Analyzing the Gaps between Engineering Education and Practice

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ABSTRACT

Engineers graduating from a typical 4-year University degree program have abundant theoretical knowledge and linear thinking in solving problems and their approach is mostly structured, boxed and bear strong resemblance to the series of courses taken during their education. For example, a Mechanical Engineer may understand the concept and idea behind filleting (rounding off sharp edges) and relate fillets to stress reduction and creating esthetic round presentable parts. The engineer can easily analyze stresses either using hand calculations or perform stress analysis using Finite Element Analysis Software but he or she may not be aware of the implications of filleting in relation to the cost of a product, or the cost of the tool that is used to produce those fillets or the excess lead time it takes to process fillets.

Real world engineering problems are often dynamic, complex and evolving [2] and is very difficult to achieve complete success by using structured linear approach alone. This disconnect between education and practice is due to the lack of exposure and understanding of the real-world problems. This disconnect called “Gaps” is what I want to explore through this project.

Through my research on the web and from my experience as a practicing Engineer for the past 30 years, I had designed an initial survey to address the gaps. From the results of the survey I could classify and analyze gaps. Based on this assessment I had designed an education program that would address the gaps identified.

Author Keywords

Engineering Education; Analysis of Engineering Education and Gaps; Practice vs Education; Real world engineering;

INTRODUCTION

“Gaps” can be defined as **disconnects** between engineering education attained through a typical 4-year engineering degree program and real-world engineering practice. The first part of this project is to understand where those gaps exist, the extent of those gaps, why those gaps exist and how to bridge those gaps. The success of this part of the project depends on data collection and analysis. For data collection, quality, quantity and source of data are very important factors as much as an in-depth analysis of the data.

In the second part of the project I have focused my efforts on designing an education program that addresses the gaps. This education program can be made available as a part of a continuing education program for graduating engineers or can be included with the 4-year engineering curriculum. This program is designed to complement theoretical knowledge gained during the 4-year college program with practice oriented problem-solving skills or POPS. This program includes an understanding of reverse engineering skills needed for real-world products’ design and development, an understanding of the Engineering industrial products from the standpoint of application, develop project management leadership, teamwork and communication skills through a well-designed capstone course. The capstone course is aimed at satisfying an unmet engineering need.

PROBLEM STATEMENT

The problems that engineers solve daily is complex, dynamic and evolving [1]. Engineers need to communicate effectively, manage projects and work with cross-functional teams having different backgrounds and experience levels. The need for understanding problem statements, real world problem solving techniques and effective communication has become more important than ever before [5]. These issues are magnified several times if the Engineer is fresh out of college and if he or she lacks the training needed to handle this dynamic environment. As a result, Engineers need to be trained in various practice areas before they enter the job environment. This project aims at understanding the gaps between what an engineer learned in school and what he or she is required to do in real life.

PURPOSE OF THE CURRENT STUDY

The goal of this project is to help produce well trained engineers who can handle complex, dynamic engineering problems, who can think outside the box, who can utilize their potential fully to lead complex engineering projects [5], and work well with their team members and communicate effectively. In my research, I have put my maximum effort to conduct a systematic unbiased assessment of gaps for the first part of my project and then designed a well-balanced Education Program that can address the gaps in the second part of my project.

RESEARCH QUESTIONS

A survey was designed to find out the answer to the very basic question. Do gaps exist? If gaps exist what are the areas in which the gaps exist?

Then the extent of the gap areas need to be understood, so the questions were designed to find the extent of those gaps. Each question which addresses gaps were framed in such a way to determine if it is a type 1 or type 2 gap.

Type 1 gap: Not knowing what one **should** be knowing as a practicing engineer.
Type 2 gap: Not knowing to the **extent** of what one should be knowing as a practicing engineer.

Further research was done to understand if there exists a correlation between the level of experience and the gaps identified? And if there exists a correlation between the engineer's area of expertise and the gaps identified?

The final question area was what needs to be done to minimize the gaps or how to bridge the gaps. In this the participants were asked to identify the gap areas and were asked to define further the gap areas identified.

METHODOLOGY

Based on my background as an experienced professional engineer, I had designed my initial survey and had sent it to a few participants to obtain a quick initial feedback. Based on the feedback the survey was redesigned. The final survey was sent to many practicing engineers at my workplace, OMSCS class mates, team members who were not engineers and was posted in the Facebook page of Georgia Society of Professional Engineers (GSPE) and finally the survey was sent nationally through National Society of Professional Engineers (NSPE).

