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ADOPT QUALITY MANAGEMENT APPROACH TO ACHIEVE EXCELLENCE IN EMPLOYABILITY OF ENGINEERING GRADUATES OF INDIA

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Abstract

Globalised industrial production has opened-up large employment opportunities across industry verticals across, while throwing lots of challenges on the Industries in getting the products early to the market by leveraging latest cutting-edge technologies from every domains of engineering and at the same time being 'cost competitive' for their survival. Under the dynamic market with cost pressures, expectations of the industries across the globe is that, the fresh graduates hired from the educational institutions are 'job-ready' while offering lots of employment opportunities for young engineers graduating and more specifically in India. It is estimated in India that, the automotive industrial sector alone would create 48 million job opportunities by 2022. To meet this demand Indian education system in the last few decades has undergone accelerated growth and is equipped to produce 1.4 million engineering graduates across the Nation for employment.

However, there appears to be huge un-met expectations of the employers on the employability of fresh engineering graduates, resulting in huge percentage of engineering graduates are not, either 'job ready 'or 'employable' as perceived by the employers. Issue of employability is a complex problem and requires a multi-pronged approach across all domains of engineering. This research work is more specific to mechanical engineering under graduate students, to understand and analyse the reasons for such a lower employability, by considering employers' perspective of employability as a defect in educational process.

This research work attempts to leverage the successful six sigma quality management approach adopted by the Industry in addressing their process defects, by considering educational institutions similar to process industry. The scope of this research work is to identify issues which are like low hanging fruits and suggest solutions that would make significant impact on the employability as perceived by employers.

Keywords:

Employability, Engineering Graduates, Quality Management, Six Sigma

1. INTRODUCTION

The employable engineering graduates produced by the educational institutions in India are reported to be very low and in varying percentages, though it is a global phenomenon but is of lesser magnitude in developed countries. The defect rate of un-employable engineering graduates in India is observed to be as high as 82% as latest as 2015 [1]. It is a worrying trend to the society, government and a major concern for the stake holders like regulators, accreditation bodies, society and industries. It results in mere existence of the institutions themselves.

Lower employability of engineering graduates is due to many complex factors like curricula of multiple universities, educational policies of governments, social policies on admission procedures, varying inputs as students admitted to the engineering education process and other similar factors. Both National and State Governments of India are cognizant of the gravity of the situation and have initiated many reforms at the National level along with industrial bodies and associations like CII, FICCI and others.

Reported observations on the lower employability of engineering graduates as observed in majority of the literatures during literature review, some of them are referred in this work [2][11] points to 'soft skill' as the major issue in lower employability of engineering graduates. However it has been observed in that there is no improvement in the employability [12] irrespective of the focussed action by governmental agencies, institutions, regulatory and accredited bodies on the 'soft skills' since the last four years. This finding correlates with the observations of the National employability report [13], which brought-out the interrelationship between applied knowledge skills, people skills, work place skills and personal skills and their importance in employability. Literatures [14] [15] through simple experiments demonstrated the existence of domain skill gap in application of theory to practice as a factor in employability and as perceived by the employer.

In finding research solutions to the employability issue of engineering graduates, efforts have been made to understand whether the adoption of Industries' expertise in leveraging quality models for solving defects in their process issues by the educational institutions have been analysed through literature survey. It has been found from the literatures [16] [22] that educational institutions across the globe are realising the benefits in leveraging quality models towards enhancing quality in higher education and a practical example as an application in utilising any one of the quality models for addressing the process improvements in educational institutions is not available. Hence in this research work attempt has been made to utilise the one of the quality model namely Six Sigma has been adopted to address the employability issue as a process defect in educational process.

Detailed literature survey, research questions, research methodology and other approaches are available in [24], however focus of this work is explain how various phases of six sigma can be merged with different phases of research in addressing the process towards the employability of mechanical engineering graduates.

2. NEED AND SCOPE OF THIS RESERACH

Complex issue on employability and cannot be resolved only by the Government and regulatory bodies alone and needs a multi-pronged approach [24]. Employers' touch point is the educational

institutions which deliver the fresh engineering graduates; the lower employability percentage affects not only the institutions' reputation but, their mere existence under the stiff competition amongst themselves. Hence, it is absolutely essential that apart from the initiatives from the governments, universities, regulatory bodies etc., it is absolutely essential to identify few factors which shall make a significant impact on the employability as perceived by the employers and are implementable at the institutional level. The Fig.1 pictorially explains the complexity of employability issue using 'solution tree' one of the tools of six sigma quality management tool, apart from the scope of this research study.

