AC 2011-173: TOOL USE AND ACTIVITIES OF PRACTICING ENGINEERS OVER TIME: SURVEY RESULTS

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Tool Use and Activities of Practicing Engineers over Time: Survey Results

Abstract

A major goal of higher education is to provide students with the knowledge they need to be successful in their professional careers and prepare them to be lifelong learners who can adapt in a dynamic environment. To understand what that knowledge entails requires insights into what activities current practicing engineers are engaged in and what tools they use in the workplace. How those activities have changed over time will provide insight into how to properly train students to be lifelong learners. To assist with this effort, this work undertook a survey of a representative group of practicing engineers. The link for a web-based survey was sent to a chapter of the Society of Manufacturing Engineers. In addition to demographic and employer information, details regarding work-related activities and how those activities have changed over time was requested. Additional information regarding the tools used by the responding practicing engineers was also collected.

Survey results show design, manufacturing engineering, and project management as the major activities of the respondents. Results show that these activities have required approximately the same amount of time over the respondents' careers; with the exception of project management, which has increased. 75% of respondents' companies use product platforms and manufacture outside their home countries. The majority of respondents companies' use some type of cost estimation tool. The greatest number of respondents had a Bachelors degree and worked for companies with less than 1000 employees. These results are discussed in the context of the current engineering technology curriculum at the authors' institution.

Introduction

As educators, preparing students for their future industrial or further educational careers is of paramount importance. In addition to providing them with definitive skills, students should be prepared to acquire future necessary skills as their careers evolve. ABET outcomes for Manufacturing Engineering Technology programs explicitly state that graduates should be prepared for "careers centered on the manufacture of goods" [1]. The ability "engage in lifelong learning" is also explicitly stated in the general technology program outcomes [1]. Understanding what skills are required of graduates and preparing them to be lifelong learners entails learning about the types of careers these students will pursue. One way of gaining this information is through ABET mandated advisory committees. While these committees can help with identifying industry trends and skill requirements, they are limited in size and therefore only offer limited insight.

To broaden the amount of information about the types of tools and the trends over time using those tools, a survey of the Houston chapter of the Society of Manufacturing Engineers (SME) was organized. Houston is the largest city in Texas, located approximately 90 minutes from

Texas A&M University (the authors' institution), and serves as a destination for a significant portion of the department's graduates. While the engineering technology program at Texas A&M is a combined manufacturing and mechanical engineering technology program, SME was chosen given the large number of manufacturers in the area and the number of former students working for manufacturers in the area. It was thought that the experiences of engineers and engineering technologist from this chapter would be representative of the larger community. The next section details the methods used to gather survey results; these results are then detailed and discussed in the following sections.

Methods

The survey was carried out over the internet using the SurveyMonkey website. The survey was compiled on the SurveyMonkey site and a link was mailed to the e-mail list subscribers of the Houston chapter of SME. The chapter e-mail list contained approximately 450 addresses. The initial e-mail stated the purpose of the survey and told potential respondents to please complete the survey by October 31^{st}, 2010. A follow-up e-mail asking additional respondents to please fill out the survey was sent out on October 27^{th}. The initial request garnered 35 responses; the follow-up email garnered 15.

The survey initially asked for consent regarding the use of data for research purposes; all 50 respondents consented. Of 50 total respondents, 38 completed the entire survey. The questions asked in the survey are shown in the Results section. In addition to reporting responses, statistical analyses were used to examine any correlations between responses and differences between large and small employers.

Results

The first goal of the survey was to establish how respondents spent their working time; the first question asked them to describe how much time in a 40 hour week they spent on various activities. The results from this question are shown in Table 1. The data were not checked for internal consistency – it was possible for respondents to compile responses that exceeded 40 hours. A graphical representation of this data is shown in Figure 1. The data show that the majority of respondents have several responsibilities that take up a limited portion of their time. The highest response rate was for manufacturing related activities (as could be expected from a SME sample). The lowest response was for analysis related activities (e.g., computer-aided engineering or finite element analysis). Outside of the analysis related activities, the average response for each of the activities was approximately three; this corresponded to between 8 and 14 hours of a standard 40 hour work week.

Table 1. Work Time Distribution Responses for Various Activities

Please describe what portion of your time is dedicated to the following activities. Assume standard 40 hour work week.	**No Time (1)**	**1-7 Hours (2)**	**8-14 Hours (3)**	**15-21 Hours (4)**	**22-28 Hours (5)**	**29-35 Hours (6)**	**My Entire Time (7)**	**Rating Average**
Engineering Design	5	**19**	6	4	1	4	1	**2.83**
Manufacturing/CAM	7	**12**	7	4	5	1	3	**3.08**
Analysis/CAE/FEA	14	**15**	7	0	0	0	0	**1.81**
Project Timeline Management	3	**12**	10	10	3	0	1	**3.05**
General Project Management	4	**12**	11	8	4	1	0	**2.98**