Some of the questions of the survey are as follows:

Q1: If you are a practicing engineer, specify the level of experience?

Q2: In what field do you work?

Q3: Do you think Gaps exist between what an Engineer learned in School (Education) and what he does in real life (Practice)?

Q4: If you answered 'Yes' or 'Gaps Exist but it depends' to the previous question, please specify areas where the gaps exist?

Q5: If you selected, "Problem statement understanding", as one of the gaps, please define further.

Q6: If you selected, "Project management", as one of the gaps, please define further.

Q7: If you selected, "Real world problem solving" as one of gaps, please define further.

Q8: If you selected, "Teamwork", as one of the gaps, how big is the gap?

Q9: If you selected, "Communication" as one of the gaps, how big is the gap?

Q10: If you selected, "Innovation--Out of Box and Creativity" as one of gaps, how big is the gap?

Q11: If you selected "Basic manufacturing process", as one of the gaps, please elaborate the gap?

Questions 5 to 11 had choices to determine if the gaps were of Type 1 or Type 2.

Q12: Please indicate what needs to be done to bridge the gap between Engineering Education and Practice.

Q13: If you had mentioned Non-technical skills development as one of the means to bridge the gap, please elaborate below

Q14: If you had mentioned Real World Engineering Products or Real-World Projects as one of the means to bridge the gap, please elaborate below

Q15: Enter in your own words what needs to be done to minimize the gap between Engineering Education and Practice "OR" Explain in your own words why do you think that Gaps do NOT exist.

Question 15 was an open-ended question to give a chance to the participants to explain their reasoning regarding the presence or absence of gaps.

RESULTS-Survey Analysis

After the survey was sent out for data collection, the incoming data was stored in the survey monkey collector to be processed latter. In the following several pages, the results were analyzed question by question. Overall there were 93 responses.

If you are a practicing Engineer, please specify the level of experience?

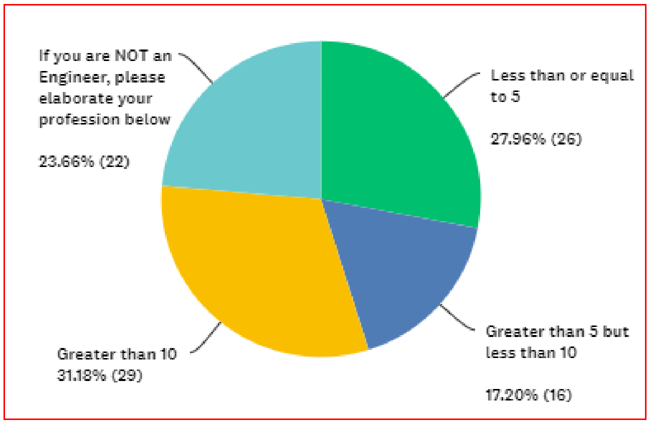
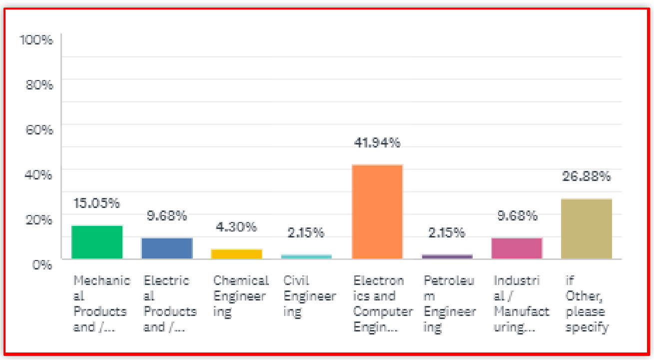


Figure 1. Shows the experience of the population taking this survey.

In what field do you work?



Field of Experience	% of Participants
Mechanical Products and /or Design	15.05%
Electrical Products and /or Design	9.68%
Chemical Engineering	4.30%
Civil Engineering	2.15%
Electronics and Computer Engineering	41.94%
Petroleum Engineering	2.15%
Industrial / Manufacturing Engineering	9.68%
Others (*Purchasing, Oil & Gas, Forensic, Financial Engineering, Refrigeration, Automotive, Market research, Health Research*)	26.88%

Figure 2. Shows the distribution of respondents from engineering majors and others taking this survey.