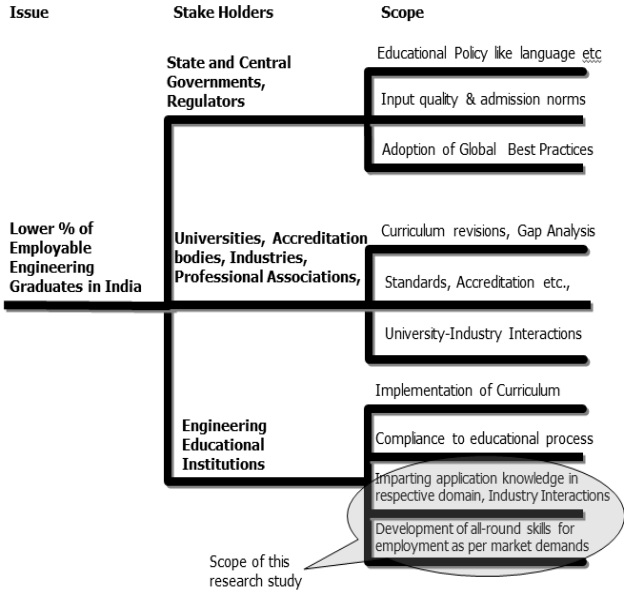

Fig.1. Employability Issue of Engineering Graduates - Stake Holders and Scope

3. RESEARCH GAP AND APPROACH

Un-met expectations of the industry on the engineering graduates as 'job ready', arise from many factors such as, lack of theoretical knowledge relevant to the current day needs of the industry, lack of practical application knowledge of the theory into the practice (applied knowledge), lack of analytical ability to analyze risks, lack of communication ability to convey the thoughts and ideas, lack of awareness on the impact of cross domain engineering into the process or product, lack of knowledge and its impact on quality and cost, cultural difference due to the presence of multi-national companies in India and consequent higher expectations in a globally competitive market. Each of the above factors contributes to the employability of engineering graduates in its own way. Some of the above mentioned factors might be common across all the branches of engineering, some factors are specific to domains of engineering and factor interactions.

During the literature review, it was found that most of the work approached the lower employability by investigating the issue from soft skills aspects. This trend was found to be the same across all branches of engineering. Over emphasis on attributing the lack of soft skills as a major cause for the lower employability issue of engineering graduates, resulted in solutions to improve soft skills in many institutions. But this might have made a marginal improvement, but not been found to have remarkable improvements in the employability.

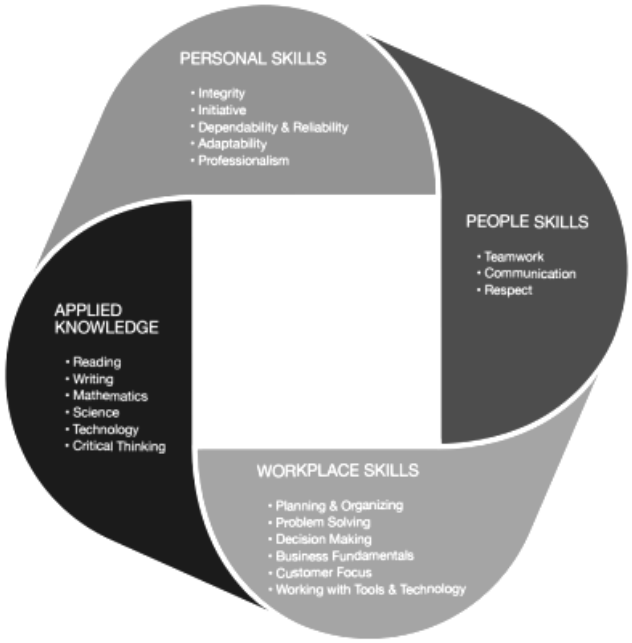

Fig.2. Skills and their Interlinks in Successful Work Place

Absence of studying the various factors and their interactions towards employability would result in implementing the solutions without much impact. As seen in Fig.2 [13], applied knowledge largely implies applying theoretical knowledge to practical application is related to domain specific needs of engineering. Reading and writing are part of communication skills and critical thinking is part of analytical skills, which are sub-sets of applied knowledge as seen in Fig.2.

Therefore while studying the employability issue, applied knowledge related to the domain and their interactions with other soft skills have to be studied with the inputs from the employers. When receiving the inputs for domain specific needs, the respondents have to be knowledgeable on the specific domain studied. Most of the literature relating to employability have not covered domain specific factors and their interactions; further their respondents as employer representatives were largely human resource professionals. Most of the employability related studies did not deal with specific branch of engineering and thus the element of applied knowledge skills related to a specific domain and its interactions with other factors. Some of the studies on employability of mechanical engineering graduates, apart from falling short of not covering the applied knowledge factors, are confined to specific regions or states of India, thus lacks in sanctity due to mobility of work force across India.

Under the above context, an attempt has been made through this research study, to bring the factual information to that extent possible (as the research gap in this zone is big), by capturing the voice of customers (VoC) in the first stage as explorative research. It was followed by the second stage of conclusive research for identifying the gap in skill attributes through survey constructs. Total of 534 respondents to VoC and survey are employers' representatives involved in hiring process and knowledgeable in mechanical engineering in identifying the significant factors as they perceive important in employability which can be addressed

at the institutional level. This approach is like plucking the low hanging fruits [25] in addressing the complex problem on employability.

4. RESEARCH QUESTIONS

The research works attempts to answer the following major research questions while adopting quality management model to the research work.

- Employable mechanical engineering graduates issue, is it across Institutions?
- Application of theory to practice, does it affect employability?
- Lack of Soft skills like communication, listening etc affects application of theory to practice. Does it have influence in employability and application of theory to practice?
- Lack of analytical and problem solving skills, affects application of theory to practice. Does it have influence in employability and application of theory to practice?
- Lack of knowledge on quality aspects and tools affects application of theory to practice. Does it have influence in employability and application of theory to practice?
- Lack of application knowledge from theory of mechanical engineering domain to practice. Does it have influence in employability and application of theory to practice?
- Absence of institutions close interaction with industry and consequent support in guiding the students on practical needs, in applying theory to practice for products and process. Does it have influence in employability and application of theory to practice?

