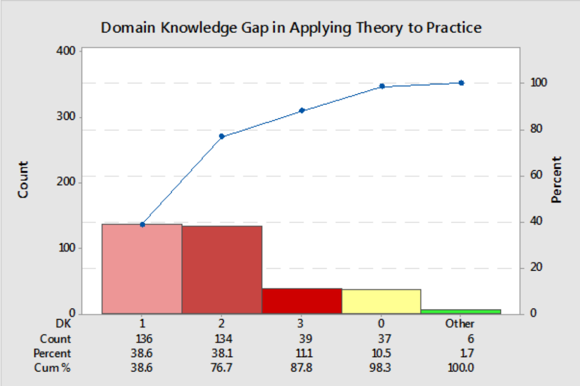

Fig. 1 Domain Knowledge Gap to Practice

It is interesting to know from the survey data as shown in Fig.2 for gap on the attributes of domain knowledge; many of them except for attribute DK-1 and DK-7 have outlier data on both positive and negative sides of the gap. First quartile Q1 is indicative of gap with a score of 1 for all the attributes, while it is 0 for DK-7. The attribute DK-7 relating to modern tools for manufacturing has median with a score for the gap as 1, implying 50% of the respondents opinion there is a gap due to this attribute above 1 and 50% below 1.

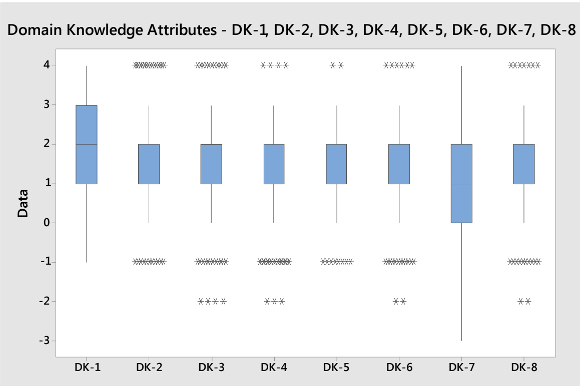

Fig. 2 Domain Knowledge to Gap - Attributes Gap

Anova and Regression Analysis

To confirm the attributes' statistical relevance with respect to regions of India, segments of Industry and its significance in relationship to the factor (independent variables significance with dependent variables) statistical analysis was carried-out with the confidence interval of 95%.

Hypothesis testing was carried-out for the attributes and the factor and found that there is no statistical significance on domain skills application knowledge gap to practice either by segments of industry or by regions of India.

Linear regression analysis is carried out to establish the relationship of the independent attributes (variables) to the dependent variable. Regression was also useful in testing the hypothesis as stated earlier in testing the relationship with dependent variable to quantify the importance of individual attribute statistically.

As we have detailed in the regression for building the relationship between soft skill gap and its sub factors [5], in domain skill gap and its sub factors we fond a lower values of R^2 values of around 32&. As could be observed from the ANOVA table for regression, the sum of squares of within is less accounting for the high variance in error. Large portion of sum of squares accounted in error explains the un-explainable causes which could be due to lower order of fit like the ones considered in the regression equation above or due to many other sub factors which are important in building the relationship might not have been accounted.

Table 2 ANOVA Table of Linear Regression

ANOVA						Regression Terms				
Source	df	SS	MS	F-Value	P - Value	Term	Coef	SE Coef	T-Value	P-Value
Regression	8	89.921	11.240	20.720	<0.000**	Constant	0.6565	0.085	7.710	<0.000**
DK-1	1	11.683	11.683	21.540	<0.000**	DK-1	0.2387	0.051	4.640	<0.000**
DK-2	1	1.350	1.350	2.490	0.116	DK-2	-0.082	0.052	-1.580	0.116
DK-3	1	0.000	0.000	0.000	0.993	DK-3	0.0004	0.042	0.010	0.993
DK-4	1	0.591	0.591	1.090	0.297	DK-4	-0.052	0.050	-1.040	0.297
DK-5	1	9.863	9.863	18.180	<0.000**	DK-5	0.218	0.051	4.260	<0.000**
DK-6	1	7.943	7.943	14.640	<0.000**	DK-6	0.1911	0.050	3.830	<0.000**
DK-7	1	0.110	0.110	0.200	0.653	DK-7	0.0235	0.052	0.450	0.653
DK-8	1	0.134	0.134	0.250	0.619	DK-8	0.0245	0.049	0.500	0.619
Error	343	186.053	0.542							
Lack-of fit	294	173.762	0.591	2.360	0.000					
Pure Error	49	12.292	0.251							
Total	351	275.974								