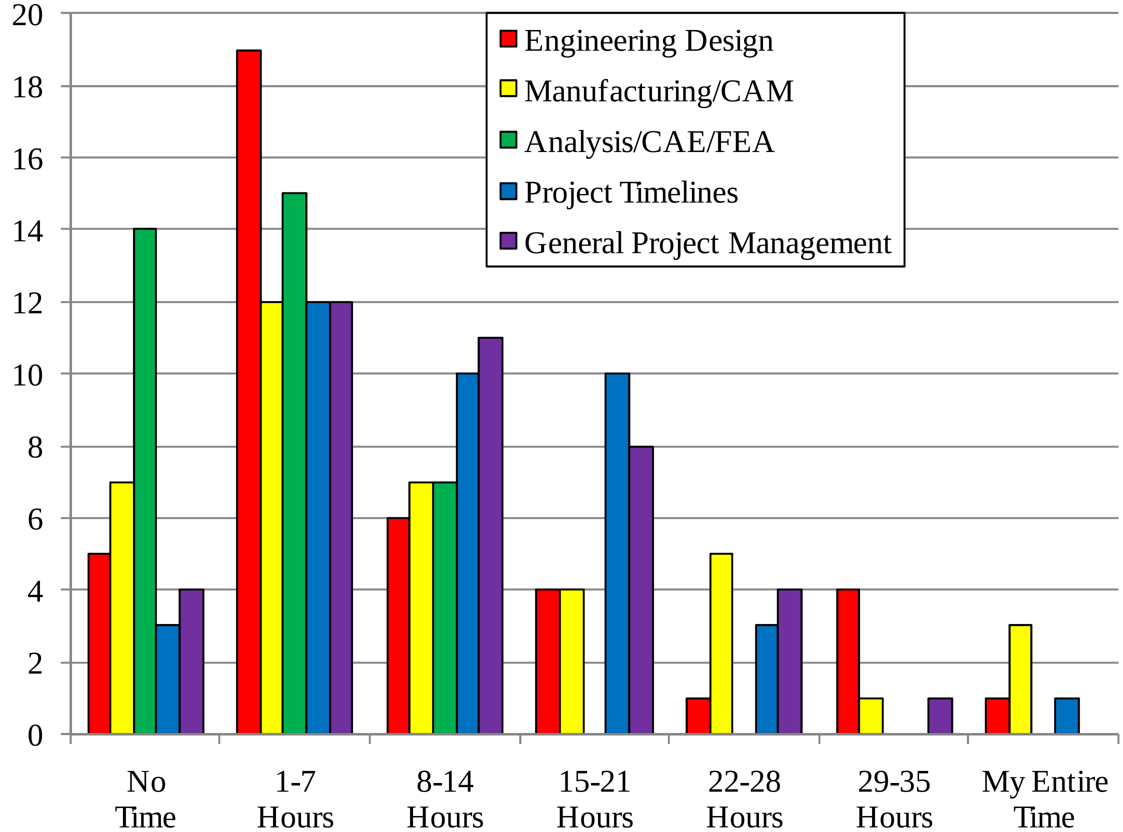

Figure 1. Work Time Distribution Responses for Various Activities

The next question attempted to understand how the amount of time respondents spent on these activities had changed over time. For most of the activities, the mean response equated to between decreasing slightly and staying about the same (between three and four on the scale). The exceptions were the two project management related activities. In both cases, the mean response to these two questions was almost five. The responses are shown in Table 2 and Figure 2.

Table 2. Work Time Change Responses for Various Activities

Please describe how the amount of time you spend on the following activities has changed over the course of your career.	**It has decreased significantly (1)**	**(2)**	**(3)**	**It has stayed about the same (4)**	**(5)**	**(6)**	**It has increased significantly (7)**	**Rating Average**
Engineering Design	9	7	3	**16**	3	1	2	**3.20**
Manufacturing/CAM	7	5	6	**12**	3	4	4	**3.66**
Analysis/CAE/FEA	8	4	3	**12**	6	2	2	**3.49**
Project Timeline Management	2	1	2	**12**	9	10	3	**4.72**
General Project Management	2	3	2	7	**12**	8	6	**4.8**