5. QUALITY AND SIX SIGMA APPROACH TO THIS RESEARCH WORK

According to American Society of Quality (ASQ), quality [25] is defined as "Quality denotes an excellence in goods and services, especially to the degree they conform to requirements and satisfy customers". Quality is a measure for success of any organisation. It helps in setting target metric for achieving higher goals of accomplishments either from the historical data within the organization or from bench marking the current level of performance with leaders in the particular domain. Quality is metric driven, helps in continuous improvement and to excel in the given function, service or product performance. There have been many quality initiatives in the industries for achieving higher standards over the period of time not only sustaining existing levels of performance, but also in achieving higher levels of excellence

National Assessment and Accreditation Council, NAAC while dealing with the needs of enhancing quality in higher education, emphasised on leveraging any one of the quality models used by the industries in achieving excellence. NAAC has dealt in detail on the importance of quality models. One can observe the acceptance and recommendations of Six Sigma as one of the quality models in higher education.

IBM, GE and others during 1990s, demonstrated to the world the benefits of deploying Six Sigma approach to various facets of industrial needs. Six Sigma is a structured approach either for designing complex products like medical devices or for finding out the root cause of an issue [26], as it uses a set of simple quality tools in making informed data driven decisions. Though there are two different methods in six sigma approaches like DMIAC and DFSS, DMAIC is more popular with Industries and for process improvement projects. Academic institutions have started embracing the Six Sigma quality approach towards process improvements, after seeing the benefits reaped by the Industries. Little information is available in the literatures on six sigma applications either as examples projects or case studies in the academic process improvements or academic research. The Fig.3 explains various phases of this research study mapped to the DMAIC method of Six Sigma approach.

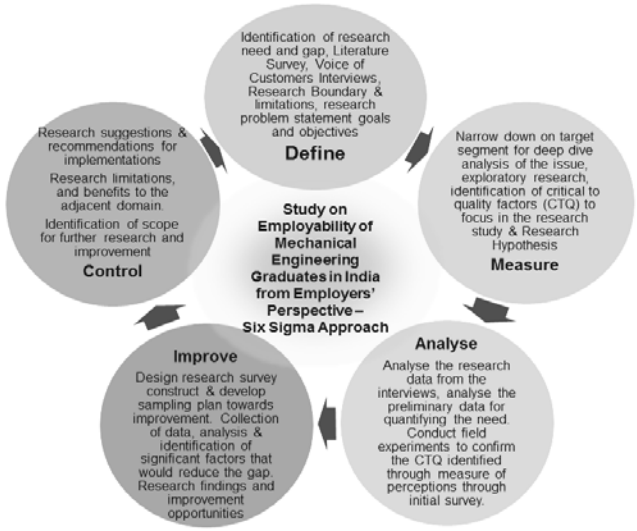

Fig.3. Research Study on Employability Mapped with DMAIC Phases of Six Sigma

A simplified blog diagram using a process map for the DMAIC (Define, Measure, Analyse, Improve and Control) model of Six Sigma and its approach to this study is as captured in Fig.4.

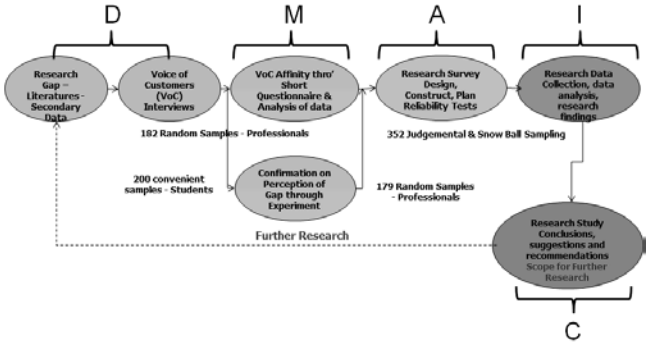

Fig.4. DMAIC Integration with Research Study on Employability

5.1 DEFINE PHASE OF SIX SIGMA

Employability defect of engineering graduates as high as ~80% or higher level of employer dissatisfaction in hiring fresh engineering graduates is the defect from the engineering educational process. The defect is generally viewed as failure of the educational institutions in not meeting the customer (industry)

expectations, as the outputs of graduated engineers emerges from the institutions. As observed from literature survey, this gap of expectations from industry vs employable engineering graduates is an active area of research in ensuring improvements to the current scenario. As far as six sigma approach is concerned, its focus is on customer satisfaction and hence, the define phase of a project is crucial to identify the critical to quality needs of the project, which when implemented will have a significant impact on customer satisfaction. In industry the customer need is reflected into every stage of the process as requirements or specifications, including supplier of materials or inputs to the process. The business process flow starts with suppliers and ends with customer, while it is absolutely essential to embed customer oriented thinking in every stage of the process.

In this phase of Six Sigma, covers the research steps like need for this research, importance, scope of the research, collection of secondary data from literatures and listening to the customer through interviews. This phase of research largely employs six sigma tools like VoC (Voice of Customer), data collection from literatures and aligning them through the tool called affinity diagrams. This phase uses a six sigma quality tool called SIPOC and is as in Fig.5, it maps the business process and in this study relates to engineering educational process. The benefit of this tool is connecting the flow in both forward direction for various steps, while reverse flow is connected with customer oriented thinking of COPIS.