Do you think gaps exist between what an Engineer learned in School (Education) and what one does in real life (Practice)?

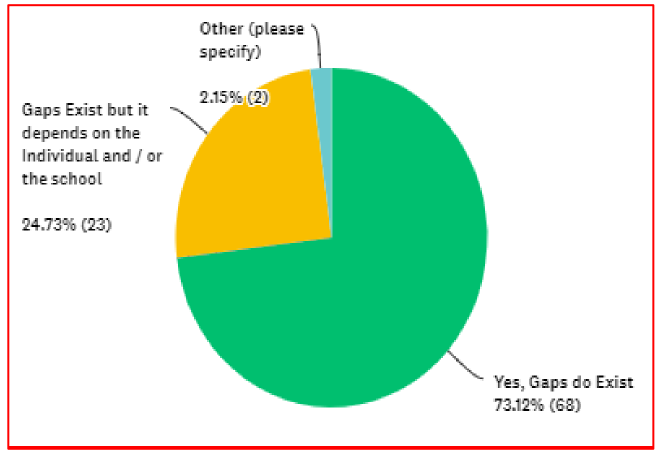
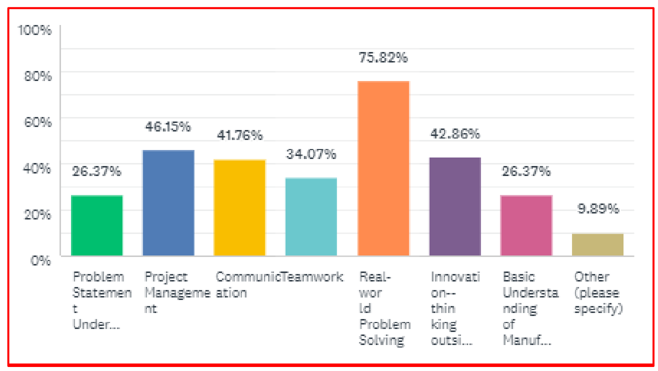


Figure 3. Shows the responses to the question whether gaps exist

If you answered 'Yes' or 'Gaps Exist but it depends' to the previous question, please specify areas where the gaps exist



Gaps	% of Participants
Problem Statement Understanding	26.37%
Project Management	46.15%
Communication	41.76%
Teamwork	34.07%
Real-world problem solving	75.82%
Innovation / Thinking outside the box	42.86%
Basic understanding of Manufacturing process	26.37%
Others	9.89%

Figure 4. Shows the response distribution to the question in which areas the gaps exist

If you selected, “Problem statement understanding”, as one of the gaps, please define further.

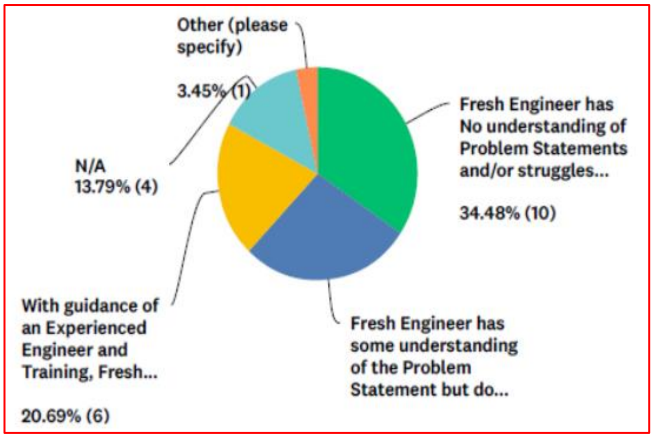


Figure 5. Shows the response distribution to the gap, “Problem statement understanding”

If you selected, “Project management” as one of the gaps, please define further.