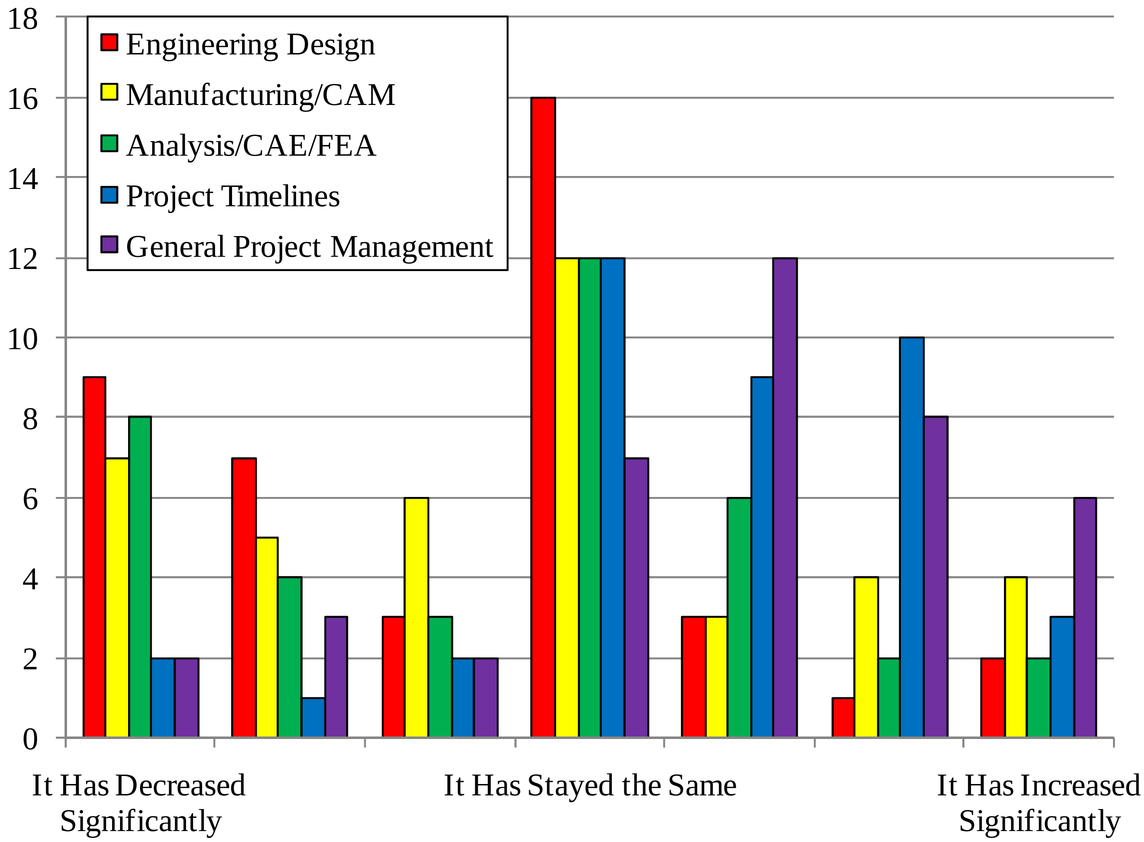

Table 2. Work Time Change Responses for Various Activities

The next set of questions attempted to determine what types of tools and strategies the respondents' companies used and how they were carried out. The general questions are shown in Table 3 with the implementation answers shown in Table 4. Over 75% of companies used product platforms or product families for manufactured goods. It was slightly more likely that all variants were developed beforehand (as opposed to variant products being developed after the initial variant). 75% of respondents reported that their company manufactured in a country outside the one in which they worked. It was slightly more likely than not that when this occurred a member of the technical staff visited the foreign manufacturer. It should be noted that the response to this question was bimodal – 10 of the respondents said it was highly unlikely (response one or two) and 11 respondents saying that it was highly likely (response six or seven). The next question concerned the use of a cost estimation tool for manufactured goods. Again, over 75% of respondents said that their companies used such a tool. The majority of the respondents that answered in the affirmative to tool usage said that the tool they used captured development effort and supply chain costs. The overwhelming majority of the tools used were non-commercial (i.e., developed by the engineer or a colleague or proprietary to the company).

Table 3. Tool Use and Manufacturing Strategy Responses

	Yes		**No**
Does your company use product platforms/ product families for their products	**31**		10
Does your company manufacture in a country outside the one where you reside	**30**		10
Does your company use a cost estimation tool for manufactured goods	**30**		9
→Does this tool capture the cost of the development effort	**20**		11
→Does this tool capture the cost of supply chain or distribution costs	**24**		7
	Commercial	**Proprietary**	**Personal**
→What type of cost estimation tool is used	5	**15**	11

Table 4. Product Platform Strategy Distribution

	Not likely/ never happens (1)	**(2)**	**(3)**	**Happens about half the time (4)**	**(5)**	**(6)**	**Very likely/ happens all the time (7)**	**Rating Average**
How likely is it that the product family or platform are designed beforehand (as opposed to an initial product with follow-on variants)	0	6	3	**9**	5	2	5	**4.30**
How likely is it that technical staff visit the foreign manufacturer to monitor ramp-up/production	1	**9**	4	4	0	3	8	**4.17**

Next information regarding the nature of project management timeline creation was gathered. Specifically, the amount of input provided by technical personnel was queried; these results are shown in table 5. These data showed mostly equal input between technical and managerial staff; responses of more and less input were almost equal. The data for the creation of project timelines was skewed towards more top down timeline creation. The average response for this question was 3.1, with almost 30% of respondents reporting that project timelines were created to meet a specified goal.