Note:
** denotes significant at 1% level
* denotes significant at 5% level

Firstly, we approached this by considering the two term interactions between the sub factors to understand whether there is a significant improvement to R^2 values. It brought out the fact the R^2 values have increased significantly with the independent variables considered and their interactions. R-sq improved to 45%, R-sq (adj) improved to 38.7 and and R-sq (pred) to 32.2%. The corresponding ANOVA data is presented in Table 3. It could be found from Table 2 with linear regression, that the independent variables DK-1, DK-5 and DK-6 are alone significant in the relationship with the dependent variable of domain knowledge gap. However as brought-out in Table 3, except for the independent variable DK-3, all other independent variables are significant in their relationship with dependent variable when considering the two way interactions between the terms. It is due to the fact that, if one has to control the variation in the output variable, it can be controlled by controlling input variable as it would not be possible to control interaction terms. However in social research, unlike in science and engineering it is observed that higher order terms are not usually considered as observed in the literature.

The higher order interaction brings-out the fact there are factor interactions, which are complex towards the employability. This complex nature of factor interaction has been reported in literature. Considering the domain skills as a factor in employability study of engineering graduates as this study is first of its nature, as observed by the researcher during literature survey.

Secondly, it is clear that all the domain knowledge sub-factor is not captured in the survey which is also a contributor to un-explainable causes reflected by large contribution sum of squares contribution for the error term, when compared to sum of squares of within. However, as mechanical engineering domain is large and it would not be feasible to capture all the sub factors, as each of the employers' requirement would be different, as requirements constantly varying based on the job role needs and product segments. From the reasonable knowledge of the researcher as available in the published literature on employability of engineering graduates, this study is the first in nature which accounts for domain knowledge. Further, this factor which got evolved from explorative research for this study captures reasonable amount of sub factors which are generic and applicable across product and industry segments.

