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Identifying essential learning skills in students' Engineering education

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***Abstract:** This study presents results of skills and competencies sought in today's engineering graduates that would be required for a successful engineering professional. The results indicate that employers prefer to hire new graduates that not only possess technical competencies but also the non-technical skills from project management (PM). Analysis of the survey data has identified a list of important skill-attributes that are most sought after by employers, and the six most highly valued skill attributes are: interpersonal communication, planning/scheduling, people management, problem solving, team management and cost control. The implications of the findings are also examined.*

***Keywords:** graduates; skills; project management (PM).*

Introduction

In today's changing global environment many organisations have voiced the need for new graduates of engineering programmes to have a stronger soft-skills emphasis. For example, employers need new graduates to be good communicators and to work in multidisciplinary teams of diverse cultural backgrounds and differing personality styles. Therefore, learning institutions that are able to align with industry demands to produce graduating engineers with the right kind of skills will reap substantial benefits. The integration of project management (PM) skills into the university engineering curriculum offers one solution for training and preparing students with the necessary transferable hard- and soft-skills from the classroom to the workplace. Unfortunately, essential non-technical skills are still lacking among engineering graduates because most engineering schools provide students with little practical experience and few applications competencies.

Consequently, there is a need to equip students with the skills that employers currently desire. Indeed, many employers have expressed dissatisfaction with their hired graduates, especially with respect to soft-skills (Alpern, 1997; Shtub, 1994; Tan, 1998); and projects failed not because the engineer was technically incompetent, but because they lacked the requisite soft-skills. This shows that having technical skills alone is simply not enough as one also needs soft-skills to interact with others and to get the work task running smoothly. Other studies also affirm the importance of acquiring essential PM soft-skills by new graduates in order to succeed (Chapman & Martin, 1996; Clagett, 1997; Goldberg, 1996; Goleman, 1995; Gordon, 2001; Klukken, Parson & Columbus, 1997; NSPE, 1992). These studies have all provided

some valuable insights into the skill-attributes highly valued by employers of engineering organizations.

This survey aims to shed light on the importance of PM skills as perceived by employers in engineering organizations in Malaysia. It is hoped that this study will provide the relevant information for university educators to develop effective engineering curricula which address the present deficiency so as to produce engineering graduates that are better equipped for the industry today.

Research methodology

The objectives of this research programme were to: (1) provide information, opinions, and ideas to address the current and future skills requirements of engineering organizations; (2) rank the importance of the surveyed skill attributes; and (3) examine the perceptions expressed by employers concerning skill-deficient problems in their organizations. The main focus of this work is to achieve these objectives through the collection of data using survey questionnaires and interviews.

The population comprised all the major engineering firms in Malaysia with a project-intensive-background. These companies were screened with regard to the types of projects they dealt with, to ensure that only specific types of industries were investigated so as to maintain a consistent comparison in the statistical evaluation. The major projects involved in this study were categorized as: product manufacturing, machinery/equipment, electrical and electronic, and construction. The targeted participants comprised experienced senior/principal engineers, managers and managing directors with PM experience and technical knowledge. The participants chosen were likely to possess substantial experience in data collection methods and to make judgments and opinions on the importance of PM skill attributes or to be in a position to pass the questionnaire to the right person if they were not participating. To encourage participation, each company was contacted by telephone prior to posting the questionnaire. From this initial contact, the respondent's name, functions, and responsibilities within their respective department were determined. About 80 per cent of the respondents agreed to participate in the survey. A total of 600 questionnaires were utilized and sent to the identified and selected project-intensive engineering organisations.

The data collection was based on a detailed, six-page, pre-tested research questionnaire. The questionnaire was presented in a user-friendly multiple-choice format, with only a few open-ended questions, to reduce the effort of answering. The surveyed skill-attributes were developed and formulated by thoroughly reviewing specific skills identified by engineering firms and by the review of current literature. In the postal surveys, the questionnaire was accompanied by a personalized cover letter. A self-addressed stamped envelope was included for the convenience of the participants. These procedures yielded a response rate of 30 percent. To boost response rates and to ensure a timely completion of the questionnaire, two weeks after the initial mailing, non-respondents with e-mail accounts were sent online questionnaires as a friendly reminder. This improved the response rate to approximately 40 percent. A week after that, a telephone follow-up call was carried out to request their cooperation; that resulted in a further 12 percent response rate. Up to three attempts were made to reach individuals who had not yet returned the questionnaire by the set deadline.