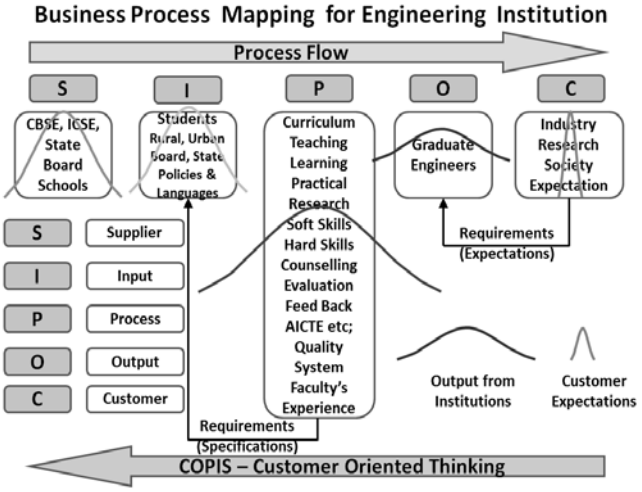

Fig.5 SIPOC and COPIS Model of Engineering Education Process Depicting Variations

Unfortunately unlike the industries, engineering educational institutions in India do not have a control in the inputs that comes to them for the process of converting the students into engineering graduates. Like any process variations, the educational process itself has its inherent variations due to many factors involved in the process and majority of the institutions have limited controls in the process. For example, many of them do not have a control in the changes to the curriculum to meet the customer expectations. With these restrictions, for the research study, the voice of the customers (VoC) is collected through interviews; their affinities were followed-up with a short questionnaire to convert the verbose data into measurable one. In the absence of structured define phase to define the goal of the project, one would have ended in multiple factors that are responsible for the output variations as seen in Fig.5.

5.2 MEASURE PHASE OF SIX SIGMA

The most important phase in research study is to identify the research goals and the frame work, which is similar to identification of CTQs (Critical To Quality) in Six Sigma. It is an important and most critical activity to the success of a six sigma project. Further investigations, approaches for model development, improvements etc., are based on this phase. As observed from literature, most of the work relating to employability were focussed on employability issue from 'soft skills' as the target audience as respondents to these surveys were employers who are not knowledgeable on domain specific needs of engineering, lead to the scenario of CTQs of the research very broader unlike in the present study which is focussed on mechanical engineering graduates. Andreas [2] who touched upon 'professional skills', which is largely addressed as 'domain skills' in industry, but his work was covering almost all the domains of engineering, hence could not deep dive into the issues specific to a particular domain of engineering like in this study. It has been observed from the VoC and the short survey of the data for this study, employers agree that the students have enough of theoretical knowledge, but there exists a gap in 'application of theory to practice' and it is a significant factor in impacting employability, which could be easily addressed at institutional level. 67% of the employers across industrial segments as found in Fig.6; perceived that employability issue is across institutions in India and with the gap in applying theory to practice.

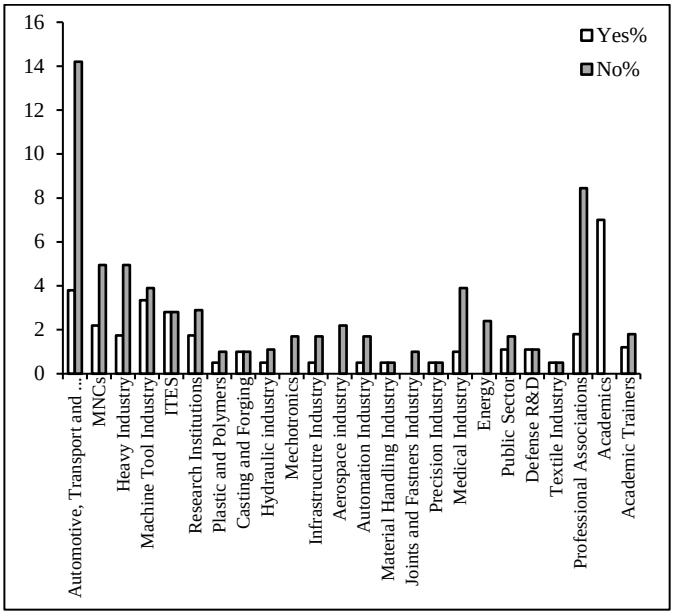

Fig.6. Employability Issue of Mechanical Engineering Graduates - Across Institutions & Segments

The researcher acknowledges the verbose information and views from subjective questions of the survey are likely to bring in subjective elements in assessment and arriving at the CTQ for improvements. However, subjective questionnaires have become the order of the day in service sectors and accepted practice. Further, Bertrand et al.[26] argued that the subjective measures can be inferred with due diligence in the interpretation of results.

However, Six Sigma approach is data driven and shall not accept qualitative or subjective opinion before the next phase of six sigma can be commenced. Hence, this study developed a simple experiment in quantifying whether the subjective element of 'Gap in application knowledge of theory to practice' as an important factor in lower employability of engineering graduates. A simple experiment that was conceived and conducted to test whether subjective measure are quantified [14 and 15] concluded that 37% of first year engineering graduate students failed to apply theoretical knowledge to practice, while it was 20% for final year students and as seen in Fig.7. Further, it has been proved that this knowledge gap of applying theory to practice is also carried forward into profession. Thus the data for the research gap identified during define phase is validated by collecting primary data through interviews (VoC) as an explorative research and is been validated with experiment as a quantitative measure, thus validating the research gap which is the CTQ from Six Sigma terminology.