Table 3 – ANOVA Table with Two Way Interactions

ANNOVA						Regression Coefficients				
Source	DF	Adj SS	Adj MS	F-Value	P-Value	Term	Coef	SE Coef	T-Value	P-Value
Regression	36	124.184	3.450	7.160	<0.000**	Constant	0.541	0.127	4.280	<0.000**
DK-1	1	2.708	2.708	5.620	<0.018*	DK-1	0.302	0.127	2.370	<0.018*
DK-2	1	1.558	1.558	3.230	0.073	DK-2	-0.27	0.150	-1.800	0.073
DK-3	1	0.880	0.880	1.830	0.178	DK-3	-0.1264	0.094	-1.350	0.178
DK-4	1	0.008	0.008	0.020	0.896	DK-4	-0.015	0.116	-0.130	0.896
DK-5	1	0.982	0.982	2.040	0.154	DK-5	0.18	0.126	1.430	0.154
DK-6	1	2.847	2.847	5.910	<0.016*	DK-6	0.282	0.116	2.430	<0.016*
DK-7	1	0.018	0.018	0.040	0.845	DK-7	0.024	0.121	0.200	0.845
DK-8	1	2.194	2.194	4.550	<0.034*	DK-8	0.269	0.126	2.130	<0.034*
DK-1*DK-2	1	3.500	3.500	7.260	<0.007**	DK-1*DK-2	0.1437	0.053	2.700	<0.007**
DK-1*DK-3	1	0.184	0.184	0.380	0.537	DK-1*DK-3	0.0316	0.051	0.620	0.537
DK-1*DK-4	1	0.551	0.551	1.140	0.286	DK-1*DK-4	-0.0863	0.081	-1.070	0.286
DK-1*DK-5	1	0.247	0.247	0.510	0.475	DK-1*DK-5	0.0461	0.065	0.720	0.475
DK-1*DK-6	1	0.051	0.051	0.110	0.745	DK-1*DK-6	0.0198	0.061	0.330	0.745
DK-1*DK-7	1	0.101	0.101	0.210	0.647	DK-1*DK-7	-0.031	0.068	-0.460	0.647
DK-1*DK-8	1	2.655	2.655	5.510	<0.020*	DK-1*DK-8	-0.1813	0.077	-2.350	<0.020*
DK-2*DK-3	1	0.002	0.002	0.000	0.948	DK-2*DK-3	-0.0036	0.055	-0.070	0.948
DK-2*DK-4	1	0.009	0.009	0.020	0.892	DK-2*DK-4	0.0087	0.064	0.140	0.892
DK-2*DK-5	1	0.806	0.806	1.670	0.197	DK-2*DK-5	-0.0904	0.070	-1.290	0.197
DK-2*DK-6	1	0.426	0.426	0.880	0.348	DK-2*DK-6	-0.0593	0.063	-0.940	0.348
DK-2*DK-7	1	0.496	0.496	1.030	0.311	DK-2*DK-7	-0.0651	0.064	-1.010	0.311
DK-2*DK-8	1	0.942	0.942	1.950	0.163	DK-2*DK-8	0.0964	0.069	1.400	0.163
DK-3*DK-4	1	1.026	1.026	2.130	0.145	DK-3*DK-4	-0.0711	0.049	-1.460	0.145
DK-3*DK-5	1	0.036	0.036	0.080	0.784	DK-3*DK-5	0.0169	0.062	0.270	0.784
DK-3*DK-6	1	1.327	1.327	2.750	0.098	DK-3*DK-6	0.0855	0.052	1.660	0.098
DK-3*DK-7	1	1.287	1.287	2.670	0.103	DK-3*DK-7	-0.0986	0.060	-1.630	0.103
DK-3*DK-8	1	0.700	0.700	1.450	0.229	DK-3*DK-8	0.0715	0.059	1.210	0.229
DK-4*DK-5	1	2.824	2.824	5.860	<0.016*	DK-4*DK-5	0.164	0.068	2.420	<0.016*
DK-4*DK-6	1	0.760	0.760	1.580	0.210	DK-4*DK-6	-0.0945	0.075	-1.260	0.210
DK-4*DK-7	1	3.369	3.369	6.990	<0.009**	DK-4*DK-7	0.1693	0.064	2.640	<0.009**
DK-4*DK-8	1	0.234	0.234	0.490	0.486	DK-4*DK-8	-0.0436	0.063	-0.700	0.486
DK-5*DK-6	1	0.494	0.494	1.020	0.312	DK-5*DK-6	-0.0553	0.055	-1.010	0.312
DK-5*DK-7	1	0.015	0.015	0.030	0.859	DK-5*DK-7	0.0129	0.073	0.180	0.859
DK-5*DK-8	1	0.338	0.338	0.700	0.403	DK-5*DK-8	-0.0573	0.069	-0.840	0.403
DK-6*DK-7	1	0.110	0.110	0.230	0.634	DK-6*DK-7	0.0258	0.054	0.480	0.634
DK-6*DK-8	1	0.152	0.152	0.320	0.575	DK-6*DK-8	-0.0341	0.061	-0.560	0.575
DK-7*DK-8	1	1.620	1.620	3.360	0.068	DK-7*DK-8	0.0733	0.040	1.830	0.068
Error	315	151.790	0.482			Note:				
Lack-of-Fit	266	139.498	0.524	2.090	0.001	** denotes significant at 1% level				
Pure Error	49	12.292	0.251			* denotes significant at 5% level				
Total	351	275.974								

The closeness of the R-sq, R-sq (adj) and R-sq (pred) values reported for both linear regression with and without factor interactions, is an indicator of the relationship of the independent variables considered in the regression model. Unlike in the regression relating to soft skill and its sub factors where we did not find much of improvements in R-sq values, we find considerable improvements by considering two term interactions. Based on the significance provided in the Table 3 for the factors and their interactions, the null hypothesis stated earlier, except for $H_0$35 rest is rejected.

In the domain knowledge gap in applying theory to practice of mechanical engineering graduates, based on the regression on the dependent and independent variables with linear and interaction terms, brings-out except for the attribute DK-3 namely knowledge gap in manufacturing process to practice, employers views are that all other sub-factor and their gap has a significant influence on domain knowledge gap of mechanical engineering in applying theory to practice.

IV. APPROACH TO SOLUTION IN REDUCING THE GAP

As detailed earlier, the solution development and deployment cannot be for one factor as most of the factors and their attributes have their interactions. Hence it is appropriate to use the quality management tools in finding the minimum number of solutions covering all the factors that are listed in [5, 6, 7 and 8] along with the domain skills and their attributes. Towards this objective QFD (Quality function deployment) was found to be handy.

National Employability report [9] findings of employability of mechanical engineering graduates is as low as 5.5% and there is no significant improvement on the employability in the last 5 years, relates with the researcher's opinion that this is largely due to the fact that the attempts made so for towards employability were focused on soft skills. But there are interactions between attributes of domain skills, analytical skills, soft skills and other skills. In the absence of identifying the significant attributes by studying the interaction effects, the solution approach would not be effective. QFD is one such tool in studying the interactions between Xs with various Ys.