Table 5. Project Timeline Creation Responses

	No input (1)	**(2)**	**(3)**	**Negotiated with equal input (4)**	**(5)**	**(6)**	**Complete oversight (7)**	**Rating Average**
Describe the amount of input that development/technical staff has in the establishment of project timelines at your company	1	3	5	**20**	5	3	2	**4.08**
	Top Down – completion time determined and tasks chosen to fit desired timeline (1)	**(2)**	**(3)**	**Negotiated equally between requirements and desired timeline (4)**	**(5)**	**(6)**	**Bottom Up – tasks and durations summed to define timeline (7)**	**Rating Average**
Describe how project timelines are established at your company	11	4	2	**18**	1	1	2	**3.13**

Finally, information about the companies, the respondents, and their computer-aided design programs was collected. The plurality of the respondents worked for relatively small companies; 47% of respondents worked for companies with less than 1000 employees. The distribution of company size responses are shown in Figure 3. The effect of company size on the other responses was examined. A paired t-test was used to examine the responses of those working for employers with less than 1000 respondents and those working for companies with more than 1000 employees. Only two questions showed statistically significant differences; these are shown in Table 6. Small companies were less likely to use cost estimation tools or manufacture in countries outside the one where they were located. The distribution of respondents' company or division business line is shown in Figure 4. The majority of respondents stated "Other". The highest listed response was for industrial machinery. The supported CAD programs are respondents' companies are shown in Figure 5. The most popular program is SolidWorks followed by Pro/Engineer. A histogram showing the respondents' experience in the engineering field is shown in Figure 6. The distribution is relatively uniform. The distribution of respondents' highest level of educational achievement is shown in Figure 7. The plurality of respondents had a Bachelors degree followed by a technical Masters degree. Figure 8 shows the distribution of respondents' job titles. As would be expected from a sample provided by SME, the majority described themselves as manufacturing engineers.

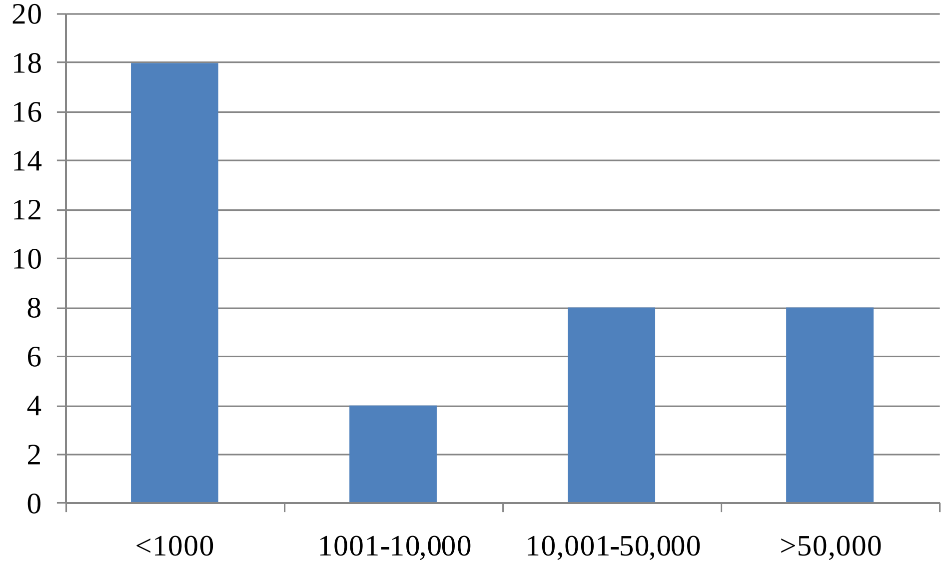

Figure 3. Company Size Distribution from Survey Respondents

Table 6. Statistically Significant Variables between Large and Small Companies

	Mean – Small	Mean – Big	t-Stat	Sig. (2-tailed)
Cost Estimation Tool Usage (Yes-1; No-2)	1.35	1.10	1.84	0.078
Foreign Manufacturing (Yes-1; No-2)	1.50	1.05	3.43	0.002