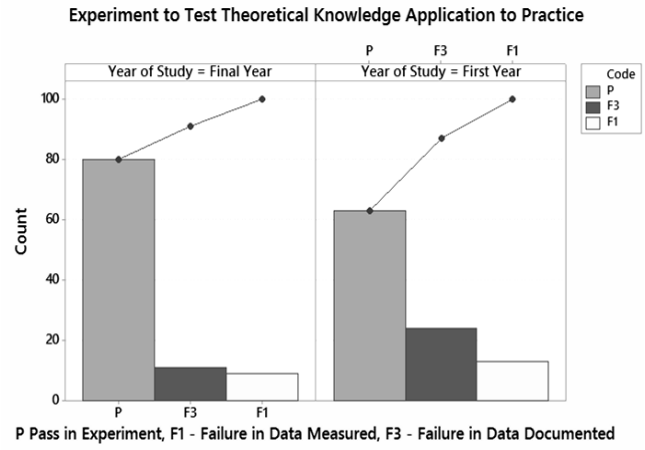

Fig.7. Experiment Conducted to Test Theoretical Knowledge into Practice

5.3 ANALYSE PHASE OF SIX SIGMA

This phase of Six Sigma largely can be related to research model development in research studies and can be investigated to root cause investigation The most important phase in research.

Knowledge gap in applying theory to practice is observed and quantified as an important factor in employability and referred as CTQ during measure phase, is investigated for the root cause. The respondents of the VoC has been asked to provide their importance for various factors towards this cause on a liker scale in identifying whether it is one factor or multiple factors or their interactions that are responsible towards the gap in application of theoretical knowledge to practice. This approach helps in building a statistically validated research model through hypothesis testing and regressions. This conceptual model shall be useful in further refinement during the improve phase of the six sigma approach of this research study with their attributes. The research study [27] had a Cornbach alpha above 0.95, while the soft skill had a value of 0.75 with all other factors, indicating 'soft skills' as an independent variable did not found to be statistically significant in impacting employability of mechanical engineering graduates from the stand point of applying theory to practice as depicted in Fig.8, however itis concluded from the sensitivity analysis through Monte Carlo simulations and perceived views, that the factor's attributes would impact with their interactions with other independent variables like domain skills, analytical skills, quality knowledge and industry interactions. Further, most of the literatures have found 'soft skills' like communication, included fluency in English language etc., which are not implementable at institutional level which are policy decisions of state government [2], which encourages teaching in native languages, hence out of scope of this study. This phase of the Six Sigma in developing a conceptual model utilises the tools hypothesis testing, Anova, regression, Correlation studies and Monte [25] is as shown in Fig.8.

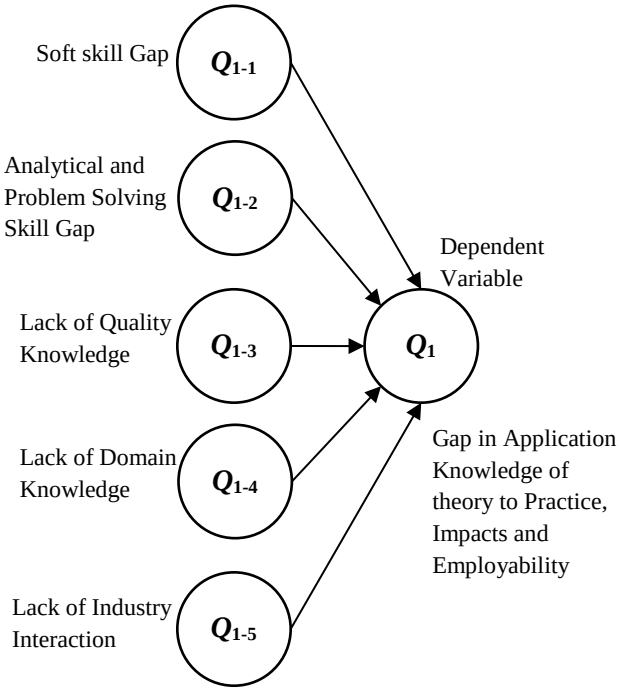

Fig.8. Conceptual Model on Factors Affecting Employability of Mechanical Engineering Graduates

5.4 IMPROVE PHASE OF SIX SIGMA

This phase of Six Sigma is an important step in developing solution to the root cause that was identified in the previous step. It can be relates to identifying the specific attributes that are responsible for each one of the factors in the research.

The independent variables/factors as identified have many attributes that have an influence on them and are actionable during solution implementation phase. This leads to the research construct, by consulting the relevant literatures, applicable standards like Washington accord [29] for attributes of engineering graduates etc. As the graduate engineering students are mobile across the states of India, hence the target audience are from all the four regions of India, across Industrial sectors, respondents have to have a direct knowledge on mechanical engineering needs and are involved in hiring process of fresh engineering graduates, thus eliminating any bias. The sample size recommended by Andreas [2] for a similar study with 95% confidence interval has been exceeded in this work by receiving inputs from 352 respondents through judgemental and snow ball sampling. The survey questionnaire was constructed in such a way that the respondents could rank their importance of the need related to the specific attribute and also rank the skills of fresh

hires, thus facilitating to identify the gap as perceived by the employers. A total of 32 attributes forms the questionnaire distributed under each of the above five independent variables. Questionnaire consistency and reliability has been tested through pilot tests and consultation with experts, before rolling-out the questionnaire for larger audience, an overall Cronbach Alpha value of 0.92 for importance of needs, 0.96 for ranking of skills was predicted indicating high correlation and consistency of the questionnaire during pilot study. It was suspected that some of these attributes may find an influence on the other independent variables; hence an exploratory factor analysis was performed to simplify the research model or independent variable. However we found from the factor analysis with a factor load of above 0.55, which is observed as "very good" in factor analysis has been considered for the attributes. This confirms the attributes in five different variables groups are valid and the attributes' factor loadings are as seen in Table 1.