To meet the employer expectations on the skills and attributes of the mechanical engineering graduates for employability, the perceived current level of application knowledge gap from theory to practice has to be brought to zero, which requires new solutions to be implemented. They could be new ideas, suggestions and improvements to the process or design. In this study the researcher has taken care by considering the solutions proposed shall be implementable at the institutional level with least effort and has a significant impact on factors viewed as important by the employers in employability of mechanical engineering graduates.

This research study was started by listening to the voice of the customers (VoC) which is an independent process by listening to their needs and importance on employability. VoC is an independent process and the needs collected during the VoC are addressed as 'Whats' of customer in Quality Function Deployment (QFD). QFD is a dependent process by considering the customer wants (Whats-Ys) and then relating them with how (Xs) it can be achieved. QFD is extensively used in market, social research and also in research and development of products. There could be multiple levels of houses in a QFD based on the issue handled. In this study the researcher has used two levels of the houses in the QFD. In the first level (house) of QFD, it uses the mean scores on various factors and their attributes as received from the survey and a snap shot is captured in Fig. 3 in building their relationships in correlation matrix.

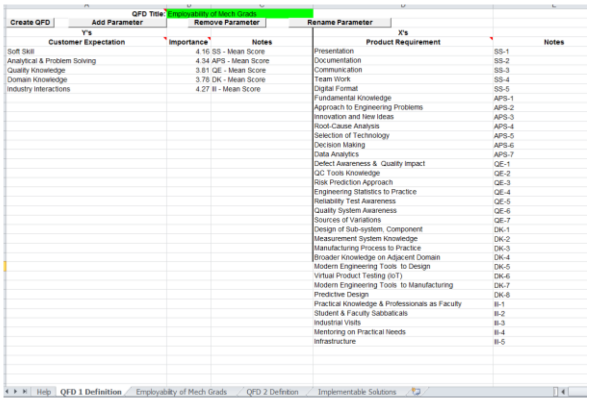

Fig. 3. QFD Snap Shot of Employability Skills and Their Attributes.- House 1

Direct relationships of sub-factors with their factors score higher correlation in the correlation matrix as seen in Fig. 4. However there could also be a relationship of a given sub-factor with other factors, which is not directly related to them and hence may not be of importance at the same level as h (high). Their relationships may be either medium (m) or low (L) or even no correlation. These are brain stormed with few of the industrial experts and are populated in the relationship matrix accordingly. This helps in identifying the significant sub factor that has not only a direct influence on the factors it is directly associated or grouped with, but also with other factors either at medium or low correlation levels. These scores together reflect as the scores of technical importance in the vertical column and form the basis for the importance in the next level of QFD.

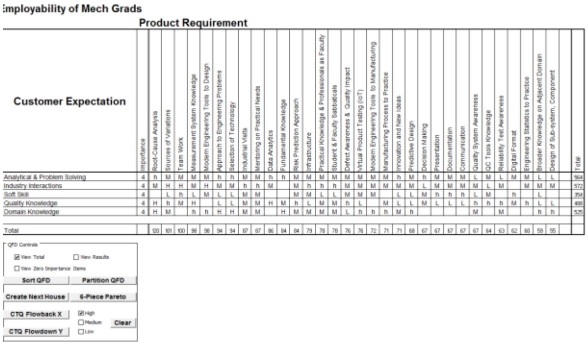

Fig. 4. QFD House 1 – Correlation Matrix

Level 2 of the QFD is the second house, where each of the sub factors of level 1 QFD or hows of level 1 QFD becomes the whats (Ys) (of the customer or employer) level 2 of the QFD. For the second house, hows (Xs) are arrived based on the brain storm with few academic experts, review of existing curriculum objectives of few leading universities and bench marking few of the best practices adopted in international and is captured in partial in Fig. 4.