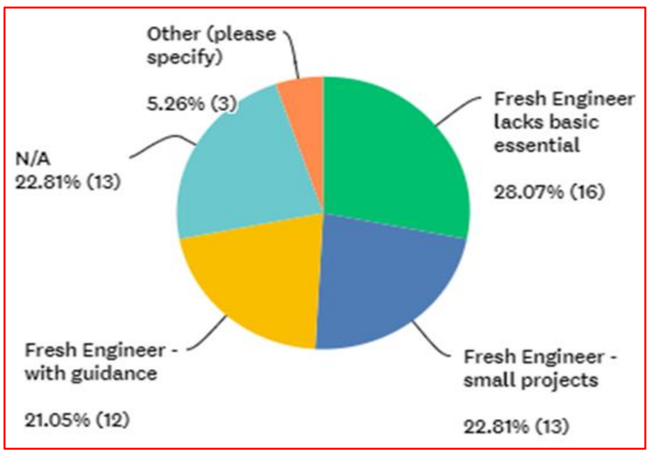


Figure 6. Shows the response distribution to the gap, “Project management”

If you selected, “Real world problem solving” as one of the gaps, please define further.

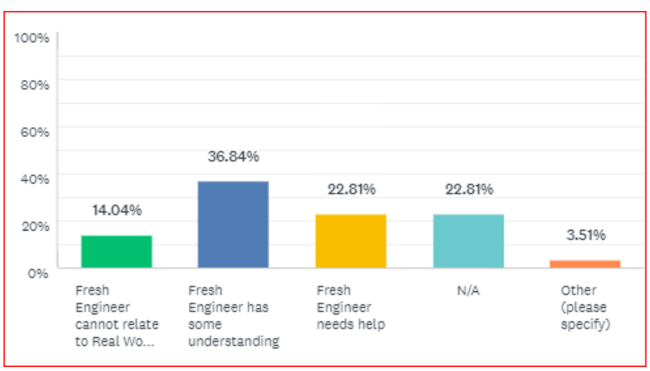


Figure 7. Shows the response distribution to the gap, “Real world problem solving”

If you selected, “Teamwork”, as one of the gaps, how big is the gap?

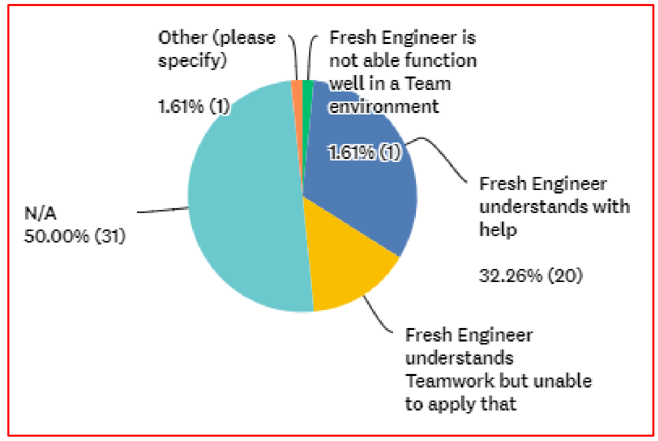


Figure 8. Shows the response distribution to the gap, “Teamwork”

If you selected, “Communication”, as one of the gaps, how big is the gap?

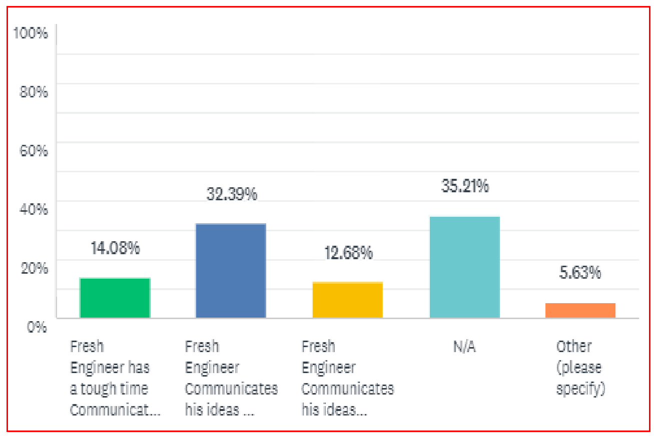


Figure 9. Shows the response distribution to the gap, “Communication”

If you selected, “Innovation—Out of Box and Creativity”, as one of the gaps, how big is the gap?