Attributes for the skills	Factor 1 (Analytical and problem solving Skill)	Factor 2 (Quality Knowledge Skill)	Factor 3 (Domain Knowledge Skill)	Factor 4 (Industry Interaction – Practical Knowledge)	Factor 5 (Soft Skill)	Communality
Presentation					0.696	0.491
Documentation					0.698	0.491
Communication					0.762	0.603
Team work					0.746	0.575
Digital format					0.745	0.574
Fundamental knowledge	0.748					0.568
Approach to engineering problems	0.702					0.517
Innovation and new ideas	0.753					0.582
Root-cause analysis	0.831					0.705
Selection of Technology	0.802					0.673
Decision Making	0.638					0.444
Data Analytics	0.778					0.617
Defect Awareness and Quality Impact		0.789				0.630
QC Tools Knowledge		0.877				0.773
Risk Prediction Approach		0.852				0.742
Engineering Statistics to Practice		0.723				0.535
Reliability Test Awareness		0.624				0.413
Quality System Awareness		0.602				0.367
Source of Variations		0.759				0.593
Design of Sub-System, Component			0.730			0.550
Measurement System Knowledge			0.789			
Manufacturing Process to Practice			0.637			
Broader Knowledge on Adjacent Domain			0.705			
Modern Engineering Tools to Design			0.707			
Virtual Product Testing (IoT)			0.680			
Modern Engineering Tools to Manufacturing			0.681			
Predictive Design			0.669			
Practical Knowledge and professionals as faculty				0.785		
Student and Faculty sabbaticals				0.790		
Industry Visits				0.809		
Mentoring on Practical Needs				0.832		
Infrastructure				0.662		

Fig.9. Attributes for Skills with Factor Loading

Gap analysis has been performed from the inputs of the importance perceived by the employers on the need of the attribute as a skill in employment vs. the skills perceived to be available with the fresh engineering students hired. The Fig.10 depicts the perceived views of employers in India. Research study found a gap of 41% in industry interactions, 38% on analytical and problem solving skills, 33% on Quality knowledge and 31% on Soft skills. The observed views on domain specific skills are consistent with existing literatures view that most of the employers are satisfied with the curriculum and domain knowledge with a lower level of gap as 28%, when compared to other factors. This helped in focussing on developing a solution that is implementable at the institutional level.

Factor	Importance - Mean, Score out of 5	Availability of Skill - Mean, Score out of 5	Gap Perceived - Mean, Score out of 5
Soft Skill	4.16	2.62	1.55
Analytical & Problem Solving Skill	3.81	2.13	1.68
Domain Knowledge	3.78	2.37	1.40
Industry Interactions	4.27	2.20	2.06

Fig.10. Mean Score of Importance and Availability of Skills as Perceived by Employers

This phase of the Six Sigma steps utilises the research tools like correlation analysis, factor analysis, hypothesis, ANOVA, Montecarlo Simulations, gap analysis, percentage contributions, regressions and frequency distributions [10][28].

5.5 CONTROL PHASE OF SIX SIGMA

This last phase of Six Sigma is a step in suggesting implementable solution to address the defect and identify further improvement opportunities that were not addressed in the project, which is similar to research study by offering research recommendations and identifying scope for further research.

For this research study based on the importance and gaps identified implementable solutions at the institution level was developed. Out of the 32 attributes considers as various skills that would have an influence on 5 independent variables has to be analysed carefully to identify minimum attributes that are implantable which shall make a significant impact on employability. In such scenarios of analysing quality function deployment (QFD) is found to be of highly valuable tool and is also as found in literature [17] for educational causes. In this research as found in Fig.11 the QFD used has been used as two levels or house. In the first house, where we have found during exploratory research the 5 elements (Fig.8) becomes the 'Whats'. Whats are those which customers would like to have and are represented under Ys in the first house. Their ratings are accorded with the mean scores collected from the survey. The adjacent columns are 'Hows', which explains the 32 attributes and are populated based on their scores and relating to their independent variable. However, their relationship with other independent variables are brainstormed and populated with subject matter experts. As the fits house is completed, then the second house of QFD is formed where, whats of first house becomes how's of the second house. To achieve these whats, it is brain stormed with subject matter experts, what hows can be done and they become the adjacent house. Thus few final 'hows are arrived at which action items should address the employability. The intention of this article is not dwelling on entire QFD process and tools usage, a representative picture is provided in Fig.11, which explains the flow. After completion of the QFD, one can find, either for addressing one Y at the first house, what are the action needed to be done and which will also have a consequential effect on many attribute which is known as flow back. Similarly, by deploying one action item at house two, which are Ys that will be addressed in first house and the attributes.QFD was also helpful in accounting the interactions between various attributes and factors. Views of the few academic experts and luminaries in India on the implementable solutions at the institutional level are ascertained. QFD was very helpful in identifying few of the 'Critical Xs' from the 'trivial many' that would impact majority of employer needs as shown in Fig.11.

This phase of the research utilises the tools such as QFD, Pareto Analysis and Excel.