Y's Product Requirement	Importance	QFD Score	X's X Title
Root-Cause Analysis	12	120	DFMEA & PFMEA in Lab Expt
Sources of Variations	10	101	Virtual Simulation - CAE Lab
Team Work	10	100	Variations in inputs and Impact on Output - Experiment in Workshop
Measurement System Knowledge	10	98	Lab Experiment as Group Actiivty
Modern Engineering Tools to Design	10	98	Measurement System Variation in Metrology Lab
Approach to Engineering Problems	9	94	CAD Lab with Variations to Sub-systems and Components
Selection of Technology	9	94	Introduce Defect to machine & Experiment to Rectify in Lab
Industrial Visits	9	87	Process Data Analysis - Mini Industry Project
Mentoring on Practical Needs	9	87	Faculty Engagement With Industry
Data Analytics	9	86	Reduction of Administrative Work Load of Faculty
Fundamental Knowledge	8	84	Presentation of Lab Experiments Results in Groups
Risk Prediction Approach	8	84	Industrial Faculty for Subjects like Quality Management
Infrastructure	8	79	Industry Professionals as External Examiners for Lab
Practical Knowledge & Professionals as Faculty	8	78	Modern Machines in Labs for Experiments
Student & Faculty Sabbaticals	8	78	Statistics Lab
Defect Awareness & Quality Impact	8	76	Mid-Term Project as Industry-University engagement
Virtual Product Testing (IoT)	8	76	Product Quality Issue Resolution as Academic Lab Experiment
Modern Engineering Tools to Manufacturing	7	72	Realiability Testing of Simple Products like Pen in Lab

Create QFD | Add Parameter | Remove Parameter | Rename Parameter

Fig. 2 QFD Snap Shot (Partial) – House 2

Similar to QFD level 1 the correlation matrix is populated to with high, medium and low correlation in consultation with few experts and correlation matrix is not shown here due to space constraints.

The beauty of the QFD in multiple levels is that, Xs and Ys of each level are not mixed. As in this study, the first level of QFD and its associations are with Ys and Xs which are factors and their sub factors. Second level of the QFD relates to the association between sub factors which are the whats of the customer and Xs that are the hows which is from research recommendations. QFD also helps in understanding which X at the lowest level of the QFD will address which Y at the higher level, through CTQ flow back of X. Similarly to address the Y at the top level, which are the Xs down the line need to be addressed, through CTQ Flow down of Y.

The findings from the QFD analysis as detailed above for all the factors and their attributes [5, 6, 7 and 8] and along with the factors and attributes of domain skills as presented in this work is captured in the pareto chart as presented in Fig. 5 brings out the eight research suggestions and recommendations for reducing the application knowledge gap from theory to practice.

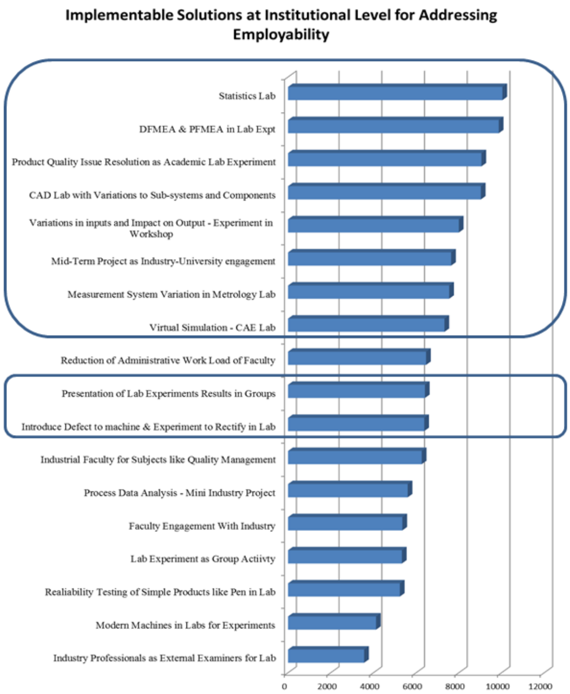

Fig. 5 Research Recommendations in Addressing the Employability of Mechanical Engineering Graduates in India.

V RESULTS AND CONCLUSSIONS

The following research suggestions are arrived based on the analysis of the skill and their attributes which are found to be significant from employability of mechanical engineering graduates as perceived by the employers. As brought-out earlier, the gap in expectations of the customers over the availability of skills is treated as a defect as in quality management approach and the six sigma models and approaches for this purpose. It is recognised that it would be beneficial if minimum solutions as suggested or recommended, that would address the most of the skill attributes. Towards this objective the following ten suggestions are made that would address all the thirty two skill attributes by using the quality management tool QFD.

- Introduction of Statistics Lab in First Year of Engineering Curriculum:

This suggestion on introduction of statistics lab is easy in implementation either as a separate lab or can be embedded into other existing physics, chemistry and workshop laboratory practical. Students should be advised to report, present and debate the variations on their observations and also within a small group. This suggestion is expected to improve apart from gaining the practical knowledge on variation and its impact, is expected to increase presentation, analytical and critical thinking skills and abilities.