Both telephone and personal interviews were conducted, with participants from various industrial segments, with the help of structured questionnaires. Interview questions centred around the business profile and environment, project activities, issues of recruitment

problems, current and future skills requirements, hiring practices, employer expectations and perceptions on skills training, and any other issues that were deemed important to the employer but not covered in the questionnaire.

Results and discussion

Of the 600 mailed questionnaires, 312 usable questionnaires were returned, representing a response rate of 52 percent. The non-respondents quoted the following for their non-participation: against company policy, lack of time (too busy), lack of interest, and matters of confidentiality. Table 1 shows the results of the mailed survey. The majority of the respondents were from the areas of product manufacturing (47.1%) and construction (35.6%). Table 2 shows the distribution of local and overseas graduates hired by the employers, of which the majority were from Mechanical (21.2%), E&E (21.2%), Industrial (20.5%) and Civil (18.3%). Overall, the table indicates that Malaysian employers show only a slight preference for hiring new graduates from overseas universities (51.6%).

Table 3 shows the relative rankings, in descending order of importance, for the 22 skills covered that employers seek when recruiting graduates. The mean ratings obtained for the extent of importance were between 1 and 7, where 1 implies “*not at all important*” and 7 implies “*extremely important*”. As noted, these skill-attributes received mean averages ranging from 4.5 to 6.4, (all attributes > median 3.5), which highlighted differences and patterns. In Table 3, the six skill-attributes the majority of organizations considered most important were interpersonal-communication (6.34), project planning/scheduling (6.28), people management (6.24), problem solving (6.21), team management (6.14) and cost control (6.09). The other PM skill attributes, which scored mean ratings above 5.0 but below 6.0, are still to be considered to be important, though their relevance varies with the size and nature of the business. These encompass 19 of the 22 PM skill attributes identified. The remaining three form the least important skill-attributes (those with average ratings in the range of 4.5 to 4.9): law for engineers, product marketing, and international perspective. Engineer’s perspective on international business ranks lowest in the list as it was presumed that this skill-attribute was required of high executives but not their newly recruited employees.

Communication was listed as the most important skill attribute. The results highlight the fact that employers overwhelmingly agree that interpersonal-communication skills are very important for a graduating engineer to possess. For example, most employers want their hired graduates to be able to follow instructions, speak clearly, give clear instructions and make effective presentations. Project planning/scheduling ranked second possibly because this skill-attribute is needed at various points in a project life-cycle. For other types of skill categories such as people management and team management skills, graduates need to acquire the ability to organise, inspire and empower their subordinates/coworkers, as well as to practise good listening skills and keep an open mind to promote the generation and flow of creative and innovative ideas. People management is seen as an important attribute for building good working-relationships with a project team, keeping the project moving, establishing clear expectations with customers, identifying potential problems and soliciting suggestions to improve project performance; whereas the team management skill-attribute requires the use of effective interpersonal-communication by each member to explain to one another, develop know-how, and understand each other. Problem solving skills, which recorded the least variability (0.506), include the sub-skill areas of problem-identification/formulation, evaluation of alternative solutions, uncertainty analysis, modelling, and qualitative analysis. All these categories of skill-attributes are actually interrelated; they interact for the execution

of a successful project. Indeed, all the best equipment and business processes will only be guaranteed success if accompanied by these essential skill-attributes.