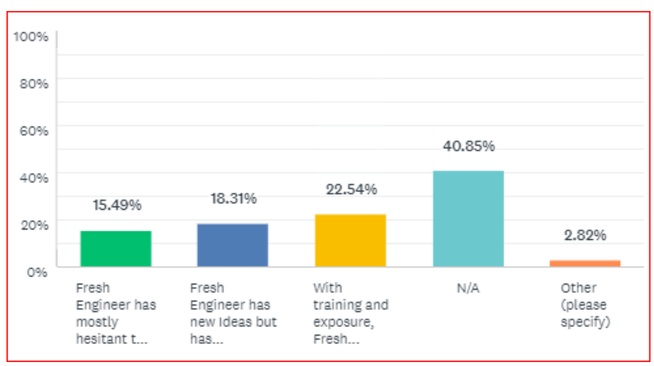


Figure 10. Shows the response distribution to the gap, “Innovation—Out of Box and Creativity”

If you selected “Basic manufacturing process”, as one of the gaps, please elaborate the gap?

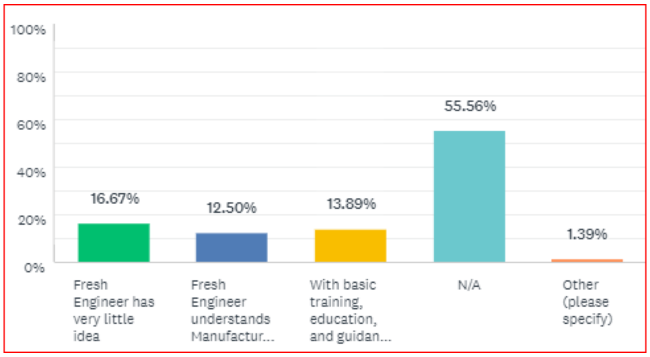


Figure 11. Shows the response distribution to the gap, “Basic manufacturing process”

Please indicate what needs to be done to bridge the gap between Engineering Education and Practice.

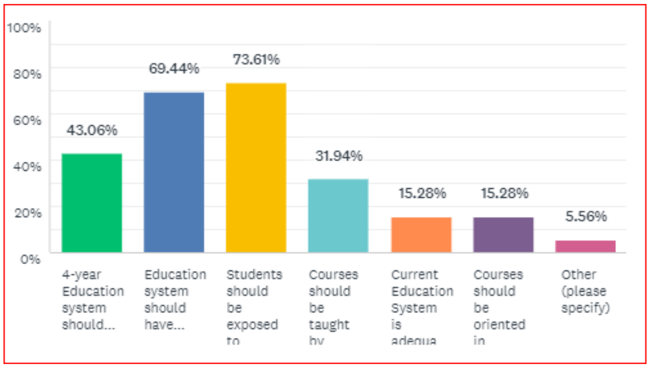


Figure 12. Shows the response distribution to the question, “What needs to be done to bridge the gap between Engineering education and practice”

If you had mentioned Non-technical skills development as one of means to bridge the gap, please elaborate below

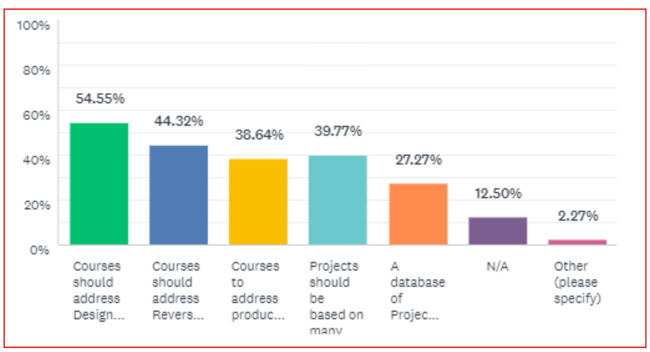


Figure 13. Shows the response distribution to the question, “Non-technical skills development” as one of the means bridge the gap

If you had mentioned Real World Engineering Products or Real-World projects as one of the means to bridge the gap, please elaborate below.

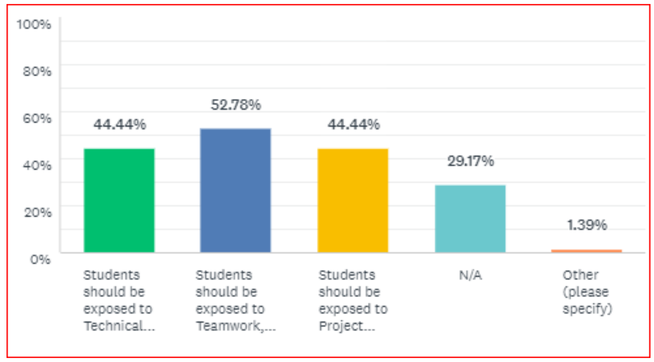


Figure 14. Shows the response distribution to the question, “Real World Engineering Products or Real-World Projects” as one of the means bridge the gap

Enter in your own words what needs to be done to minimize the gap between Engineering Education and Practice “OR” Explain in your own words why to do you think that Gaps do NOT exist.