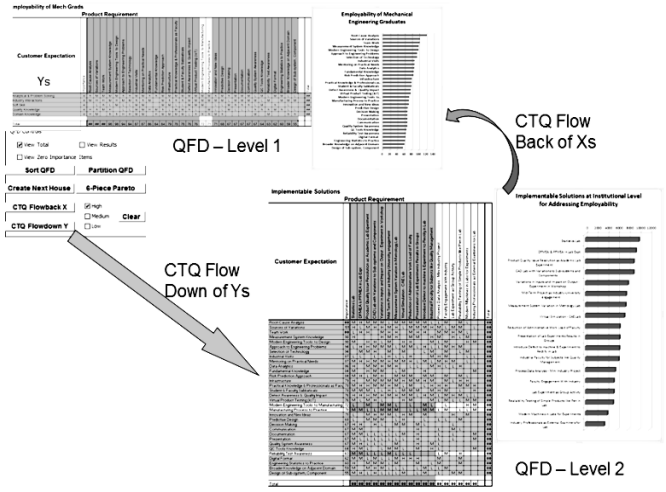

Fig.11. Houses of QFD - Schematic of the Two Levels and its Flow down and Flow-up

6. RECOMMENDATIONS

This last phase of either Six Sigma or any project or the research step concludes with suggestion or recommendations for implementable solution to address the defect. It is also will identify further improvement research work is highly helpful by defining the research goals & objectives, identifying the research gap, defining the research frame, identifying the measurable CTQs, investigating the factors significant to impact the employability and critical few Xs from the trivial many in suggesting research recommendations. Eight of these research recommendations shall address most of the thirty attributes perceived to be important by the employers with mechanical engineering graduates for employability.

The findings from the QFD analysis as detailed above is captured in the Pareto chart as presented in Fig.10 brings out the eight research suggestions and recommendations for reducing the

application knowledge gap from theory to practice, thus enhancing the employability. The researcher has observed that the recommendation as emerged from QFD analysis of this research work on Statistics Lab was found to be implemented in some of the western universities and University of Toledo, USA is one of them and also with Thiagarajar College of Engineering Madurai.

QFD analysis was very helpful in finding out the minimum research suggestions that would have maximum impact on the employers' expectations on employability of mechanical engineering graduates. Based on the QFD findings through the relationship matrix and Pareto analysis, there are eight research suggestions which are more than 3 pieces of the 6 piece Pareto as seen in Fig.12.

This shall serve the researchers as an example in guiding the research work, as little or no literature is available on the application of Six Sigma to a research project.

Six Sigma is a structured approach in taking informed decisions which is data driven and with the application of appropriate quality tools. Various quality tools that could be used in the different phases of Six Sigma method has been explained in each phase.

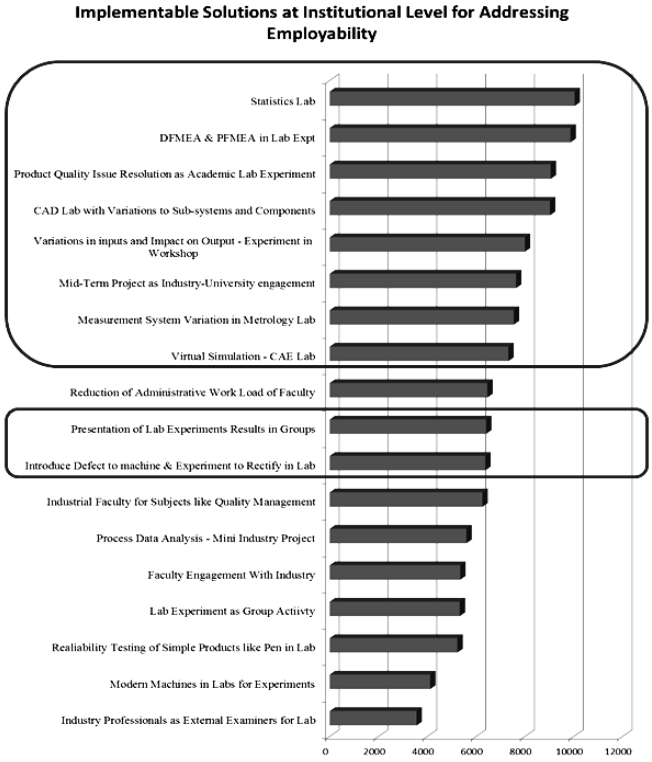

Fig.12. Mean Score of Importance and Availability of Skills as Perceived by Employers

7. RESEARCH FINDINGS

Findings from the entire research work is detailed her which has culminated in good number of research publications and some of them are cited in this work. Extensive documentation has been recorded in the doctoral thesis of the second author [24]. The following findings are from the entire research work by adopting the Six Sigma quality management approach to this research work.

Total of 713 practicing industrial professionals and domain experts in mechanical engineering, representing 18 industries segments, 11 states and 4 regions of India, are the respondents to this study covering various phases of this research. This excludes 200 engineering students from 11 different institutions as respondents in the sanity check and confirmatory experiments for subjective opinion.

97% of the employers' opinion that the knowledge gap of applying theory to practice is a significant issue in employability of mechanical engineering graduates during the explorative study. It is further confirmed during the conclusive research that 97.4% of the respondents recognise the applied knowledge gap is the major concern for them in mechanical engineering graduates employability.

67% of the employers expressed that the employability of mechanical engineering graduates issue is across institutions.

Soft skills, analytical and problem solving skills, quality engineering knowledge, domain knowledge and industry institution interactions are factors to the application knowledge gap with a significance level at 1%, or with the confidence interval of 99%.

Relationship between application knowledge from theory to practice as a dependent variable with independent variables such as soft skills, problem solving skills, quality engineering knowledge, domain knowledge and industry institution interactions are brought-out through regression at R-sq value of 82%.