Employers' views

The survey results revealed significant gaps between what universities currently offer and what industries demand. An estimate of 70 percent of participants interviewed expressed the view that university programmes focused too intensely on scientific theories and technical knowledge in most subjects. These participants indicated that they were not interested in theories/concepts *per se* but rather they wanted to see practical results, a demonstration by graduates that they were able to do something with the knowledge/experience they had acquired at university. For example, most skills demanded for the effective management of projects requires engineers to have soft-skills competency in order to perform their job smoothly, without which the organisational machinery will not run smoothly. Most participants also indicated that the teaching and learning of PM skills was an important subject and should be integrated into the university curriculum to complement technical knowledge. They concurred that these essential skills could not be developed in one PM-taught subject and suggested that these be consistently built and developed into other subject areas and practised throughout the four-year engineering degree programme. Generally, local teaching institutions that run a 3-year engineering degree programme offer only the limited engineering disciplines.

Participants interviewed identified two fundamental causes of project failure. Firstly, projects were unsuccessful due to factors such as schedule and cost overruns, poor resource selection, over-commitment at the outset, lack of team inspiration, and poor management expectation. As a result, the expectations of customers were not met. Secondly, projects failed because communication among the team failed. It is evident from this revelation that PM-related skills should form an intrinsic part of engineering education and deserve serious attention and consideration by university educators.

Here are some comments and suggestions expressed by employers concerning this education dilemma:

- Improving communication and links between industry employers and educationists to create a clearer direction for student learning.
- Making the curriculum content more relevant to current and future needs of engineering organizations.
- Restructuring/redefining classroom pedagogy so that it incorporates essential skill-attributes.
- Encouraging students to obtain the needed skill-attributes through a structured and well-planned industrial internship programme, class projects/thesis, involvement with student and professional organisations and involvement in other campus organisations.
- Standardising and making essential soft-skills education compulsory in the engineering curriculum.

Performance of new graduates

Figure 1 shows the different skill-levels between overseas and local graduates as perceived by Malaysian employers. Employers indicated that both local and overseas graduates were perceived to be poor in many essential PM-related skills. Leadership skills, people management, project planning/scheduling, problem solving received relatively mediocre performance ratings (5.5, 5.4, 5.3, & 5.0 out of 10.0, respectively). Interpersonal-

communication skills received the lowest performance rating (4.6). Roughly, graduates employed were rated an average score of 5.9 for all the skill attributes tested, which is not particularly poor *per se* but could be improved further. These performance results were consistent with earlier findings of skill-attributes that were importance to Malaysian employers.

The results also showed that the overall skills exhibited by overseas graduates produced slightly higher skills rating (51.6%) than local graduates (48.4%). However, the ratings of some of these skills may depend on the maturity of the university, and the inherent qualities of individuals and their motivation to learn new skills. The slightly higher overall ratings towards overseas graduates may indicate possible deficiencies in some areas of the local engineering syllabus. For example, better pedagogical techniques practised in well-established overseas universities may help students to improve some skill attributes. For example, overseas graduates appeared to surpass local graduates in IT and presentation skills by 23 per cent and 28 per cent, respectively. This result may reflect possible areas of importance that local teaching institutions may like to examine further to address any essential skill deficiency areas in their current engineering curriculum.

Figure 2 compares the percentage scores of the expected skills and the actual performance of graduates as perceived by employers. The skills deficiency is the difference in mean ratings between the expected skills and actual performance of graduates. The skill-attribute is considered deficient if the expected skill differs considerably from performance. And if their values are close, then the employers' expectations have been met. Taking into account the relative importance of the skills to employers, the gaps-in-skills deficiency can be ranked in decreasing order as follows: interpersonal-communications; project planning/scheduling; people management; problem solving, whereas the performance of graduates ranked in increasing order were: interpersonal-communication, problem solving, project planning/scheduling and people management. These analyses reveal that the interpersonal-communication attribute shows the highest percentage deficiency (45%) compared to other skill attributes. Problem solving (37%), project planning/scheduling (36%), and people management (35%) were found to be almost as deficient. This is followed by team management (32%) and leadership skills (30%). Overall, these results highlight a serious learning gap with regard to these skill-attributes.