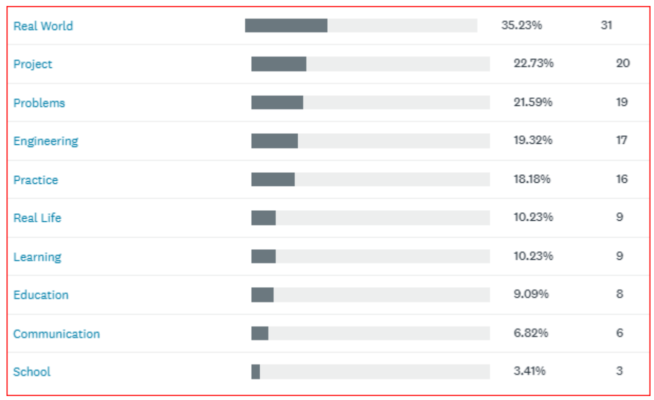


Figure 15. Shows the response to an open-ended question, “What needs to be done to minimize the gap”

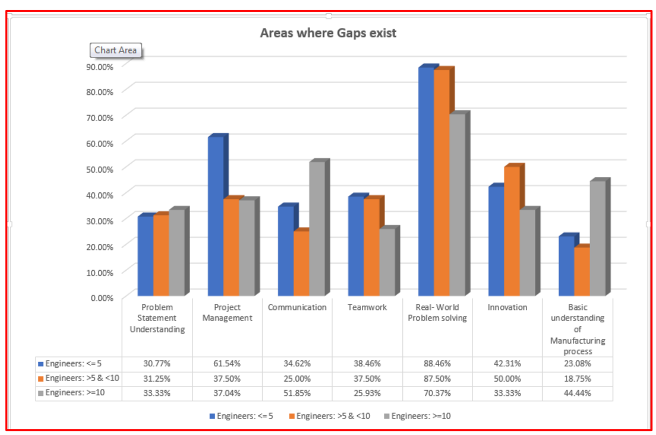


Figure 16. Shows the response distribution to the question, “Select areas where gaps exist”

From figure 16, 61% of the engineers with less than 5 years' experience felt that project management as one of the gaps much more than the 37% of the engineers with more than 5 years of experience. This is due to fact that fresh or new engineers with recognize project management as a required skill. Whereas engineers with experience have learned project management skill through years of experience.

As engineers become experienced, the more they feel that communication is critical to resolving issues.

All engineers with various levels of experience felt that real world problem solving is a valid gap that needs to be addressed.

Engineers with more experience felt that basic understanding of manufacturing process is a gap. As projects become more complex and because of additional responsibilities which the engineer must shoulder, the need to have an in-depth understanding of various manufacturing processes become critical.

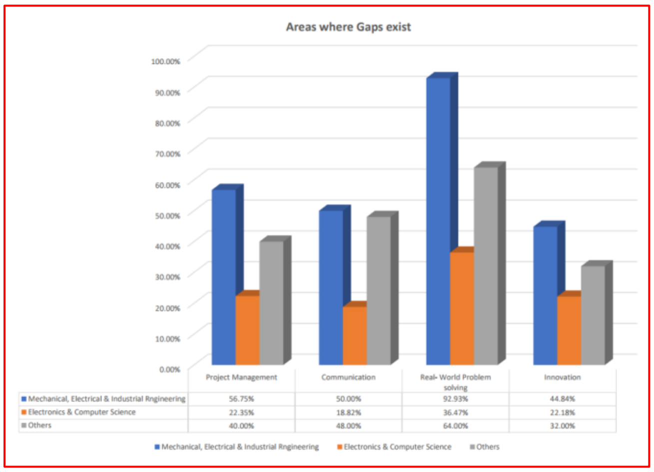


Figure 17. Shows the response by respondents belonging to various engineering branches to the question, "Select areas where gaps exist"

From the analysis, Engineering branches vs analysis of gap areas, more mechanical engineers compared to other engineering majors felt that gaps exist in project management, real world problem solving. This is probably because mechanical engineering jobs are broadly based and highly depend on project management and real world problem-solving skills to be successful.