From the CTQ flow back it was found that this suggestion is expected to have a larger impact on many factors considered in this study.

- Introduction of DFMEA and PFMEA in Lab Experiments:

Introduction of DFMEA (Design Failure Mode Effect Analysis) and PFMEA (Process Failure Mode Effect Analysis), in design and manufacturing lab experiments. This suggestion is expected to impact the team work skills as FMEA is a team activity and have to be brainstormed in identifying the failure modes and probable solutions. Apart from the analytical skills, it shall be helpful in enhancing the practical application knowledge on mechanical engineering domains related to design and manufacturing. As the team has to identify and justify their failure modes their oral and written communication skills are expected to increase apart from analytical and problem solving skills.

Failure mode effect analysis both in design and manufacturing process lab shall largely enhance the application knowledge and found to have an impact on eleven sub factors by flowing back in the Xs in the QFD.

- Introduction of Product Quality Issue Resolution as a Lab Experiment:

The design lab experiments apart from having examples for designing new components, suggested to have inclusion of studies of one or two practical experiments from product quality defect from the field. The experiments should be focused with design goal to resolve the issue with least cost.

This suggestion is expected to make an impact on building skills like team work, usage of modern technology tools, approach to engineering problems, fundamental knowledge and practical knowledge thus covering all the five factors as found from QFD flow back.

- Introduction of Analysing Variances and their Effect in CAD Lab:

CAD lab exercises in the machine design lab can be modified to study the impact on the assembly model from the effect of variations due to sub systems and components. This is found to have a significant impact on understanding sources of variations and its practical effects on real life scenario, effect of accommodating variations like DFM and other sources in the design and modern tools usage in engineering design, innovation and new ideas and decision making.

Impact of this suggestion is found on 8 of the skill attributes and all the four factors from the CTQ flow back in the QFD.

- Introduction of Studying Variation of the Inputs on the Output in Manufacturing Lab:

Current work shop lab practices can be modified to accommodate variation studies. For example variation of cutting speed, feed rate and depth of cut and the effect on the surface finish can be made as a group experiment. This will facilitate team work, understanding the effect of variations and other related quality issues on the product and process.

CTQ flow back for this suggestion is expected to make a significant impact to skills on risk prediction approaches, defect awareness and other factors.

- Mandate Mid-term Projects with Industry or Internship:

During the interviews employers expressed their opinion that the industry visits are more ritualistic than value additions as they could not spend quality time with students. Instead the employers suggested short-term projects like process capability studies, variation studies and similar others. This if implemented is expected to increase the practical knowledge, industry interactions skills and also the benefit of getting mentored by the practicing industry professionals. Securing an internship with an industry will enable the student to work with engineering product development team to learn different aspects in the industry and its expectations for employability.

- Introduction of Measurement System Analysis in Metrology Lab:

Introduction of measurement system analysis in metrology lab shall make the engineering students to understand the risk that would come from the measurement system itself. They will understand the practical needs and also on why a calibrated instrument alone is not sufficient in understanding the risk from measurement systems. As the variations comes from part to part, measurement instrument to instrument and people to people. This exercise has to be conducted in a group of minimum three or more people and three or more samples and hence a group activity. This suggestion will improve the skills on presentation, decision making, and team work apart from understanding of practical needs of risks from measurement system.

- Introduction of Virtual CAE Simulation Experiment in Design Lab:

'Early to market' needs of the industry require the emphasis on faster turnaround time in product life cycle with least cost as they are left with less physical testing of prototypes. Hence the employers expect from the mechanical engineering graduates to be aware of modern technology tools as a skill with fundamental knowledge. To meet this need it is suggested that virtual CAE simulation experiments and validation with proto type will enhance the practical knowledge on product development and improve the analytical and problem solving skills with the thought process for innovation and new ideas and predictive design.

- Presentation of Lab Experiment Results as a Group Activity:

There are fewer labs in which the experiments are conducted as a group activity, but the results are presented as a lab record as observed in many of the institutions. It is suggested that all the lab experiments could be considered to be performed as a group activity in a cluster of three or more students and the lab experiments are re-designed accordingly. Students should be encouraged to present their results as a group, compare their results with other groups and class average. This is expected to deliver a huge impact on soft skills more specifically on presentations and analytical skills. This also enhances their critical thinking abilities. At the end of the semester for each lab, the faculty can provide the comparative data analysis of current class with previous year batches and also discuss on the trends.

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