Communication skill issues

The results consistently reveal that interpersonal-communication skills remain a major concern of many employers today. The majority of employers expressed dissatisfaction with students' communication abilities. This ranged from failure in both written and oral communication skills to presentational and other work-specific communication skills such as informal discussions, publication of papers, public speeches and interviews, etc. For example, reports are poorly written, rife with misspellings, redundancies, grammatical errors, illogical sequencing and imprecise expressions. These failures appear to be less problematic with experienced employees and graduates from the more established universities. This observation is not surprising because experienced employees have had opportunities to develop and practice their communication skills to a higher level during their working life. Most employers said that their hired graduates know the materials well in view of their good grades achieved in the engineering subjects, but that they simply do not communicate effectively.

Employers indicated that valuable resources such as time, money, and materials were necessary assets for a project but these cannot guarantee successful completion, as it was the

people in the project team who held the key to success. This is because the dynamics of a project require a close-knit, communicative team capable of recognising and solving problems quickly. For example, each project phase has its own unique set of issues that require a substantial breadth of analysis for it to be resolved successfully on a daily basis.

Communication skills act as drivers in all the project life-cycle phases. Engineers in these project teams must have the ability to gather information, present findings or convey complex ideas clearly, articulate what must be accomplished, keep the team moving toward a common goal, and foster an environment that allows team members to communicate openly and honestly. Employers remarked that the lack of an effective communication process built into each of the project phases is the major contributing factor to project failures. Much of the evidence points to the fact that communication skills have enabled their engineers to be more effective. For example, an engineer managing a project without clearly communicating its goals and sharing his ideas with others will have vague deliverables and requirements, unresolved issues, conflicts, and a dissatisfied customer. Without the appropriate soft-skills built into the project life-cycle, it is clear that the likelihood of project success diminishes.

Implications of findings to the education challenge

The implication identified from these findings is that engineering skills alone are inadequate to produce a professional engineer with managerial abilities (soft-skills) who can take on a project successfully. Employers have expressed the view that graduates were often good technically and could produce engineering solutions to technical problems but often had weak non-technical skills and so failed to complete a project successfully. The survey results further indicate that employers are seeking employees with the ability to integrate their technical knowledge with other non-technical skills. Today's employers require employees to have a very broad range of essential PM skills to handle issues affecting all stages of the project life-cycle.

Changes in the engineering curriculum over the last decade have not been dynamic enough to keep pace with a rapidly-changing marketplace. Consequently, many graduates lack the essential skills on which to build new learning experiences. Thus curriculum changes are needed for engineering schools to stay relevant. Undoubtedly, this issue will present a big challenge for educators to design and implement effective learning strategies for soft-skills education into the engineering curriculum.

Hence, this study shows that university education should provide a solution to address these skill-deficit issues, so as to fully prepare graduates for the engineering workforce. This is because today employers are increasingly expecting graduating engineers with more and more advanced education and training as they believe that these new recruits with prior knowledge of essential PM skills can be more easily trained in their workplace compared to those with less exposure of PM skills. For a start, universities and engineering organisations can form an industrial advisory committee to address any PM skill deficiencies that are facing today's businesses. The engineering faculty must be open to feedback from the industry as to what skill-sets are important for organisational success. The benefits of this effort in joint curriculum design can be expected to build important bridges on the path to long-term partnerships.

A stronger emphasis on acquiring and practising soft-skills while at university is likely to better prepare students for the workplace. Not all students possess PM skills-attributes naturally, and hence students need help in acquiring soft-skills techniques to handle human-relationship issues that match employer expectations. Other ways of encouraging soft-skill

development include co-op education, internships, mentoring, and by engaging students in practical real-world design problems and case studies. These should provide students with valuable opportunities for teamwork, problem solving, project planning/scheduling, people management, and communications.

The current employers' preference is to recruit graduates who have a solid foundation of both technical and non-technical skills because they are easy to train and become productive in a shorter time. Employers indicated they recruit fewer graduates from institutions whose courses do not respond to their skills requirements, or whose courses are seen as costly, inconvenient and not relevant to their immediate skill needs. Employers expect universities to carry out more research studies on industrial skill needs, and to keep their curricula relevant.