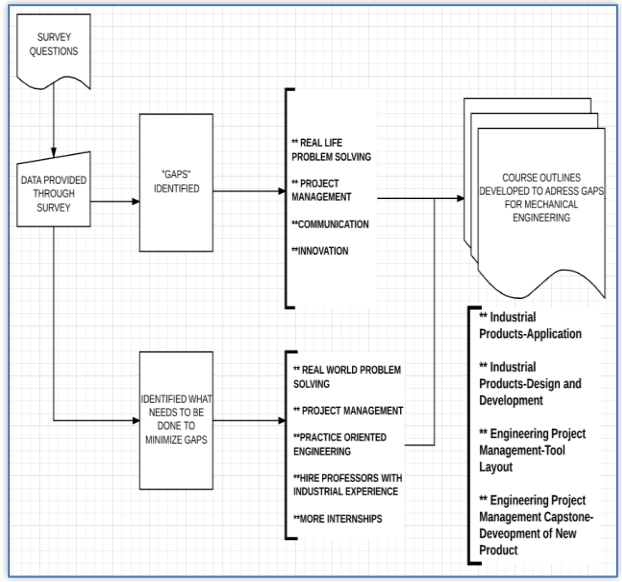


Figure 18. Shows how the gaps were classified leading to course development.

Figure 18 shows the development and classification of gaps attained through the survey. The course outlines were a direct result of respondent's suggestions toward minimizing gaps. These course outlines can be either introduced as a part of the continuing education program or as a part of the 4-year education program.

RESULTS-Education Program development

The following courses were developed as a result of the analysis of gaps.

Industrial Products-Application:

***Course Objectives**:* In this course students will investigate various Industrial products available in the marketplace through collecting and analyzing relevant information that represents product's ultimate utility in its market place. Collect and analyze high level product requirements, market requirements, field related issues, product serviceability, customer complaints, installation and application manuals etc. Example of products include, but not limited to, pumps, gears, motors, valves, pipes, couplings, seals, bearings, shafts etc.

Course Outcomes: Can define product requirements, market requirements and analyze product's utility in the market place i.e. how best the product serves its intended purpose in a defined market space. Should be able to define and understand product features, relate product features to application requirements. Understand product application and performance measures that gage suitability of the product.

Topics Covered: Product requirements, market requirements, customer expectations, Quality Function Deployment (QFD), Requirements Management, Design and Development of user manuals, product manuals, and

Installation manuals. Assess customer requirements and convert high level customer requirements into product requirements through stakeholder communication.

Industrial Products –Design and Development:

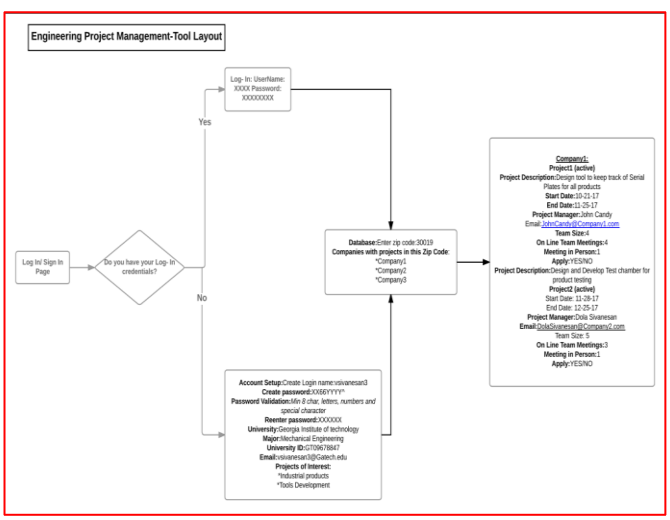
Course Objectives: In this course students will investigate various design philosophies and methodologies employed to design and develop various Industrial products. Understand fail safe mechanisms and its significance in product design and performance. Explore several standardized tests, Industry standards, employed to develop the products. Explore statistical reasoning and analytical reasoning during development. Example of products include, but not limited to, pumps, gears, motors, pipes, couplings, seals, shafts etc.