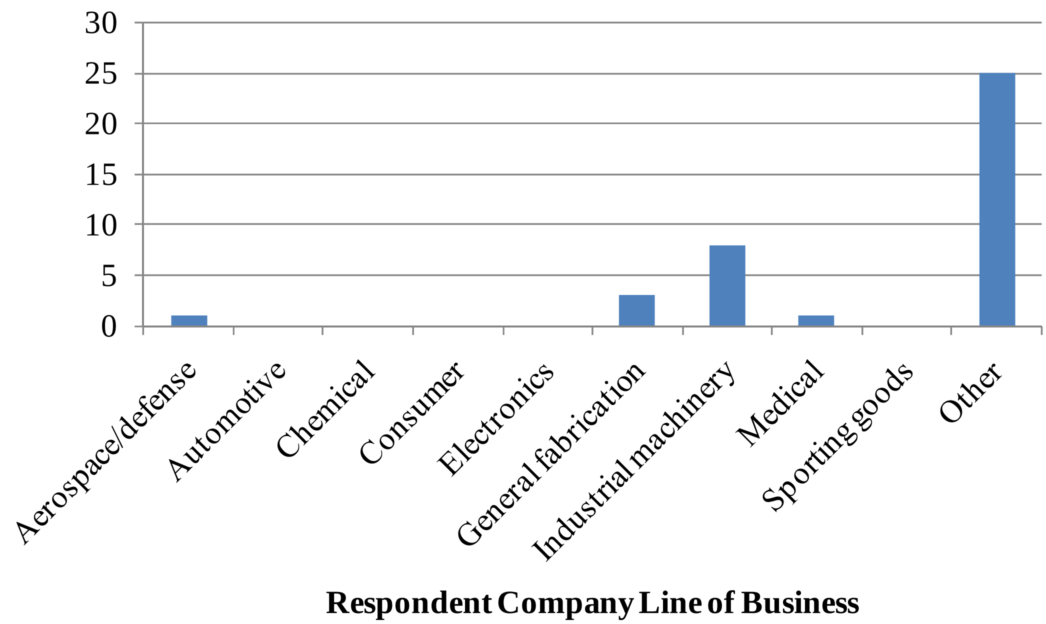

Figure 4. Stated Company or Division Main Line of Business

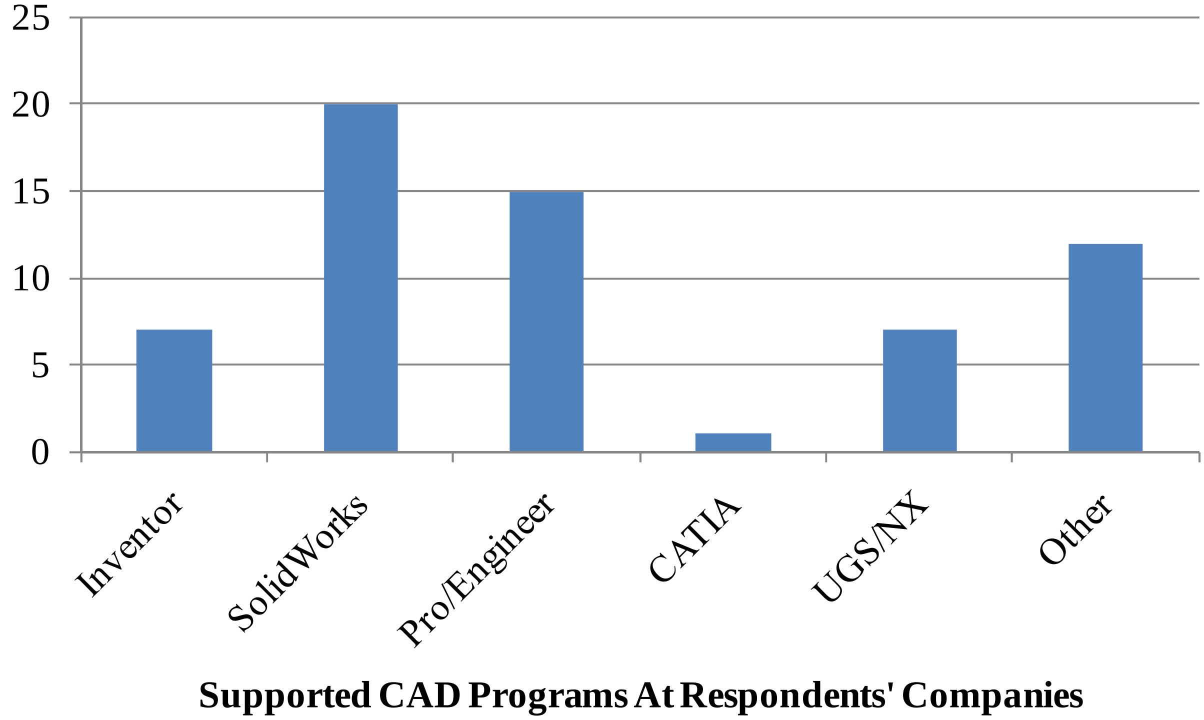

Figure 5. Computer-aided Design Programs Supported at Respondent Companies

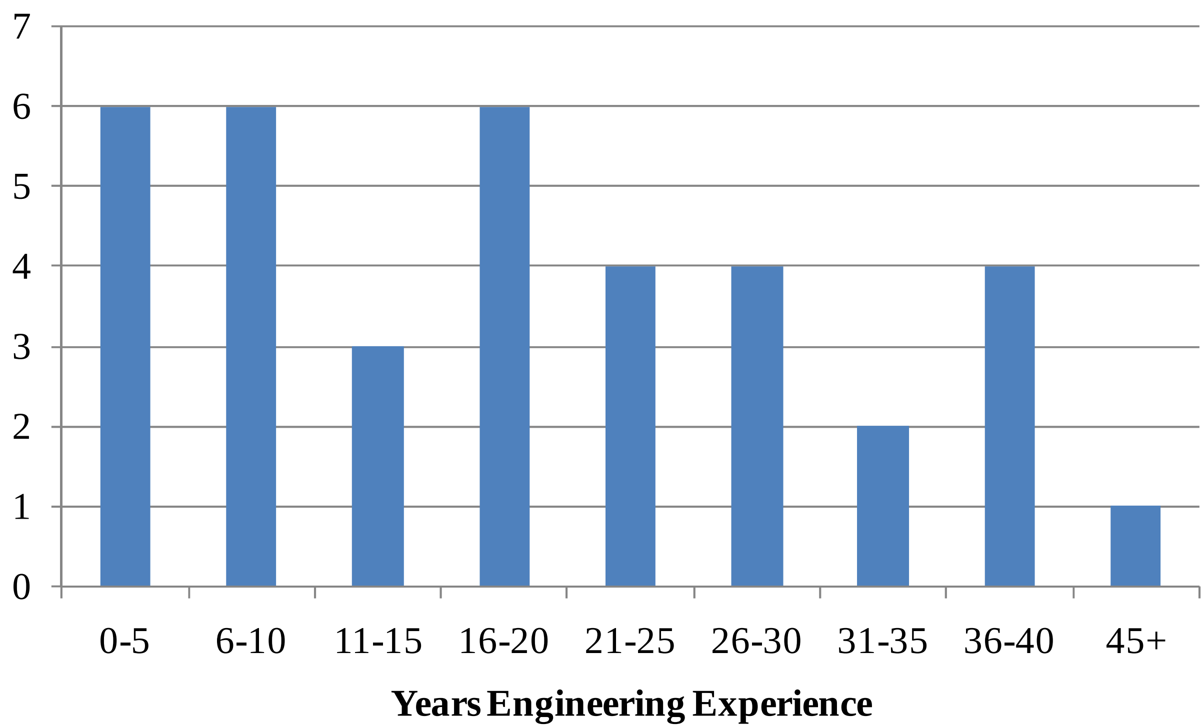

Figure 6. Distribution of Respondents Engineering Experience

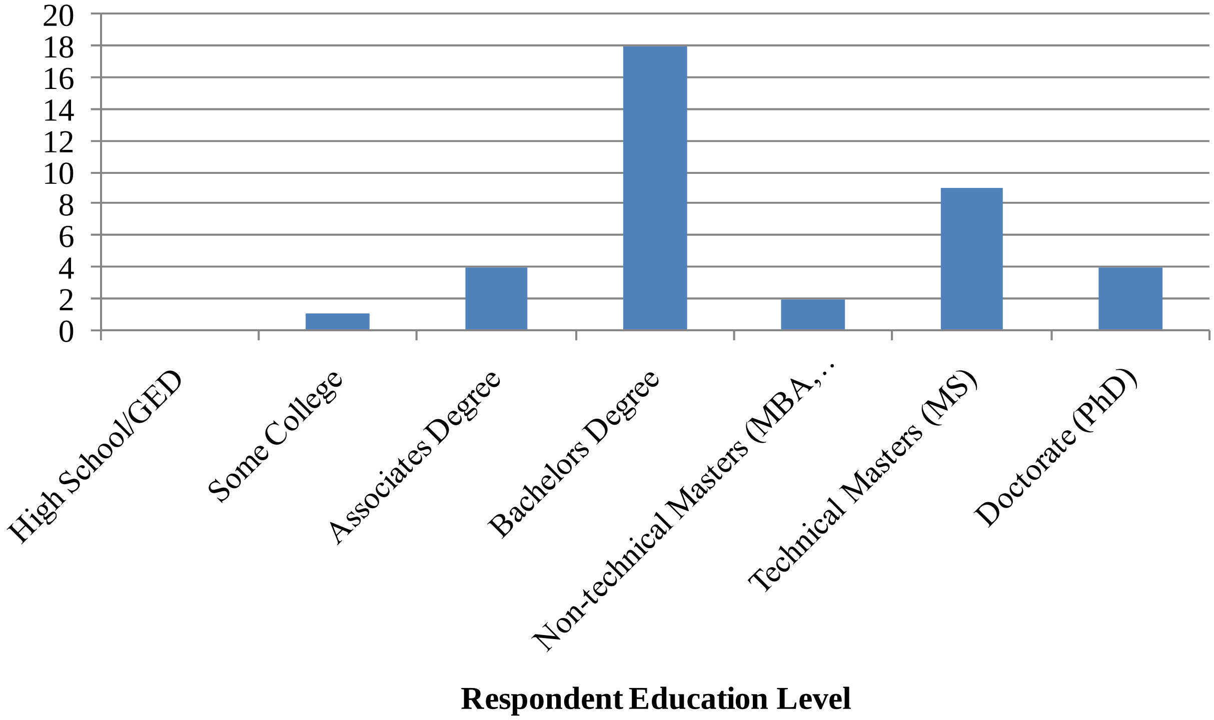

Figure 7. Distribution of Respondents' Highest Level of Educational Achievement

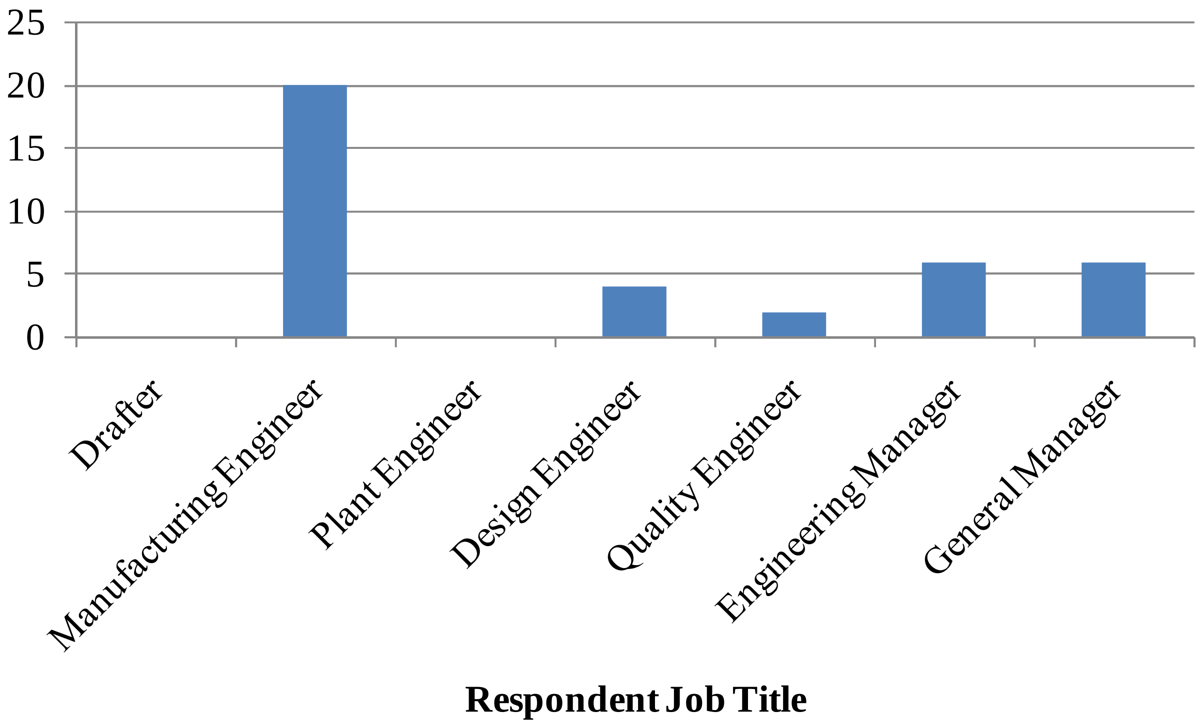

Figure 8. Respondents' Stated Job Title

Finally, correlations between the various responses were examined to determine if there was a statistically significant relationship between responses. These are shown in Table 7. Each cell in the table shows the correlation, the 2-tailed significance (those less than 0.10 are bolded and highlighted), and the number of response pairs. It should be noted that not all questions were answered, so only those results where responses were provided for both variables are included in the correlations. The responses noted "TC" are those related to how the amount of time spent on that activity has changed over the course of the respondent's career. There are statistically