Conclusions

This research provides some valuable insights into the relative importance of the various types of essential PM skill attributes as required from engineering graduates. Essentially, engineers possessing a high proficiency in both technical and PM soft skills competencies are better prepared to enter the working world. The findings support the trend toward seeing essential PM skills education as one method for addressing the soft-skills deficiency issues of new graduates. The principal skill gaps identified were attributed to skills such as interpersonal communication, project planning/scheduling, people management, problem-solving and team management. It is hoped that the results of this study will provide useful information to educators as input to review, study and reassess their present engineering curriculum.

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Table 1: Industrial classifications of employers that participate in the surveys

Industrial Classification	Frequency	Weighted Percentage (%)
Product manufacturing	147	47.1
Construction	111	35.6
Electrical & Electronics	24	7.7
Machinery/Equipment	21	6.7
Others	9	2.9
Total Questionnaires received	312	100.0

Table 2: Distribution of new graduates hired by Malaysian engineering firms

Field of Study	Local Graduate	Overseas Graduate	Total
Average	48.4%	51.6%	100%
Mechanical engineering	26	40	66
Electrical and electronics engineering	33	33	66
Industrial engineering	31	33	64
Chemical engineering	19	24	43
Civil engineering	40	17	57
Mechatronics engineering	2	14	16
Total Questionnaires Received	151	161	312

Table 3: Rankings of the 22 surveyed skill attributes.

No.	PM Skill Attribute	Mean score	Standard Deviation
1	Interpersonal Communication	6.341	0.550
2	Project Planning and Scheduling	6.280	0.557
3	People Management	6.242	0.568
4	Problem Solving Skills	6.205	0.506
5	Team Management	6.136	0.563
6	Cost Control	6.091	0.704
7	Leadership Skills	5.932	1.057
8	Quality Assurance	5.796	0.845
9	Documentation Skills	5.705	0.923
10	Personal Time Management	5.614	0.913
11	Effective Meeting Management	5.477	0.842
12	Presentation Skills	5.409	1.033
13	Negotiation Skills	5.341	1.210
14	Entrepreneurial & Business Knowledge	5.296	1.061
15	Change Management	5.250	1.115
16	Network Analysis	5.227	1.088
17	Strategic Thinking	5.182	1.341
18	Risk Management	5.068	1.079
19	Corporate Strategies	5.000	1.117
20	Law for Engineers	4.955	1.171
21	Product Marketing	4.909	1.449
22	International Perspective	4.523	1.182