Course Outcomes: Can define product design and testing methodologies and various industrial and safety standards used to develop products. Can understand materials, properties, and relate to the functional performance of the product. Can understand statistical reasoning employed during development.

Topics Covered: Reverse Engineering—reverse engineer popular industrial products. Basic design mechanisms, such as strength analysis, flow analysis, statistics in analysis, testing standards, engineering drawing, etc. Several tools such as DOE (Design of Experiments), DFM (Design for Manufacture), DFC (Design for Cost), FMEA, FMEA-D, FMEA-M will be emphasized throughout the program.

Engineering Project Management-Tool Layout:

Design, develop and build/or maintain an interface with a database of companies interested in various time sensitive small scale projects. Interface will show, fields such as mechanical, electrical, civil, materials, chemical, computers etc. and various projects under these groups. These projects will have a project lead, duration, and associated costs. Each project will have schedules for several online meetings, milestones and deliverables. Also, an in-person meeting, at least once during the life of the project will be needed to complete the project.



Engineering Project Management Capstone- Development of new product:

Course Objectives: In this course students will be presented with several unmet engineering needs and will be asked to design a brand-new product or products from scratch to address the unmet Engineering need. Each project team will start to design from engineering principles, develop project scope, and will apply design methodologies, design features, analyze cost, and customer centric requirements to produce a thorough, useful, innovative and a cost-effective product.

Course Outcomes: Emphasis on learning to solve real world problems, emphasis on solution driven approach that will be open ended. Learn and apply non-technical skills such as Project management, Communication, leadership and Teamwork.

Topics Covered: Project management using Project management framework-initiating, planning executing, monitoring and control and closing. Project Charter, Business case, Project Planning. Scope management- understand Product scope and Project scope. Engineering Change Notice (ECN), Manufacturing Change Notice (MCN), and Change logs etc.

Project Management, communication, teamwork and leadership tools: Brainstorming, Questionnaire and surveys, prototypes, benchmarking, context diagrams, Critical path method to estimate time, determine budget, Earned value management, cost of quality, Pareto diagram, Design of experiments (DOE), quality checklist, team building, conflict management. Meetings, performance reporting, Just-In-Time (JIT), TQM (total quality management), CAPA (Corrective Action-Preventive Action), Stakeholder management.

CONCLUSION

From analysis of the survey, Gaps between Engineering Education, and Practice (what an Engineer does in real life) do exist.

An analysis of the results reveal that Gaps exist in the following areas, Real-World problem solving, project management, communication and innovation.

Most respondents feel that gaps can be minimized or eliminated by exposing engineers to more internships, learn engineering through practice, solve problems that have resemblance to real-world problems and expose students to project management which helps them to learn soft skills such as leadership, teamwork, and communication.

Based on survey feedback and analysis, I had designed an education program that would address the gaps viz. Industrial products - application, Industrial products - design and development, project management tool layout to access real world engineering projects, and engineering project management capstone course that addresses innovation, and project management skills. The coursework can be implemented as a part of the 4-year Engineering curriculum or as a continuing education program.

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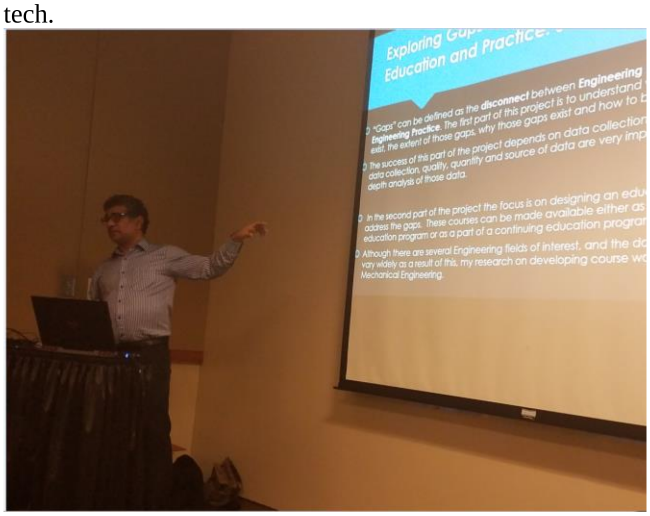

Figure 18. Shows my presentation at Georgia Tech as a part of PDH day hosted by Georgia Society of Professional Engineers on Dec 1, 2017

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