significant negative correlations between the amount of time spent doing design activities and the amount of time spent on project management related activities and the amount of time change in those activities. This would imply that people who do engineering design do not work as much on project management. This is further evidenced by the lack of statistically significant correlations between the project management related responses and the other two technical activities (manufacturing and analysis). There were also statistically significant correlations between the change in the amount of time spent doing manufacturing activities and experience and education. In the case of experience, it was positive – the more years experience, the more manufacturing activities had increased over time. In the case of education it was negative – the more education a respondent had, the more manufacturing related activities decreased over time. There was also a statistically significant positive correlation between the amount of time spent on project timeline management and education.

Discussion

The goal of this work was to relate survey responses from practicing engineers to the curriculum in the joint manufacturing and mechanical engineering technology program at Texas A&M. Currently the majority of the curriculum's emphasis is on engineering design and manufacturing. From the survey responses, this seems justified. While the current curriculum has a dedicated project management course, it would seem that more emphasis should be placed on projects and project management throughout other courses. The significant amount of time respondents spent on project management activities and the increase in that time over the course of their careers indicate that this warrants more attention. The importance of project management skills have been highlighted elsewhere [2-5], but these data further show the need for emphasis in project management. Creating a foundation for program graduates to be lifelong learners in project management would seem justified. Since the plurality of respondents' highest educational level is the Bachelors degree, it is incumbent on the program to provide this foundation. Currently the program does not highly emphasize analysis and other computer-aided engineering tools; these results suggest that is sufficient, as most respondents did not use these tools.