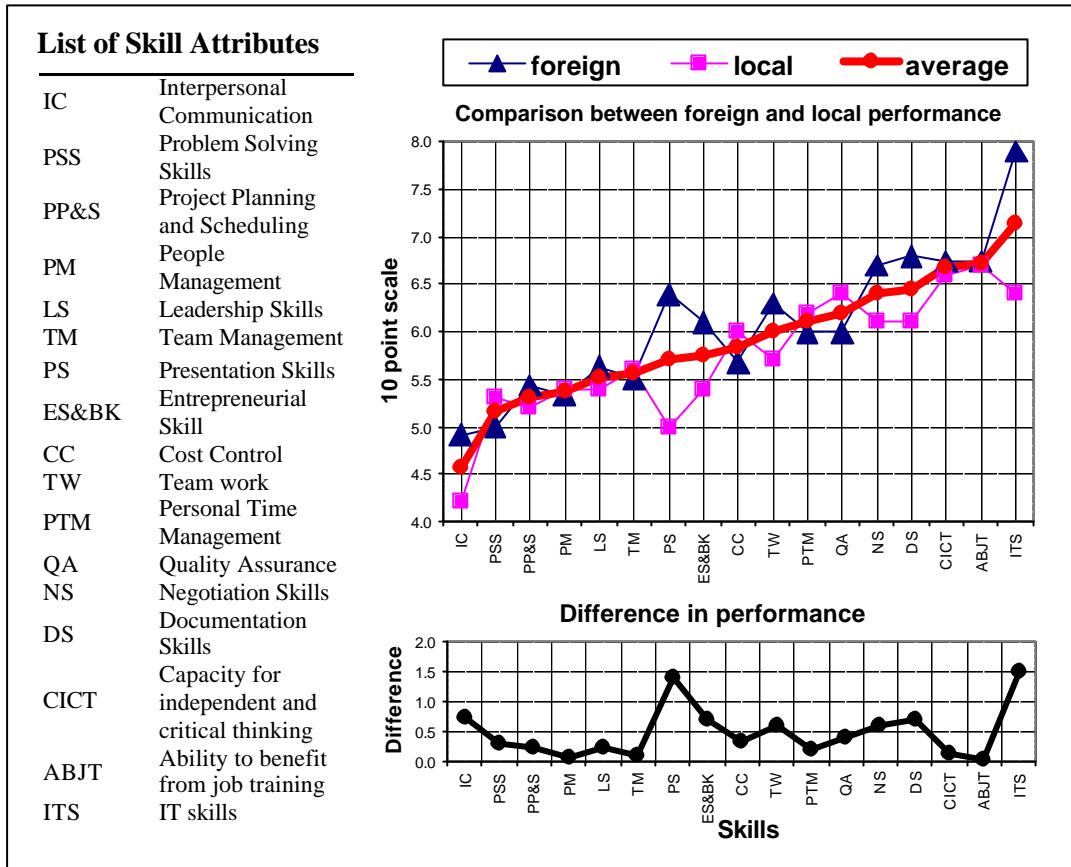


Figure 1: Performance comparison of local and overseas graduates

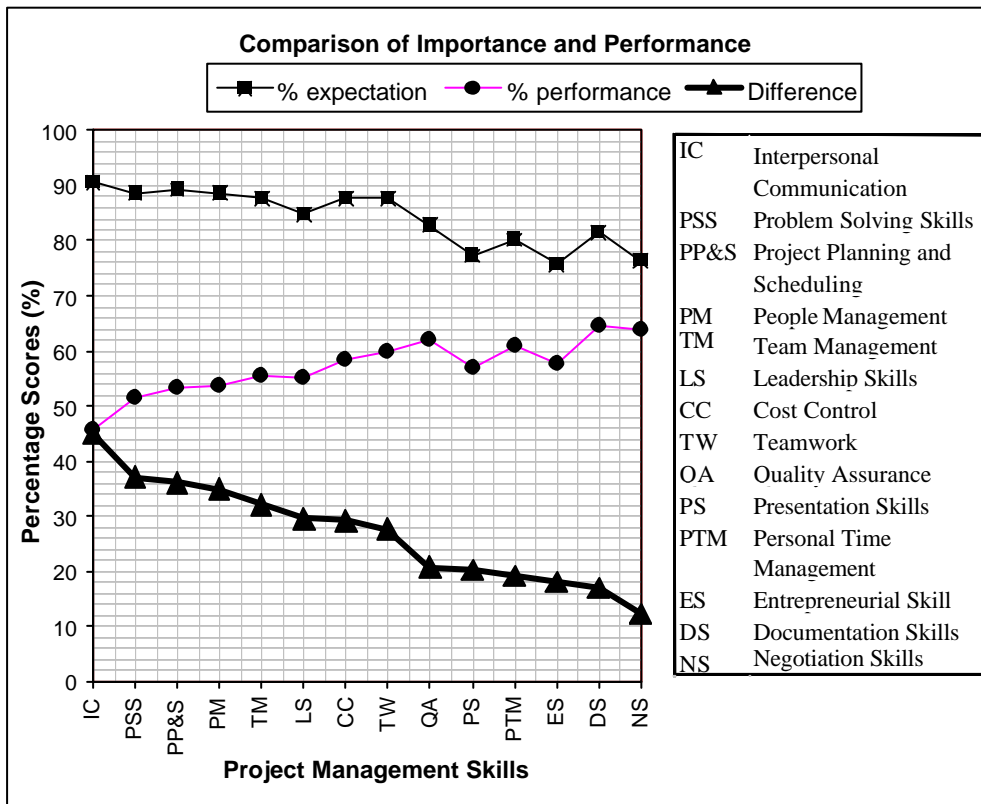


Figure 2: Comparison between expected skills and performance of new graduates