Overall Cronbach alpha value of 0.96 explains the internal consistency and reliability of exploratory survey questionnaire.

Sample size sensitivity has been confirmed with a confidence interval of 99% by Paired T-Test in the employer perception of employability skills of mechanical engineering graduates.

Application knowledge gap from theory to practice is found to be more with first year engineering students at 37%, when compared with final year engineering students at 20%. But it varies with institution to institutions and also within institutions.

Existence of application knowledge gap with engineering students has been confirmed through Wilcoxon test with a confidence interval of 99%.

Application knowledge gap of applying theory to practice amongst industries professionals has been found to be at 8% and it is largely confined to experience segment of less than five years. This observation is not specific to a particular industries segment or regions of India.

32 attributes of employability skills of mechanical engineering graduates chosen for the study from literature, explorative research, accreditation standards and curriculum goals and objectives are grouped under 5 factors identified in explorative research survey questionnaire.

Correlation study for the survey questionnaire brought-out overall Cronbach alpha value of 0.839 and between 0.787 and 0.892 for the sub factors or attributes explained the internal consistence and reliability of survey questionnaire construct. Confirmatory factor analysis with factor loading of 0.7 for the attributes grouped under five factors validates the grouping of attributes and the importance of attributes.

Importance for various attributes towards employability of mechanical engineering graduates by the employers is found to have a mean score range from 3.4 to 4.7.

Employers' perceived availability of skills with mechanical engineering graduates ranges from 1.8 to 2.8 for all the attributes considered for this study.

Gap perceived due to employer expectations on the skill availability of mechanical engineering graduates for employability is found to be at 48%.

Gap in the soft skill and their sub factors are in the range of 24% to 48% for the expectations over availability by the employer. Least gap of 24% is observed to be on presentation skills, while larger gap of 48% on the attribute related to team work amongst 5 of the sub factors of soft skills.

Gap in the expectations over availability of skills by the employers for analytical and problem solving ability and attributes are found to be in the range of 1.9 to 2.1 on a scale of 5 and implies a gap of ~40%.

Knowledge gap in quality engineering and factor from the importance over available skills as perceived by the employers is found to be in the range of 1.44 to 1.89 on a scale of 5, implying a gap ~33%.

Employers expressed domain knowledge application to practice from theory learnt has a gap significant to employability. They expressed the importance for the attributes considered in the study with a score ranging 3.4 to 4.1, while their scores on available skills is 2.0 to 2.7, implying a gap of ~25% on the expectations over available knowledge.

Industry institution interactions scored high on the importance towards application knowledge to practice from theory, while their rating on the current level is low resulting in a gap of ~40% from their expectations.

No significant difference in the opinion on the application of theory to practice for employability of mechanical engineering graduates either by regions of India or segments of industries.

Relationship between soft skill and their attributes has been established through linear regression and the R-sq value is 37%.

Relationship between analytical and problem solving skills and their attributes has been established with linear regression and the R-sq value is 54%.

Relationship between quality knowledge skills and their attributes has been established with linear regression with R-sq value of 64%.

Relationship between domain knowledge and their attributes has found to have higher order interactions of terms in with R-sq value of 45%.

Relationship between industry institution interactions and their attributes has been established with linear regression and the R-sq value is 49%.

DMAIC frame work of six sigma model for application to educational institutions has been brought out from this work. Though the need for quality model application has been expressed in literature and there has been no case studies applying quality models to educational research. Thus it will serve as a reference for quality improvement strategies at educational institutions.

Integration of DMAIC model of Six Sigma with academic research process has been explicitly expressed for its benefits (NAAC (2007)) towards quality improvement objectives excellence of educational institutions. But literature does not have the integration of DMAIC model to academic research process and this study meets the un-met needs of academic community.

Constraints of educational institutions on the educational process flow have been brought-out using SIPOC and COPIS tools of Six Sigma.

Many of the Six Sigma quality management tools like Solution tree, Four Blocker, SIPOC, QFD and Monte Carlo Simulation have found their applications and usage in this study apart from statistical tools.

The study also points out that the faculty of engineering institutions are overloaded (~125%) and this requires a detailed research. Institutions are suppliers of employable engineering graduates to the industry and their time availability for interactions with industry and students is important to address employability issues.

8. SCOPE FOR FURTHER RESEARCH

Engineering Institutions do not have control on their inputs (admission) for the process of administering engineering education. However it is observed to be significant from this study during Define and Measure phases of Six Sigma. Hence, research on knowledge variations on the inputs from state board, central board and across states, will help in understanding the variations at the input level to the engineering education process.

Research on basic educations that are the inputs to engineering education towards imparting practical application knowledge, will avoid strain on engineering education system and process.

Most of the research suggestions involve quality time of faculty in the lab towards enhancing the application knowledge from theory to practice. However it was expressed that the faculties in educational institutions are overloaded as found from a simple explorative study. This area provides an opportunity for in-depth research and to ease the workload of faculty from non-value added activities.

The research can be extended to other branches of engineering domain as there is no domain specific employability research covering the domain knowledge aspects and other factor interactions

Research on effectiveness of employing practicing industry professionals teach the academic curriculum of theory papers that have a practical significance to percolate industry's needs.

Research on the effectiveness of engaging industrial professionals as experts for lecture classes includes practical importance, practical labs and also as examiners to facilitate building bridges between industry and institution.

Research on soft skills and its impacts on engineering education focus on policy decisions of government like language for medium of instructions etc.

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