The lack of cost estimation tools and foreign manufacturing at smaller companies could signal a lack of required expertise in these fields or a general strategic decision. Smaller companies may not have the personnel resources and expertise to create these tools or oversee international manufacturing. Along with project management, these areas are included in the top four

Table 7. Correlations Between Survey Result Variables

	Portion Manufacturing	Portion Analysis	Portion TimelineMgmt	Portion ProjManage	TC Design	TC Manufacturing	TC Analysis	TC TimelineMgmt	TC Proj Manage	Proj Timeline Inpt	Proj Timeline Method	Years	Education	Employees
Portion Design	-.039	-.203	-.490	-.366	.589	.010	.172	-.542	-.453	.187	.244	.167	.072	.152
	0.82	0.24	**0.00**	**0.02**	**0.00**	0.95	0.32	**0.00**	**0.00**	0.27	0.15	0.34	0.68	0.38
	36	35	37	38	39	38	35	36	37	36	36	35	35	35
Portion Manufacturing		.066	.117	.066	.092	.455	.119	-.292	-.128	-.137	-.162	.162	-.224	-.200
		0.71	0.50	0.70	0.59	**0.00**	0.50	**0.09**	0.46	0.43	0.35	0.35	0.20	0.25
		34	36	36	37	37	34	35	36	36	36	35	35	35
Portion Analysis			.329	.222	-.069	.126	.312	-.052	.039	-.102	.018	.009	.260	.083
			0.05	0.19	0.70	0.48	**0.07**	0.77	0.82	0.58	0.92	0.96	0.16	0.66
			36	36	35	34	34	34	35	32	32	31	31	31
Portion TimelineMgmt				.261	-.315	-.092	-.210	.183	.098	.070	-.053	-.066	.380	-.076
				0.11	**0.06**	0.59	0.23	0.28	0.56	0.69	0.76	0.71	**0.03**	0.67
				39	37	37	35	37	38	35	35	34	34	34
Portion ProjManage					-.340	.030	.189	.167	.353	-.238	.174	-.158	.080	-.054
					0.04	0.86	0.27	0.32	**0.03**	0.16	0.31	0.36	0.65	0.76
					38	38	36	38	39	36	36	35	35	35
TC Design						.246	.448	-.404	-.408	-.125	-.042	.238	.000	.313
						0.13	**0.01**	**0.01**	**0.01**	0.46	0.80	0.16	1.00	**0.06**
						40	37	38	39	37	37	36	36	36
TC Manufacturing							.563	-.077	-.004	-.108	-.221	.280	-.328	-.016
							0.00	0.64	0.98	0.52	0.19	**0.10**	**0.05**	0.93
							37	39	39	37	37	36	36	36
TC Analysis								-.124	-.190	-.359	-.019	.129	-.062	.236
								0.46	0.26	**0.04**	0.92	0.48	0.74	0.19
								37	37	33	33	32	32	32
TC TimelineMgmt									.654	.142	.172	-.076	-.241	.034
									0.00	0.42	0.32	0.67	0.17	0.85
									39	35	35	34	34	34
TC Proj Manage										.135	.268	-.019	-.140	-.180
										0.43	0.11	0.91	0.42	0.30
										36	36	35	35	35
Proj Timeline Inpt											.545	.119	.319	.111
											0.00	0.48	**0.05**	0.51
											39	38	38	38
Proj Timeline Method												-.065	.206	.068
												0.70	0.22	0.69
												38	38	38
Years													.021	-.167
													0.90	0.32
													38	38
Education														.147
														0.38
														38

competency gaps identified by SME. Namely: 1 – business knowledge/skills; 2 – supply chain management; 3 – project management; and 4 – international perspective [6]. Further incorporating some of these skills into the current curriculum could help the Manufacturing and Mechanical Engineering Technology program at Texas A&M University better serve the area's employers, but especially the area's small and medium sized enterprises. Finally, one of the key tools that engineers use is computer-aided design software. These CAD tools are used throughout the engineering process [7]. The three main CAD programs supported by the respondents' companies are all in use and have dedicated courses at Texas A&M. Here it seems there is good alignment between industry and academia.

The results presented in the work should be analyzed within in some limitations. First and foremost is the limited sample size and geographic coverage of the data set. While the number of respondents is sufficient for statistical analyses, these responses may not be representative of the employment market Texas A&M Manufacturing and Mechanical Engineering Technology students are entering. The data set is further limited by its provenance; the use of the SME mailing list means that those with a manufacturing focus are overrepresented in the data; there may also be an overrepresentation of small employers. Future work will attempt to overcome some of these limitations by increases the number of areas surveyed and using other professional societies to expand the fields of interest. Overall, a method for identifying the needs and trends in industry and relating those needs to an educational curriculum has been presented.

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